Transforming Joint Air Power

The Journal of the JAPCC

Edition 25, Winter 2017/2018

2017 was another fruitful year for the JAPCC. While we continued our core business as NATO's catalyst for the improvement and transformation of Joint Air and Space Power; some significant projects were completed and many new interesting work strands were initiated. Our ongoing efforts to improve cooperation amongst NATO, EU and national air and space organizations continue to bear fruit, evidenced by expanding participation in our annual Think Tank Forum and Joint Air and Space Power Network Meeting. Our annual JAPCC Conference saw the highest turnout ever, hosting distinguished guests from the full range of political, military and industrial leadership. Finally, in an exciting turn of events, Greece revived its participation in the JAPCC this past summer, which again underlines our value to Allied nations.

The JAPCC Journal is one of the principal tools we use to fulfill our mission and it is my great pleasure to present the 25th edition. In the opening article JAPCC Director, General Tod Wolters shares his thoughts about the sustainment of the Alliance's military power through an integrated joint warfighting capability in which a robust and credible air and space force will remain an important pillar. The General also suggests this will require multilateral solutions as well as exploring new capabilities to allow the Joint Commander to meet the challenges of the future multi-domain battlefield. In this regard, viable command and control in this multi-domain environment is relevant to explore. The two following articles therefore specifically expand on this this subject, describing how the E-3A AWACS Final Life Time Extension Program may initially enable 'Multi-Domain C2 (MDC2)', and report on the results and implications of recent interoperability testing between AWACS and Allied Ground Surveillance (AGS) during Unified Vision 2016.

This Journal then moves into other relevant topics currently being dealt with, such as user requirements for a Future Battlefield Rotorcraft Capability, the interesting potential of Unmanned Aerial Systems (UAS) for use in Anti-Submarine Warfare, the importance of maritime rotary wing assets for naval and joint operations, the interoperability of air transport fleets in NATO, future options for Surface Based Air and Missile Defence, and opportunities and risks of UAS miniaturization to include developments in Counter-UAS technology. Furthermore, EUROCONTROL offers an essay outlining the current challenges and solutions in civil-military Air Traffic Management to cope with the demanding requirements for military flight integration into a 'Single European Sky'. Finally, one article deals with the critical subject of unintentional air strikes, touching upon several areas where military and civilian organizations could improve to prevent such incidents in the future.

Thank you for taking the time to read this edition of our Journal. I congratulate the authors on their contributions and I strongly encourage our readers to consider sharing your thoughts as you go forth and advocate for Air Power. The JAPCC team greatly appreciates your feedback and thoughts. Please visit our website at www.japcc.org, like us on LinkedIn or Facebook, or follow us on Twitter to tell us what you think.

Madelein Spit
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The Journal of the JAPCC welcomes unsolicited manuscripts.
Please e-mail submissions to: contact@japcc.org

We encourage comments on the articles in order to promote discussion concerning Air and Space Power.

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Purpose

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

M **Denotes images digitally manipulated**

Sustaining the Most Powerful Military Alliance

A Senior Airman's View on Challenges to NATO

By General Tod. D Wolters, US Air Force, Director of the JAPCC

Introduction

Over the past year and a half, it has been a privilege to command NATO's Allied Air Command (AIRCOM), US Air Forces Europe and US Air Forces Africa. Add in the role as the Director of the Joint Air Power Competence Centre and it has been an honour to be part of four fantastic teams. As our Command Group has travelled throughout the NATO theatre, we have been continually impressed by the quality of the personnel that nations assign to NATO, the level of cooperation among our NATO Airmen, and with our joint and non-NATO partners. It is clear that our levels of cooperation have never been higher through the dedication to NATO's three core tasks of Collective Defence, Crisis Management, and Cooperative Security, and precision focus on deterring potential threats to the Alliance. Having taken some time to reflect, there are some observations on the challenges facing our Alliance, and thoughts on the direction we are, or should be, heading.

NATO faces a 360-degree ring of security challenges. As receding polar ice opens up new trade routes and access to potential resources in the Arctic, the possibility for competition and friction between major seafaring nations grows. The Alliance is also facing challenges

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General Tod D. Wolters during his opening speech of the JAPCC's annual Joint Air and Space Conference on 11 October 2017, in Essen (Germany).

from near-peer competitors. To our east, Russia is posturing and exercising air, maritime and ground-based air defence forces along its western border with European nations, attempting to establish a sphere of regional control. Naval activity and exercises by potential adversaries have also increased in the Mediterranean, the Baltic Sea and the Atlantic Ocean. To the south-east, we face ongoing instability in the Middle East that fosters terrorist groups and generates a continuing flow of migrants and refugees into European and North American nations. To the south we also see a similar instability caused by radical ideologies, human rights abuses, and economic challenges, as well as competition for partners and resources. It is absolutely critical that our nations solidify the cohesion of our Alliance to overcome each of these challenges, counter any overt attacks, and deter future threats.

From Air Power towards an Integrated Joint Warfighting Capability

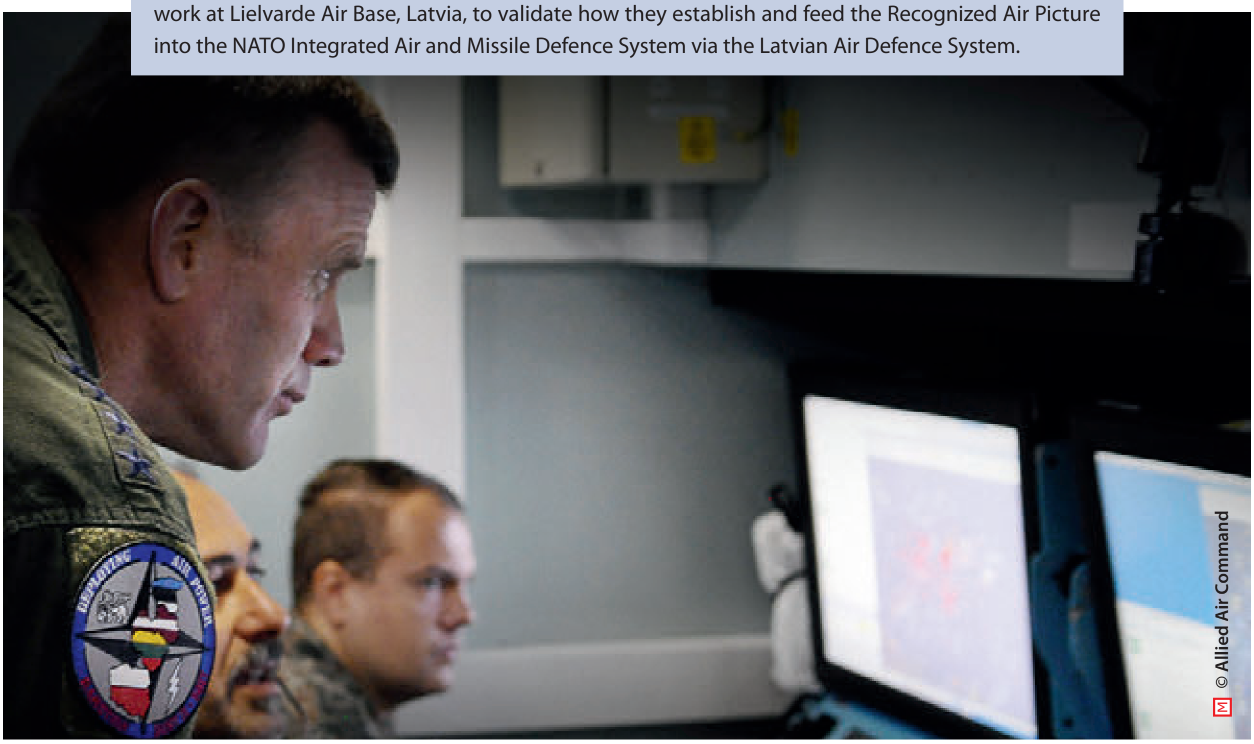
The key to deterrence is demonstrating that NATO has both the political will and the military capability to back up the assurances of the North Atlantic Treaty. Any potential adversary, whether near-peer, small state or non-state, must understand that hostile action towards any NATO nation, in any domain, will be met with the overwhelming might of 29 allied nations. A robust and credible air and space force that can establish an umbrella of air superiority over any land or maritime battlespace enables freedom of action for our land, maritime and special operations forces. Air Power is a cornerstone of effective deterrence. The soldiers and sailors in land and maritime battle groups who stand ready to counter incursions into NATO nations are the best in the world, but they must be protected and supported in the third dimension in order to succeed.

We are currently operating in a strategic environment where budgets and personnel resources have been reduced in almost every allied nation over a period of more than ten years. In parallel, we see threats to our collective security emerging, or in some cases re-emerging, from every point on the compass. In many nations, the pendulum has reversed course and defence budgets are now trending upwards. However, new investments take years to manifest into new capabilities. This means that we have to think harder about how to get the most out of the resources we have available now and those becoming available in the near future, such as fourth and fifth generation fighter integration. We must find innovative ways of posturing our forces that make them flexible, so we can 'lift and shift' them on short notice to face challenges from any direction, and from more than one direction at the same time. Additionally, we need to better integrate all of our warfighting and supporting domains: air, land, maritime, special operations, space and cyber, in order to comprehensively address all aspects of a given situation. One way we do that is through multi-domain command and control (MDC2), which goes beyond supported and supporting commands, to an integrated joint warfighting capability, and is one way in which our Alliance will stay ahead of the ever-increasing speed of warfare.

Networked Operations – Cyber and Space

Warfighting capabilities are evolving beyond the speed of voice communication and human decision-making through the use of networked communication and data-sharing at machine speeds. In order to leverage new systems fully, we must utilize computer and datalink capabilities that are heavily dependent on the space and cyber domains. While there is tremendous emphasis on developing cyber capabilities and strengthening cyber security, we must keep in mind that much of our capability in this domain, including our ability to command and control forces relies on space-based satellite systems. Space provides communication links, position, navigation and timing information for aircraft and ship movements and precision-guided munitions employment. Space also provides an Intelligence, Surveillance and Reconnaissance (ISR) capability as well as real-time global weather tracking. However, some of our space assets are still not as interconnected as we would prefer. Due to the expense involved in fielding space systems, the only way to exploit the domain effectively and maximize space support to NATO operations is to link national capabilities and consider approaching future acquisitions in a multilateral manner. Moving forward, we need to increase investment in space to preserve and protect the capabilities we already have, and to improve the ubiquitous situational awareness it provides. Robust

Commander Allied Air Command, Tod D. Wolters, sees how participants of exercise Ramstein Dust-II 17 work at Lielvarde Air Base, Latvia, to validate how they establish and feed the Recognized Air Picture into the NATO Integrated Air and Missile Defence System via the Latvian Air Defence System.



space capabilities are critical to MDC2 and to most of our modern weapon systems, as well as to the Alliance cohesion that is essential to deterring many of the threats we face.

The Importance of Robust and Realistic Training and Exercises

The foundation of a robust and credible Alliance deterrence posture is a visible and realistic training and exercise program. In AIRCOM, the degree of cooperation in our NATO exercises continues to improve. Recent NATO and European exercises like *Baltic Operations, Arctic Challenge, Saber Strike* and *Trident Javelin* highlight the improvement. However, we still have challenges. With real-world operations ongoing and limited resources, it can be hard to pull together a comprehensive joint force for live training. To offset this, we need to continue to explore and expand virtual and constructive training capabilities to link up with our live forces. We also need to ensure we are challenging our warfighters with the most realistic scenarios they might face from a near-peer adversary. We have become complacent from a quarter-century of NATO being effectively unchallenged militarily, and some achievable conditions may not be as certain against emerging competitors. We need to challenge our Airmen, Soldiers, Sailors, Marines and their leaders from the tactical to the strategic levels with exercise scenarios which test them to their limits and see how they react and adapt – this is how we really learn and improve. In addition, we can no longer afford to begin exercises at a point that assumes air, space and cyber superiority have been successfully established; we must exercise the critical first days of the fight and do so jointly. This is important to building a cohesive and interoperable multinational force, and to demonstrating combined arms credibility in the eyes of would-be aggressors.

Fifth Generation System Integration

As we continue to improve joint exercises and training, we need to figure out how to better integrate fifth generation capabilities into not only our national forces, but into the NATO Force Structure (NFS) as well.

A C-17 of the NATO Strategic Airlift Capability – Heavy Airlift Wing – on the apron in Timbuktu/Mali on 21 November 2016.

© NATO Strategic Airlift Capability Heavy Airlift Wing

Commander AIRCOM, General Tod D. Wolters, during discussion at the NATO Air Chief Symposium 17-1 (16 March 2017).

The F-35 is a game-changing system that brings myriad advanced capabilities to the table giving us a degree of access in contested environments that we have never experienced before. We are already working on how we will make the F-35 interoperable across the joint services of participating nations, and also on how it will integrate into existing NATO force and command and control (C2) structures. Ultimately, we need to mature fifth generation Air C2 systems, including the next Air Surveillance and Control platform that replaces our Airborne Warning and Control System (AWACS) fleet, to get the maximum benefit from fifth generation combat systems as they become available. We are also working on how to maximize the flexibility and punching power of NATO F-35s through cooperative information, maintenance and logistics programs. Figuring out how to share the burden in these support areas will yield important lessons to speed the integration of various advanced systems when they come online. Other advanced fighter, tanker and transport aircraft are also going to be common to multiple nations, so developing doctrine and standardized agreements for support will speed their progress towards operational capability. These are critical first steps in the transformation of NATO Air and Space Power to a fifth generation force that sustains its position as the preeminent military force in the world, and in doing so continues to deter major conflicts not just on the European continent, but globally.

Leveraging Partnerships to Address Out-of-Area Challenges

Fortunately, NATO has many partners across the globe. These include European nations such as Sweden, Finland, and Austria, as well as others in key areas worldwide, including Australia, New Zealand, Japan, the Republic of Korea, Colombia, Mongolia, and others. These partnerships are critical to addressing 'out of area' challenges such as piracy off the Horn of Africa, ongoing rebuilding challenges in Afghanistan, and countering the Islamic State in Iraq and Syria (ISIS). Such challenges are not within the geographic confines of NATO, but their outcomes affect all of our long-term interests.

Africa is extremely important to NATO. Europe and Africa are historically and inextricably linked, sharing the Mediterranean Sea across which flow people and trade. Both continents also border and are affected by

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the flow of refugees and the export of hostile ideologies from the conflicts in the Middle East. As Commander US Air Forces Africa, I see the challenges facing African nations; these are significant challenges and are not Africa's alone. Problems in sub-Saharan Africa affect human rights, access to resources, and feed instability to the north that flows across the Mediterranean into Southern Europe, from Morocco to Gibraltar and up into Spain, and from more central parts of Africa up to Libya and across to Italy. These mass migrations create internal humanitarian, economic and security challenges for Alliance nations so finding ways to stabilize Africa is vital. NATO has been assisting the African Union (AU) since 2005 with efforts to build their own peacekeeping forces and to restore and maintain stability in areas such as the Sudan, Somalia, Mali and the Central African Republic. NATO also took the lead role in Operation Unified Protector over Libya in 2011. Due to the vast distances involved in Africa, Air Power is a realistic solution for transporting AU peacekeeping forces and supplies to troubled areas, particularly those in the interior of the continent. Both the NATO Heavy Airlift Wing and the national air forces of several NATO allies have supported and continue to support these operations, and the Alliance has opened seats in the NATO School at Oberammergau to AU members to help build their own capabilities.

Conclusion

The stability of the NATO Alliance is immeasurably important to the maintenance of peace and order in the world, not just the North Atlantic. The challenges we face are multi-directional and multi-dimensional, and they will not be overcome without multilateral and multi-domain solutions. We are incredibly proud of the men and women of NATO who are performing missions at home and abroad, conquering these challenges every day. We are proud of the way they are all supporting their counterparts in the other components, despite the manning and resource obstacles we all face. From the tactical level to the strategic, they are 'out-thinking' and 'out-working' our adversaries to sustain the most powerful military alliance ever created and to deter those who would do us harm. It is an honour to continue serving alongside these heroes!

General Tod D. Wolters

is the Director of the Joint Air Power Competence Centre, Kalkar, Germany; Commander, Allied Air Command; and Commander, United States Air Forces Europe and Air Forces Africa. In his capacity as Commander, Allied Air Command he is responsible to the Supreme Allied Commander, Europe for the Air and Missile Defence of 29 NATO Alliance member nations during peacetime. In the event of a joint NATO operation he is the responsible commander of the Air Component. General Wolters is a 1982 graduate of the United States Air Force Academy. He has over 5,000 flying hours in the F-15C, F-22, Ov-10, T-38 and A-10 and has commanded at the squadron, group, wing, air expeditionary task force and numbered air force level prior to his current assignment.

Gateway to Multi-Domain Command and Control

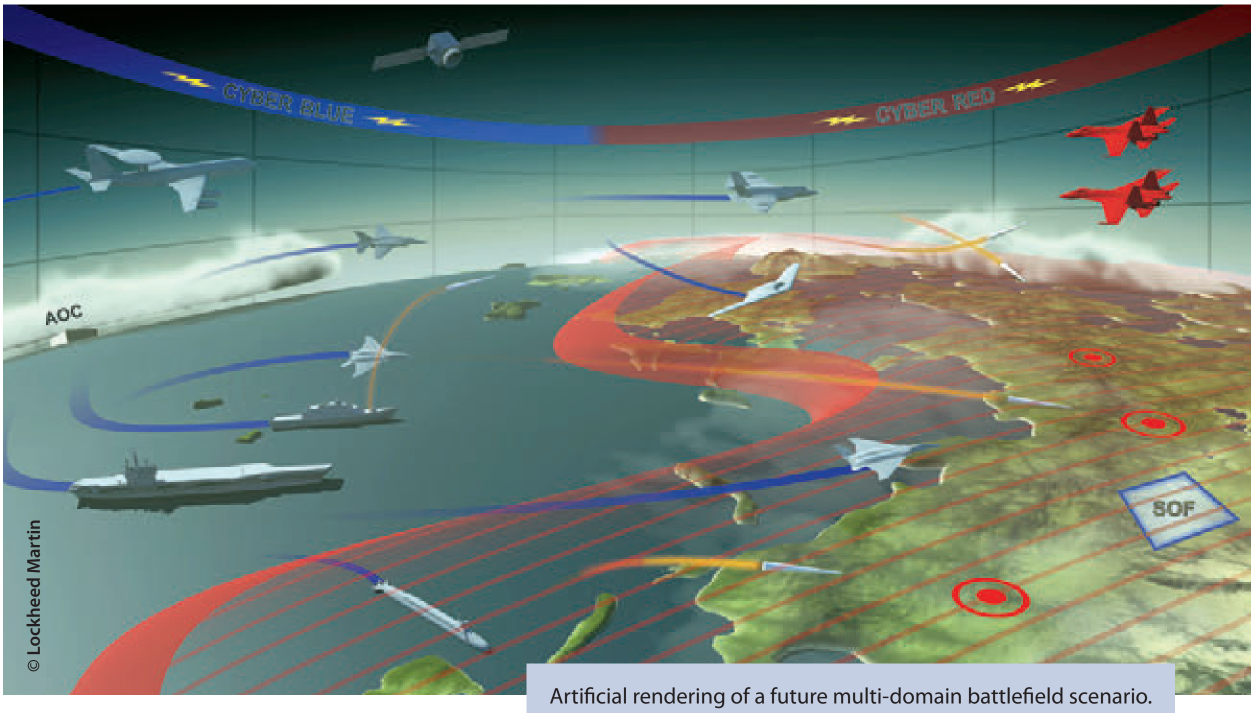
The E-3A Final Lifetime Extension Program

By Major Aaron Sprecher and Major Sameek Parsa, USA AF, NAEW&C Force Headquarters

© US Air Force, Senior Airman Dan Frost

Introduction

Since NATO's inception, airpower's role has evolved from a key enabler of military capability to that of a primary means of executing the Alliance's three core tasks: collective defence, crisis management and co-operative security. With today's fluid political landscape and rapid technological advancement, NATO has begun to anticipate future security environments in which it may have to operate, including a contested, degraded, and operationally limited (CDO) environment. NATO's military forces must be prepared to match not only rapid developments in technology but also an adversary with the political will and capacity to employ these capabilities to decisively alter the geopolitical landscape. The JAPCC's 2016 conference brought focus to this narrative, concluding that after nearly two decades of uncontested air operations, today's environment is in fact CDO. The conference further provided clarity, defining the contested as 'things the adversary does to directly hamper the mission' (e.g. electronic warfare, cyber attacks); the degraded environment as 'things that happen in the natural course of events' (e.g. stuff breaks); and the operationally limited as 'caused by the physical or operational environment' (e.g. capacity-limited Link 16 network).[1] It was also



Artificial rendering of a future multi-domain battlefield scenario.

agreed that the particular challenges for the CDO environment of the foreseeable future are instantaneous effects from increasing multidimensional threats.

Given these challenges, NATO must learn how to employ its joint capabilities as a cohesive multi-domain force. This will allow for dynamic action across the domains to provide precision engagement with the desired amount of force, at the desired time, regardless of the battlefield conditions. These synergistic effects cannot be accomplished using the traditional approach of separate components coordinating in traditional supported-supporting relationships, where each component still subordinates Joint Force objectives to priorities in its own domain that constrain the capabilities provided to the Joint Force Commander (JFC). For success in future warfare, JFCs must have real-time situational awareness of all assets in the battlespace and the ability to communicate and re-direct forces as the environment dictates. A critical component in providing NATO with this strategic advantage is its airborne Battle Management Command and Control (BMC2) capability, specifically the NATO E-3A Airborne Warning and Control System (AWACS). Current efforts to modernize the AWACS will provide Multi-Domain Command and Control (MDC2) capability required to meet challenges of future operational environments.

From Joint to Multi-domain Operations

Over the last quarter century, operational airpower has been a key and critical component to maintain the Alliance's strategic advantage. Operational concepts such as 'Air-Land' and 'Air-Sea' Battle were pivotal evolutions in defining how airpower can deliver cross-domain synergy.[2] However, in 2011, then Chairman of the United States Joint Chiefs of Staff General Martin Dempsey asked 'What's after joint?'[3] The answer is multi-domain. Multi-domain operations are the 'exploitation of asymmetric advantages across multiple domains (air, land, sea, sub-surface, space and cyberspace) to achieve freedom of action required by the mission.'[4] Quite possibly the most unique challenge to achieving this is understanding MDC2.

MDC2 can be defined as C2 across all domains that protects, permits and enhances the conduct of operations to create desired effects at the time, place and method of choosing.[5] Recently, the Chief of Staff of the US Air Force published a white paper that describes three characteristics of MDC2: situational awareness, rapid decision-making, and the ability to direct joint forces to achieve Commander's intent.[6] The challenges with operationalizing this concept reside in three domains: technical, policy, and human. In the technical domain, MDC2 systems must have a network that supports the exchange of 'big data', removes stove-piped data streams, and improves interoperability. Further, we must be able to identify and remove policy barriers to interoperability to shorten the time from data to decision. Last, in the human domain, command authorities must be established and easily delegated to the tactical level so that those with tactical control (TACON) can produce effects across domains, in real-time. This authority, when distributed to the right level, will link the Commander's Intent to tactical action, employing the right amount of force, at the right time, in the right place and with the right method of choice for maximum effectiveness.

To this end, NATO continues to transform its military force structure in separate air, land and maritime components. To ensure effective MDC2, however, a platform must be selected which can readily observe and communicate across the space, air, ground and surface domains. As NATO's key airborne tactical BMC2 asset, the E-3As are the logical platform for future MDC2 operations. They are uniquely qualified to engage in multi-domain operations, as they already engage in air, ground and surface BMC2. The next evolution of the E-3A will expand its capabilities in the space domain and enhance many of its existing air, ground and surface abilities, to provide the technical capability for effective MDC2 in NATO 2025 and beyond.

Evolution of the E-3A: Mission and Modernization

Four major modifications to the E-3A fleet in the past 25 years prove the platform can respond to military challenges or changing political environments.

Near-Term Modification Program. The first modification, known as the Near-Term Modernization Program, was conducted in the early 1990s, while the world was still adjusting to the collapse of the Soviet Union. It significantly *enhanced the radar capabilities* allowing detection of smaller and slower targets at the expanded range, and it *added electronic surveillance measures for improved passive detection of static and mobile emitters.* To effectively communicate with maritime elements, the E-3A's communications capabilities were also upgraded to include anti-jam UHF radios and Link-16.

NATO Mid-Term Program. During NATO's involvement in Bosnia and Kosovo in the 1990s, the E-3A's role was expanded from a simple Airborne Early Warning platform to that of a flying Command and Control (C2) entity. This second round of modifications, known as the NATO Mid-Term Program, was approved in 1997. The C2 enhancements included the addition of new situational display consoles to allow for additional mission crew in-flight, multi-sensor integration for improved target identification and tracking, the addition of full-spectrum VHF radios for communications with a wider range of aircraft and ground forces, and an improved internal communications network and *satellite communications system for long-range voice and data transmission.*

Large Aircraft Infrared Counter Measures. The third modification of the E-3As began for the 2001 deployments to Afghanistan in support of the International Security Assistance Force (ISAF). The mission required a Large Aircraft Infrared Counter Measures (LAIRCM) system to operate from within the theatre of operation. LAIRCM is an automated system designed to protect aircraft during take-off and landing when they are vulnerable to MANPADS and other portable infrared guided missiles. Following the addition of LAIRCM, NATO E-3As were able to support ISAF from bases within Afghanistan itself, not only increasing on-station availability while substantially reducing fuel requirements, but also *allowed Commander's to accept greater risk with a traditionally low-risk platform.*

Follow-on Upgrade Program. To keep pace with the civil aviation requirements in NATO countries, the fourth modification, known as the Follow-on Upgrade

Program, was implemented in 2010. This upgrade included a Next Generation IFF (Mode 5) and enhanced Mode S capability for improved identification capability and replacement of the analogue flight instrumentation with the new Communication, Navigation and Surveillance/Air Traffic Management (CNS/ATM) 'Glass Cockpit' system to ensure access to global airspace.

These modernization efforts helped the E-3As to adapt and perform missions beyond those for which they were originally designed. In the aftermath of the drawdown from operations in Afghanistan, NATO shifted its strategic direction and reaffirmed the need to modernize the E-3As to remain 'operationally relevant through 2035'. To extend the E-3As' operational life for another ten years, the NAEW&C Force with the support of SHAPE identified key capability gaps to advance and modernize the fleet to meet the strategic directive.

Final Lifetime Extension Programme

Since 2014, the NATO Airborne Early Warning and Control Force Program Management Agency (NAPMA) managed development of the Final Lifetime Extension Program (FLEP) to fill those capability gaps. The engineering, manufacturing, and development phase is scheduled to commence in 2019, where NAPMA will work with US and European contractors to provide a modernized, networked, secured, multi-domain

Inside the cockpit of an E-3A after glass flight deck modification.

Operators tracking signals abort the E-3A AWACS.

capable Battle Management and Command & Control platform to serve until a replacement is fielded. FLEP will address six major areas to improve the E-3A's MDC2 capabilities. These areas include:

Tactical Data Links (TDL). The FLEP will replace the existing terminal with a modern, crypto-compliant terminal capable of Concurrent Multi-netting and add IP-based, beyond line-of-sight capability with Joint Range Extension Applications Protocol C encapsulation.[7] This capability will not only aid in alleviating the capacity constraints of current Tactical Digital Information Link networks, but will also allow for the adaptation of future waveforms for greater and more secure information exchange, communication and enhanced situational awareness. Alleviating the capacity constraints of today's data network environment is a pre-requisite to the amount of data that can be collected by 5th generation sensors and platforms.

Secure Communications. To meet external mandates, the voice, data, and TDL cryptographic units will be replaced with modernized units to ensure secure communications and interoperability with NATO partners.

Airborne Networking. The wide-band SATCOM antenna installed under the CNS/ATM project will be modified to increase data streaming capability to 2 Mbps, a massive increase over today's capability. This will support the integration of advanced information sharing capabilities and handle the 'big data' (e.g. off-board sensor data) required to support operations beyond 2025.

Anti-Jam Communications. Current VHF and UHF radios will be replaced with modern, securable, anti-jam capable radios to establish and maintain communications with air, ground and surface forces in contested electromagnetic environments.

Passive Detection. The Electronic Surveillance Measure system will receive a much needed upgrade in processing capability to allow for faster emitter identification and reduction of unknown emitters. The ability to provide more timely and accurate identification of potential threats will allow the E-3A to bring order to chaos in the fight of the future.

Mission System. Due to the number of improvements added under FLEP and the advancements in


© US Air Force, Courtesy Photo

NATO AWACS going-around with the FLEP to 2025 and beyond.

computer technology since the last upgrade, the Mission Computing system will receive new hardware and a significant change in software architecture. The new features and capabilities will alleviate capacity and processing constraints of existing computer technology that is ill-equipped to handle the massive amounts of data provided by organic and inorganic sensors.

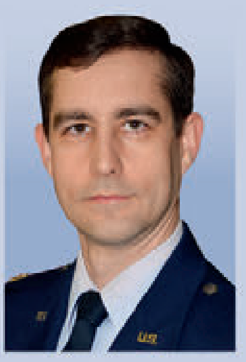
Most notably E-3As will continue to provide accurate and timely identification of air and surface targets and will gain the ability to detect, track, and identify ground targets and emitters through the ability to process off-board, ground moving target indications (GMTI). The ability to detect, track, and identify enemy movement in the air, land, and surface domain and communicate these threats beyond line-of-sight will support enhanced situational awareness and enable rapid decision making at the tactical and operational levels, allowing forces to achieve Commander's intent. Moreover, the enhanced airborne networking capability provides the necessary bandwidth to process 'big data' to ensure timely and decisive action.

For these technologies to be effective in 2025 and beyond, we must also examine the barriers in policy that prevent the rapid and free-flowing exchange of data between sensors, systems, platforms, networks, and people. While the commitment of national resources to the Alliance continues to be a source of strength, we must also consider the barriers invoked by policy that can diminish interoperability and our strategic advantage. MDC2 within NATO will require strategic alignment of people, plans, resources, requirements and technologies in order to preserve a competitive advantage. From a systems perspective, MDC2 is neither capabilities-based nor effects-based; it instead relies on resilience, interoperability and authority. Systems must be resilient in order to be effective in a multi-domain environment; they must also be able to communicate with each other and appropriate command. Last, while traditional air power capabilities have been measured by speed and reach, MDC2 systems will be measured by their ability to achieve Commander's intent, its level of adaptiveness and finally its survivability. The only way this last part is achieved is through the systematic integration of people, ideas, weapons and platforms so MDC2 systems can adapt these variables to the situation as we can never war-game the perfect storm. We must therefore also seek to find those emerging enablers vs technological game-changers in order to achieve operational agility.

Conclusion

The imperative for effective MDC2 is clear. The ability to harness capabilities across multiple domains and more importantly, provide effective command and control across domains produces dilemmas for our adversaries at a pace they will never match. Airborne C2 nodes such as the E-3A will continue to be critical in gapping the tyranny of distance in a boundary-less, multi-domain environment. The ability to overcome fog, friction and chance through on-scene or localized situational awareness remains the E-3A's most competitive advantage in 2025 and beyond. MDC2 systems, like a rapidly-deployable and FLEP-modernized E-3A, will provide operational commanders with an action arm in the battlespace to achieve desired effects. Moreover, it will require the strategic alignment of people, plans, resources, requirements and technologies in order for NATO airpower to preserve its competitive advantage in 2025 and beyond.

1. Joint Air Power Competence Centre (2016). ***Preparing NATO for Joint Air Operations in a Degraded Environment.*** Conference Proceedings. Retrieved from: https://www.japcc.org/wp-content/uploads/Conf_Proceedings_2016_web.pdf
2. US Department of Defense (2012). ***Joint Operational Access Concept,*** Version 1.0. 17 Jan. 2012. Retrieved from: https://www.defense.gov/Portals/1/Documents/pubs/JOAC_Jan%202012_Signed.pdf
3. Reilly, J. ***Multidomain Operations.*** ASPJ, Spring 2016. Retrieved from: http://www.airuniversity.af.mil/Portals/10/ASPJ/journals/Volume-30_Issue-1/ASPJ-Spring-2016.pdf
4. Ibid., p. 62.
5. Definition adapted from: Col Joshua Conine, USAF (2017). ***Multi Domain Command and Control [PowerPoint slides].***
6. Gen David Goldfein, USAF (2017). ***Enhancing Multi-domain Command and Control … Tying It All Together.*** Retrieved from: http://www.af.mil/Portals/1/documents/csaf/letter3/Enhancing_Multi-domain_CommandControl.pdf
7. JREAP C makes use of the Internet Protocol (IP) in conjunction with either the User Datagram Protocol (UDP) or Transmission Control Protocol (TCP). The IP suite is a standard set of protocols that is deployed worldwide in commercial as well as military networks. By using JREAP encapsulation over IP, JRE can be performed over IP-based networks that meet operational requirements for security, speed of service and so on.



Major Aaron Sprecher

earned his commission through the USAF Officer Training School in 2003 as a Developmental Engineer after earning his BS in Electrical Engineering. He earned an MSEE from the Air Force Institute of Technology 2008 and is certified through the Defense Acquisition University in Program Management, Test & Evaluation, and Systems Planning, Research, Development and Engineering. Major Sprecher has also provided electronic warfare support to combat forces and was forward deployed as an MC-12 liaison officer. Major Sprecher currently serves as the NATO E-3A Strategic Development Project Manager at the NATO Airborne Early Warning and Control Force Headquarters. Major Sprecher is responsible for strategic planning and requirements development for future capabilities of the NATO E-3A fleet.

Major Sameek Parsa

earned his commission through the Reserve Officers Training Corps in 2007. He is a Senior Air Battle Manager with experience in the NATO E-3A, and USAF E-3B/C/G, E-8C JSTARS and possesses qualifications as an Evaluator Senior Director/Fighter Allocator and Instructor Air Weapons Controller. During previous assignments, he served in the Combined Air Operations Center, United States Central Command and has over 1,700 flight hours supporting operations in the Pacific, Central America, and Middle East area of operations. Currently, he is the Deputy Chief of Requirements at Headquarters, NATO Airborne Early Warning & Control Force and serves as a focal point for strategic requirements development for NATO Airborne Early Warning and Control systems in support of NATO Defence Planning.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NATO E-3A and AGS Interoperability

Calibrating the Alliance for Multi-Domain Command & Control

By Major Jay B. Vizcarra, NATO E-3A Component

'Information is only of value if you give it to people who have the ability to do something with it.'[1]
General Stanley McChrystal

Introduction

Military success rests on effective Command and Control (C2). It enables the conversion of a commander's vision and intent into operational action.[2] In the background of developing both the vision and the plan for execution is Intelligence, Surveillance, and Reconnaissance (ISR). ISR is the act of gathering information on the positions and circumstances of enemy (and friendly) forces and their disposition relative to friendly forces and non-combatants.[3] A military force that seamlessly merges timely, accurate, and actionable ISR results with C2 can not only greatly increase the probability of military and operational success, but also correspondingly secure a strategic advantage.

As seen in recent near-peer deployments to Ukraine and Syria, current threats possess the capability to conduct a full spectrum of warfare, establish Anti-Access Area-Denial (A2/AD) environments, employ modern precision strikes, and conduct operations in

multiple domains (land, air, maritime, space, and cyber).[4] For the Alliance, which enjoyed success in previous conflicts through the monopoly of air dominance, the change in today's war tapestry necessitates a new, asymmetric approach. Articulating a new strategy and embracing a Multi-Domain Command and Control (MDC2) capability affords the Alliance the capacity to create multiple dilemmas for the adversary across the broad spectrum of domains at any time.[5] If fused correctly with timely ISR results, tactical, operational, and strategic leaders would increase their potential for an asymmetric decision advantage across the multi-domain battlespace. The combined effects delivered from C2 and ISR weapon systems provide a good starting point toward a complete MDC2 construct. Within the context of sharing situational awareness (SA), to promulgate rapid decision-making and direct applicable forces, a recent NATO E-3A and Alliance Ground Surveillance (AGS) interoperability trial took a small step towards the direction of this concept. Lessons from it identify considerations for further advancement as well as underline the importance of intelligence fusion and rapid information sharing for a more complete MDC2 approach.

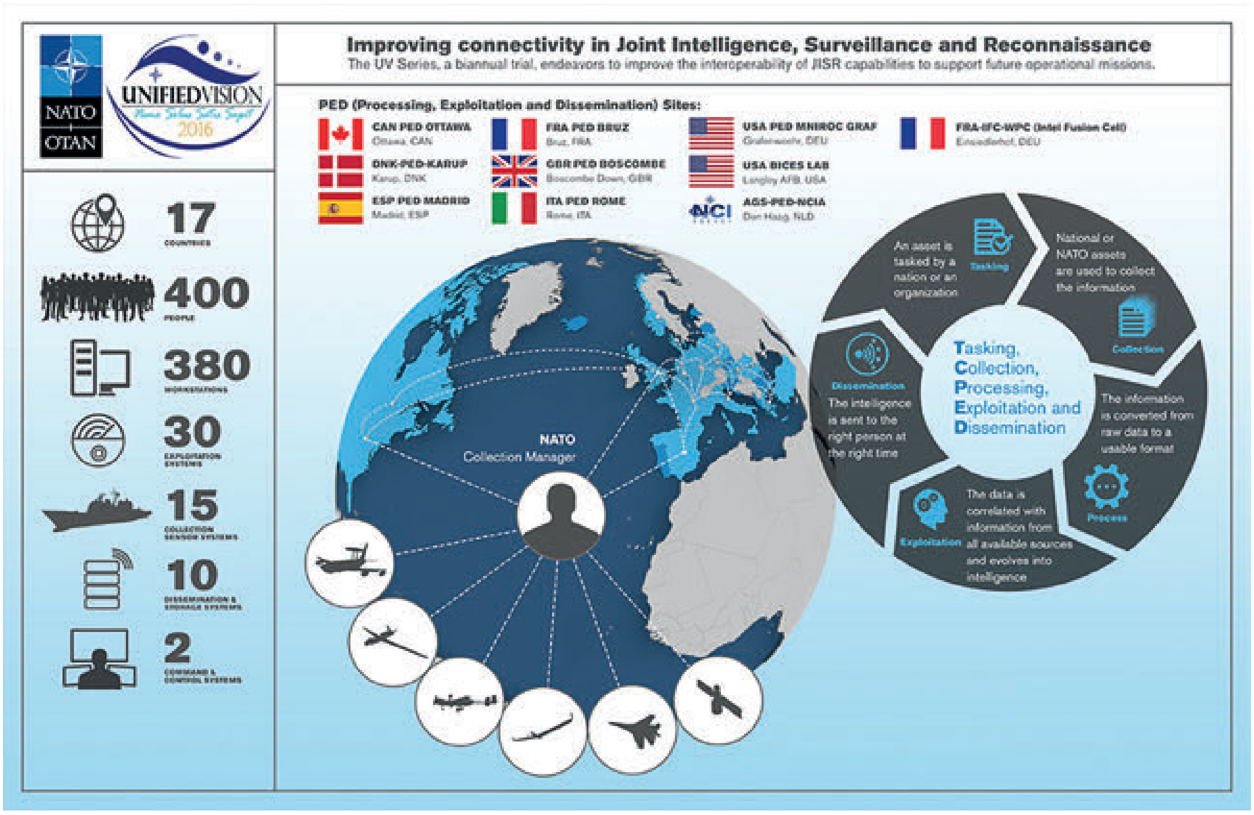
Combining Effects from NATO E-3A and AGS Interoperability

During the Unified Vision 2016 (UV16) Trial, the NATO Joint Capability Group on ISR (JCGISR) provided the first proof of concept for a federation of Processing, Exploitation, and Dissemination (PED) capability.[6] It allowed geographically dispersed PED units to share the burden of ISR data exploitation and intelligence dissemination at all levels of command – conceptually, to the right person, at the right time, in the right format. Secondly, UV16 facilitated the examination and optimization of J2 (Intelligence) and J3 (Operations) interaction to improve operational decision-making and support targeting. Most significantly, the Trial provided an inaugural demonstration of Command, Control, and ISR (C2ISR) interoperability between the NATO Airborne Early Warning and Control (NAEW&C) Force E-3A and NATO AGS. The Warrior Preparation Center (WPC), located in Einsiedlerhof, Germany, served as the central Trial node and mock Air Operations Centre (AOC) in the Live, Virtual, and Constructive (LVC) environment. The E-3A Mission Training Centre (MTC) simulator operated from

Geilenkirchen, Germany, while the AGS participated from the NATO AGS Capability Testbed (NACT), Den Haag, Netherlands.

During multiple UV16 operational vignettes over the span of two weeks, the E-3A and AGS produced reputable results in demonstrating the capacity to a) provide commanders a shared and enhanced SA of the air, land, and maritime domains, and b) effectively combine C2 and ISR capabilities in a rapid sensor-to-shooter construct to support a wide range of mission sets. AGS operators exploited Maritime/Ground Moving Target Indicator (M/GMTI) radar and Synthetic Aperture Radar (SAR) imagery to provide Near Real-Time (NRT) Surveillance and Geospatial Intelligence (GEOINT) information of the ground and maritime domains to E-3A and UV16 participants. Complementing the AGS' contributions, the E-3A delivered air and maritime surveillance, Electronic Intelligence (ELINT), and Battle Management Command and Control (BMC2) of strike aircraft. NRT ISR feeds from air, land, and sea domains were shared and cross-cued amongst platforms, UV16 participants, and the AOC via Link-16 and Internet Protocol (IP) Chat. AGS also fed a newly developed Coalition Shared Data (CSD) server architecture which enabled NATO assets with similar CSD structures to query and pull ISR PED products. Additional PED nodes fused (notional) ISR results from single collection disciplines such as Signals Intelligence (SIGINT), Communications Intelligence (COMINT), and Human Intelligence (HUMINT). The NRT synchronization of C2 and ISR functions enabled E-3A and AGS operators to perform Land and Maritime Interdiction, Time Sensitive/Dynamic Targeting (TST/DT), and Suppression/Destruction of Enemy Air Defences (SEAD/DEAD).

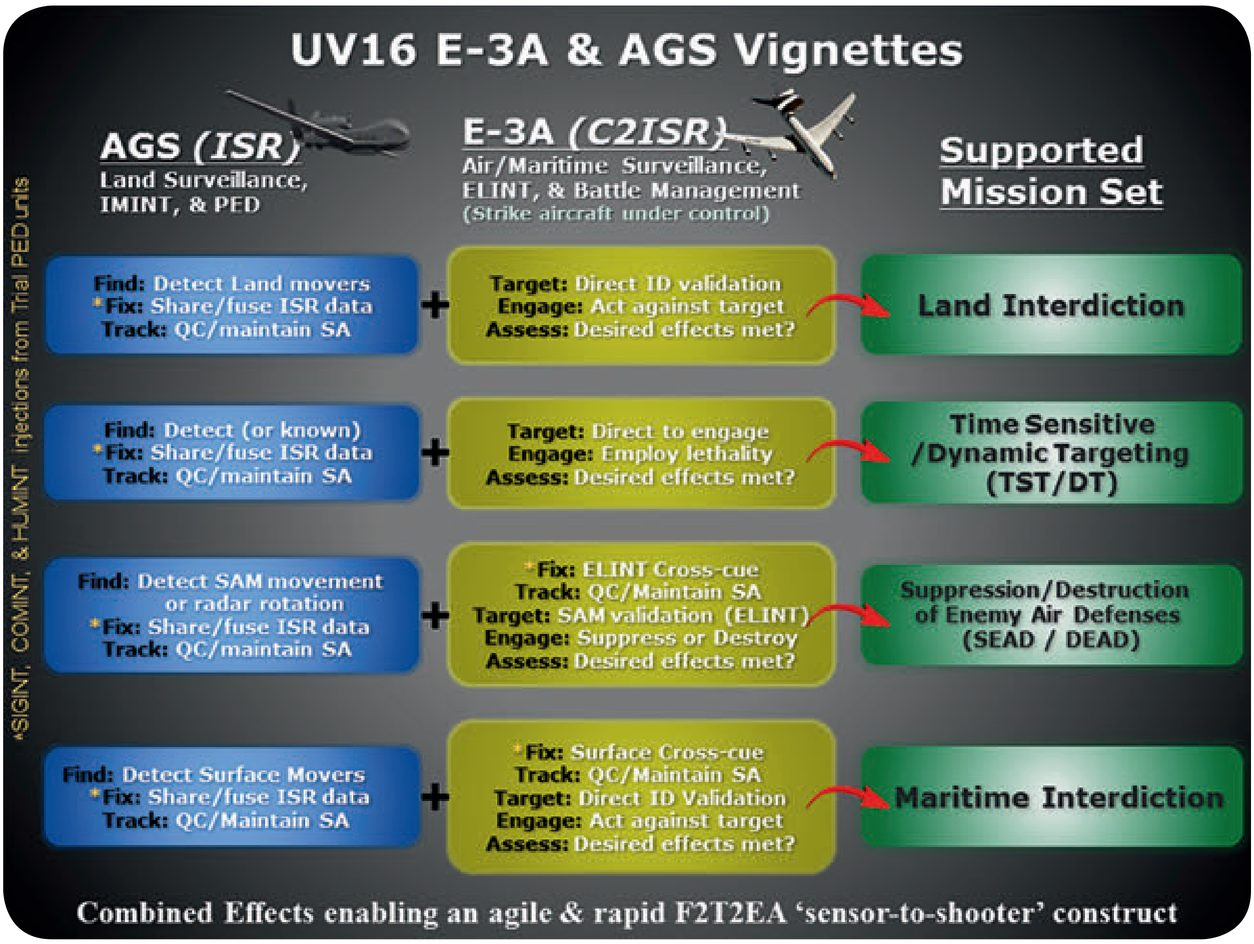
Many initial challenges stemmed from AGS design limitations (system still in development), latency in information exchange rates, and doctrinal differences between C2 and ISR communities. While UV16 offered a first 'hands-on' experience for AGS operators to manipulate their workstations, man-machine interface learning curves became apparent, especially when exposed to real-world scenarios. Experimentation in sharing GMTI information via Link-16 datalinks suffered

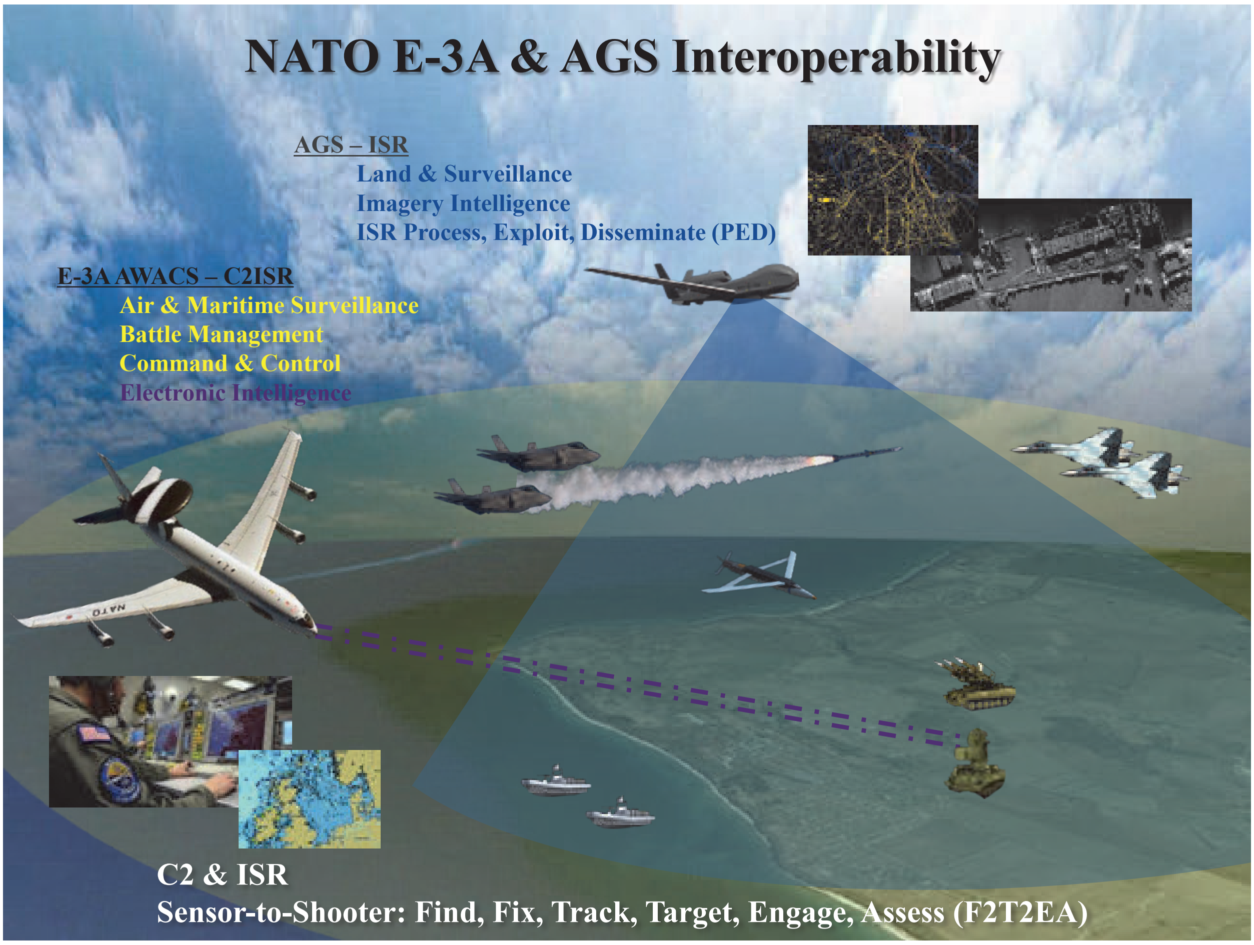


from delays inflicted by AGS system design and virtual relays rendering it inadequate to effectively support a few vignettes. Layered SIGINT and COMINT datalink information assisted in corroborating GMTI positions; however, with much variation. Additionally, while CSDs enabled UV16 participants to upload, query, and download ISR information, they were based upon traditional J2 (Intelligence) frameworks supporting longer PED timeframes. Although GMTI has historically complemented lengthier PED cycles in the past (such as the identifying patterns of life or IED backtracking)[7], current CSD configurations fall short of effectively supporting dynamic and kinetic events real-time (i.e. Interdiction, TST, and Strike). Supplemented by SIGINT and COMINT datalink data, IP Chat served as the best medium to quickly share land and maritime mover information between AGS to E-3A operators during the trial. ELINT, IMINT, and Maritime cross-cues enhanced data fidelity. Given the reactionary demands of real-world scenarios, the importance of NRT ISR sharing was quickly realized and initial operator 'man-machine-man' workflows evolved into multiple cross-platform complementary processes.

Lessons Identified and MDC2 Considerations

With recent, significant, technological advancements, information velocity has exponentially increased the potential to cut the targeting cycle from days to minutes.[8] However, without interoperable NRT technical solutions and human processes, it becomes extremely difficult to expeditiously share critical data, manoeuvre strike assets, or provide immediate threat warnings. In the case of E-3A and AGS interoperability, CSD-like concepts and system design must progress to enable NRT information sharing to harness the data's





full potential. GMTI information, fleeting in nature, loses value and utility if not rapidly circulated amongst C2 and Strike assets. Compatible systems providing faster information synthesis and seamless integration between both platforms will lead to higher combat effectiveness. Furthermore, with a rapid influx of actionable intelligence between ISR PED and C2 nodes, new paradigms are presented and current doctrine must be revisited. For the J2 side of the house, the community must break away from traditional 'stove-pipe' ISR collection frameworks (technical and cultural) and develop new Tactics, Techniques, and Procedures (TTPs) to cross-cue and share ISR data with increasing velocity.[9,10] As General (retired) Franc Gorenc[11] adamantly said: 'Amateurs concentrate only on ISR collection; professionals concentrate on PED and fusion to make sense of the data. The ability to share data, machine-to-machine, will define the effectiveness of our alliance.'[12] As for the J3 and more specifically the C2 community, an operator's tactical and operational aperture must evolve to accept all forms of actionable ISR data (from all domains) with the creation of new TTPs to integrate it. In championing these critical elements, a more rapid and lethal 'kill-chain' or Find, Fix, Track, Target, Engage, and Assess (F2T2EA) process can be obtained.[13]

Given these lessons identified from UV16, it is important to emphasize the wealth of interoperability opportunities between NATO's only two organic airborne assets: the NRT PED as well as intelligence fusion across domains and its rapid delivery to assets with the capability to produce desired effects. This agile operational 'sensor-to-shooter' framework is leveraged by the combined effects of a C2 and ISR capability capturing the full spectrum of the F2T2EA concept. While other Remotely Piloted Aircraft (RPA) missions, such as the MQ-9 Reaper, demonstrate the effectiveness of a single platform 'F2T2EA' practice (in a permissive environment against a discreet target set), the E-3A and AGS proof of concept takes a bilateral approach, enabling a cross-domain synergy in a broader battlespace, where the complementary employment of C2 and ISR capabilities enhances effectiveness and each compensates for the shortcomings of the other system. Real-world E-3A interoperability successes with US RC-135 Rivet Joint, RQ-4 Global Hawk, and NATO Control and Reporting Centres (CRCs), reinforce this same concept by demonstrating cross-platform benefits in cross-cued intelligence and threat warnings. Additionally, in a more recent exercise called Formidable Shield, E-3A interaction with US Navy P-8 Poseidon and NATO's first Integrated Air & Missile Defense (IAMD & BMD) Task Group demonstrated further potential in collaborative capabilities to include the Space domain.

By promulgating the above attributes into a more collaborative enterprise, incorporating additional ISR nodes with rapid information exchange rates via open architectures, a more formidable 'combat cloud' can be obtained, capable of yielding unparalleled SA across the air, land, sea, and space environments. Furthermore, multi-domain SA will afford C2 entities the opportunity to employ (or apply) the most appropriate available offensive and defensive capabilities from all domains in multiple environments at the Commander's desired place and time; ultimately setting the Alliance on a path from Air C2 of Joint air assets to a more mature and complete MDC2 construct.

It is not enough to simply link together more ISR sensors to provide multi-domain SA; in order to gain an advantage, ISR data must be properly integrated, synchronized, and analysed within a specific time and parameter to conduct what US Air Force Lieutenant General VeraLinn Jamieson[14] dubbed 'fusion warfare'.[15] In fusion warfare, where multiple Observe-Orient-Decide-Act (OODA) loops occur simultaneously across different domains, C2 nodes, and mission sets, John Boyd's traditional 'fastest OODA loop wins' concept evolves into a plural format. Jamieson further advocates that success in future conflicts may depend on harnessing the power of multiple OODA loops and converting the mass amounts of 'big data' in them to bring an all-encompassing battlespace picture to tactical, operational, and strategic leaders. Lastly, in order to take advantage of machine-speed data-sharing capabilities, classification, security, and automation barriers in the cyber domain must be overcome. Shifting to a network architecture that protects transported information from the current philosophy of protecting the network will allow higher security postures and the flexibility to conduct multiple missions with multiple nations.[16] With more dynamic intelligent security that protects the mission with data confidentiality and availability, along with cross-domain guards to synchronize operator authorities against data classification, a smarter and more resilient network will ensure mission critical data access to customers who really need it. Furthermore, with increasing programming and algorithms to leverage automation in 'big data' collection and 'activity based' analysis, infrastructures could be optimized to allow more malleability to influence multiple environments at any time.[17,18]

Conclusion

As NATO's strives to reinforce its core tasks of collective defence, crisis management, and cooperative security by demonstrating interoperability and a rapid military response ability through multinational exercises, the Alliance must question and refine its strategic approach to confront future challenges. An aggregate of NATO's military effective capabilities, if calibrated properly, would open the door towards unlocking the benefits of a multi-domain construct.

When combining manned and unmanned capabilities to produce C2ISR combined effects in multiple environments, NATO E-3A and AGS integration possesses the potential to provide the Alliance with an initial vector towards MDC2 operations. However, to expand on MDC2 capabilities and secure an asymmetric strategic advantage into the 21st century, NATO must gear towards a new enterprise 'system of systems' approach, tap into 'combat clouds', and leverage the competitive advantages afforded from Joint ISR fusing and rapid information sharing. Additionally, technocratic 'stove-pipes' of proprietary intelligence data must be freed to induce fusion warfare and allow

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C2 and strike assets to hastily complete the F2T2EA 'kill-chain'. As General (retired) Herbert J. Carlisle[19] stresses, 'if you don't have the ability to do something with it [the intelligence data], then you're missing half the equation'.[20] Subsequently, smarter network architectures with automatic processes will ensure cyber domain integrity and the fluid transfer of crucial information to the right person, in the right place, at the right time.

While NATO E-3A and AGS may have provided a small glimpse towards a multi-domain operational concept, it is up to the Alliance to ensure a new foundation is set to adopt and nurture an MDC2 capability.

1. Gen McChrystal, S. A., 'The Military Case for Sharing Knowledge', TED Talks, Mar. 2014 [cited 5 Jul. 2017]. Available online from https://www.ted.com/talks/stanley_mcchrystal_the_military_case_for_sharing_knowledge
2. Lt Gen Handy, R., Lt Gen (ret.) Deptula, A., Lt Gen (ret.) Sattler, J., Lt Gen Elder, R. and Col Cyr, H., 'C2 Battle Management, AFA – Proceeding from the Air & Space Conference and Technology Exposition', 15 Sep. 2014.
3. Lt Gen (ret.) Deptula, David A., 'Beyond JSTARS: Rethinking the Combined Airborne Battle Management and Ground Surveillance Mission', Mitchell Institute Policy Papers, vol.2, Sep. 2016.
4. Defense Intelligence Agency, 'Russia Military Power: Building a Military to Support Great Power Aspirations', DIA-11-1704-161, 2017: p. 29–45.
5. Davenport, Brandon, 'Multi-Domain Command and Control: The Air Force Perspective with Brigadier General Chance B. Saltzman', Over the Horizon: Multi-Domain Operations & Strategies, 3 Apr. 2017 [cited 29 Sep. 2017]. Available online from https://overthehorizonmdos.com/2017/04/03/multi-domain-command-and-control-the-air-force-perspective-with-brigadier-general-b-chance-saltzman-part-1-of-2/
6. Munday, Robert, 'Trial UNIFIED VISION 2016', Final Trial Report, vol.1, 1 Nov. 2016: p. 1–9.
7. Dr. Mooers, E., Dr. Wrick, V., Theophanis, S. and Craig, Bonaceto, 'Collective C2 in Multinational Civil-Military Operations: GMTI Utility Analysis for Airborne Assets', 2011.
8. Ibid. 2.
9. Headquarters, US Air Force, 'RPA Vector: Vision and Enabling Concepts 2013–2038', 17 Feb. 2014: p. 62, 71, 92.
10. Ibid. 3.
11. Frank Gorenc is a retired USAF four-star General who last served as the Commander US Air Forces Europe; Commander US Air Forces Africa; Commander Allied Air Command; and Director of the JAPCC.
12. Gen (ret.) Gorenc, Frank, 'NATO Air Power: The Last Word', In the Journal of the JAPCC, Edition 23 (2016).
13. Col Nicholson, T. and Lt Col Rouleau, N, 'Order in Chaos: The Future of Informed Battle Management and Command and Control', The Mitchell Forum, no.10, Mar. 2017: p. 3–5.
14. Lt Gen VeraLinn 'Dash' Jamieson currently is the Deputy Chief of Staff for Intelligence, Surveillance and Reconnaissance, Headquarters US Air Force, Washington, D.C.
15. Maj Gen Jamison, V. and Lt Col Calabrese, M., 'An ISR Perspective on Fusion Warfare', The Mitchell Forum, no. 1, Oct. 2015: p. 2–3.
16. Dr. Linderman, M. H. and Eggers, J., 'Battlespace Networking: An ISR Horizons Future Vision', Deputy Chief of Staff, Intelligence, Surveillance and Reconnaissance, Headquarters US Air Force, May 2015: p. 5.
17. Clark, Colin, 'Rolling the Marble: BG Saltzman on Air Force's Multi-Domain C2 System', Breaking Defense, 8 Aug. 2017. [cited 24 Sep. 2017]. Available online at https://breakingdefense.com/2017/08/rolling-the-marble-bg-saltzman-on-air-forces-multi-domain-c2-system/
18. Maj Kreuzer, M. P. and Maj Dallaire, D. A., 'Targeting the Islamic State: Activity-Based Intelligence and Modern Airpower', The Mitchell Forum, no. 11, Apr. 2017: p. 4–8.
19. Herbert J. 'Hawk' Carlisle is a retired United States Air Force four-star General who last served as the commander of Air Combat Command (ACC).
20. Ibid 3.

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earned his commission through Officers Training School in 2004. His unique operational, test, and acquisitions experience includes the E-8C, RQ-4, and E-3A weapon systems. He is a Senior Air Battle Manager and possesses qualifications as an Instructor Weapons Controller, Instructor Surveillance Controller, Fighter Allocator. He is certified through the Defense Acquisition University in Program Management Test & Evaluation. During his previous assignment, as Global Hawk Test Lead and Combined Air Operations Centre Liaison Officer, he was responsible for the initial stand-up of RQ-4 Block 40 combat operations in three different Combatant Commands. Currently, he is an Instructor Passive Controller and Chief of Training Development for Electronic Warfare, Operations Wing, E-3A Component, NATO Airborne Early Warning & Control Force. He is an advocate for C2 & ISR interoperability and has led E-3A integration with multiple weapon systems.

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Aqua-Quad Drone.

Unmanned Air Systems in NATO Anti-Submarine Warfare (ASW)

Potential Future Applications and Concepts

By Captain William A. Perkins, US Navy, JAPCC

Background and Introduction

The resurgence of Russian Federation Navy (RFN) submarine activity in the past few years has stimulated a response action from the Alliance. At both the 2014 Wales and 2016 Warsaw NATO Summits, Anti-Submarine Warfare (ASW) was identified as a crucial focus area which the Alliance must address to ensure it maintains its advantage and freedom of movement in the maritime domain. Many documents have cited NATO's decreasing ASW capability and capacity, mostly due to the rapid decline of RFN submarine operations, which from the early 1990s until recently had nearly ceased. Furthermore, following the Cold War, NATO adopted a more expeditionary strategic view, causing many former ASW resources to be re-aligned to support other functions, many of which were out of the European theatre. The pendulum has recently begun to shift back, as acceptance of this challenge is growing in both the military and political spheres.

The Smart Defense initiative following the Wales Summit stimulated an intriguing line of thought. As operations in the air domain have relied heavily on unmanned and remotely operated systems for the last three NATO operations, what role do unmanned systems above, on and below the ocean's surface have in NATO's ASW mission? This article will explore the role that Unmanned Air Systems (UAS) serve today, as well as offer insight into potential future applications.

Benefits of UAS over Manned Systems

In general, unmanned systems have the following characteristics which can be distinct from manned systems, as expressed by Dr. Kevin LePage, Principal Scientist and Cooperative ASW Programme Manager at NATO's Centre for Maritime Research and Experimentation:[1]

- force multiplier, integration with other systems and capabilities above and below the surface without the overhead of training a manned crew;

- improved endurance;
- operations in degraded/denied environments – greater risk threshold than manned systems;
- higher proportion of platform dedicated to payload;
- modularity;
- scalability;
- potentially lower unit cost than 'equivalent' manned platform.

Specific to ASW, this means an unmanned system could conduct certain time-consuming functions, such as loitering in a designated search location to monitor the ocean and conduct initial detection of a submarine moving through the area. This specific function has consumed a significant amount of the life-span of manned systems, such as the P-3 Orion series Maritime Patrol Aircraft (MPA), yet remains the most critical link in the ASW kill chain, as it is hard to engage a submarine with a torpedo if you have not yet determined its location. However, in the role of initial acoustic detection of a submarine and subsequent monitoring of its movement, sufficient bandwidth to support off-board acoustic processing remains a technical challenge, but research in this area is ongoing. Furthermore, persistent multi-sensor coverage provided by a single UAS can then cue in a manned system to conduct the next level of submarine prosecution, be it continued tracking or engagement with torpedoes.

Role of Larger Unmanned Systems

Larger UAS airframes, such as the US Navy's MQ-4 Triton, are already serving in mutually supporting roles with other manned ASW platforms. However, the Triton's sensor suite is better suited for other types of collection. Its method of detecting a submarine is limited to detection of any signals emitted or via radar should the submarine expose its periscope, snorkel or fully surface. The Triton is designed to work in concert with the P-8 Poseidon due to its limited ability to support purely ASW functions (such as acoustic processing or torpedo carriage).

However, these limitations to the Triton's ASW capability reveal how a different type of unmanned system could actually better fill the role. The Global Hawk airframe

'… unmanned system could conduct certain time-consuming functions, such as loitering in a designated search location to monitor the ocean and conduct initial detection of a submarine moving through the area … and then cue in a manned system to conduct the next level of submarine prosecution.'

(around which the Triton is designed) already has the payload and endurance to serve well here. The sensors would need to be adapted to specific ASW detection sensors. These new sensors could be a new type of undersea imaging system developed as a follow-on capability to the Littoral Airborne Sensor Hyperspectral (LASH)[2], underwater laser imaging, or even an acoustic processor which interfaces with other sea-based or bottom mounted sensors. Currently, acoustic data on submarines is traditionally generated from sonobuoys launched from aircraft. This concept requires a large airframe capable of carrying and delivering at times more than 100 sonobuoys. The weight and carriage requirements make UAS use as a 'sonobuoy truck' unlikely, therefore other methods of leveraging off-board detection sensors must be explored.

Concept of Smaller Networked Systems

Smaller tactical UAS, such as Scan Eagle, are being deployed from many nations' ships to serve in an Intelligence Surveillance Reconnaissance (ISR) role supporting the development of the maritime picture. As the case with the Triton, these tactical UAS have a limited ASW role, mostly in visual detection of submarines. However, should their sensor payload be changed out with a sensor capable of tracking a submarine (such as magnetic anomaly detection or other tracking sensor), they could provide an invaluable service in the tracking function and reduce flight hours required from MPA and ASW helicopters.

Furthermore, smaller, networked systems open up an interesting range of possibilities. In 2017, the US DoD launched 103 PERDIX micro-drones and demonstrated their ability to operate as a single entity, reorganizing their own formation to accomplish a set of missions and spatially arranging themselves to account for loss or failure of some of the drones to maintain coverage and accomplishing the mission.[3] This concept is readily adaptable to an ASW role against a dynamic and evasive target.

Consider the Aqua-Quad. This small quad-copter drone is powered by solar cells providing a three month duration, and it has the ability to land on the ocean, deploy a small acoustic sensor below the surface, retrieve that sensor and lift off to reposition itself.[4] In testing, it has proven capable of operating in 14 feet seas (4.3 m) despite its seemingly fragile frame.[5] Extrapolating the concept of multiple networked drones self-synchronizing to perform a set of mission tasks, one can envision a fleet of Aqua-Quads serving both the initial detection **and** long duration tracking function.

A formation of these systems could be set across a known submarine transit area, such as a geographic choke point, with acoustic sensors deployed and solar batteries being charged while they wait and monitor. Upon detection of a submarine, the formation then re-organizes itself to surround the submarine, ensuring that multiple elements always

Figure 1: The Navy's Aqua-Quad drone is a solar-powered ocean-drifting unmanned vehicle that can fly and trail sonar arrays.

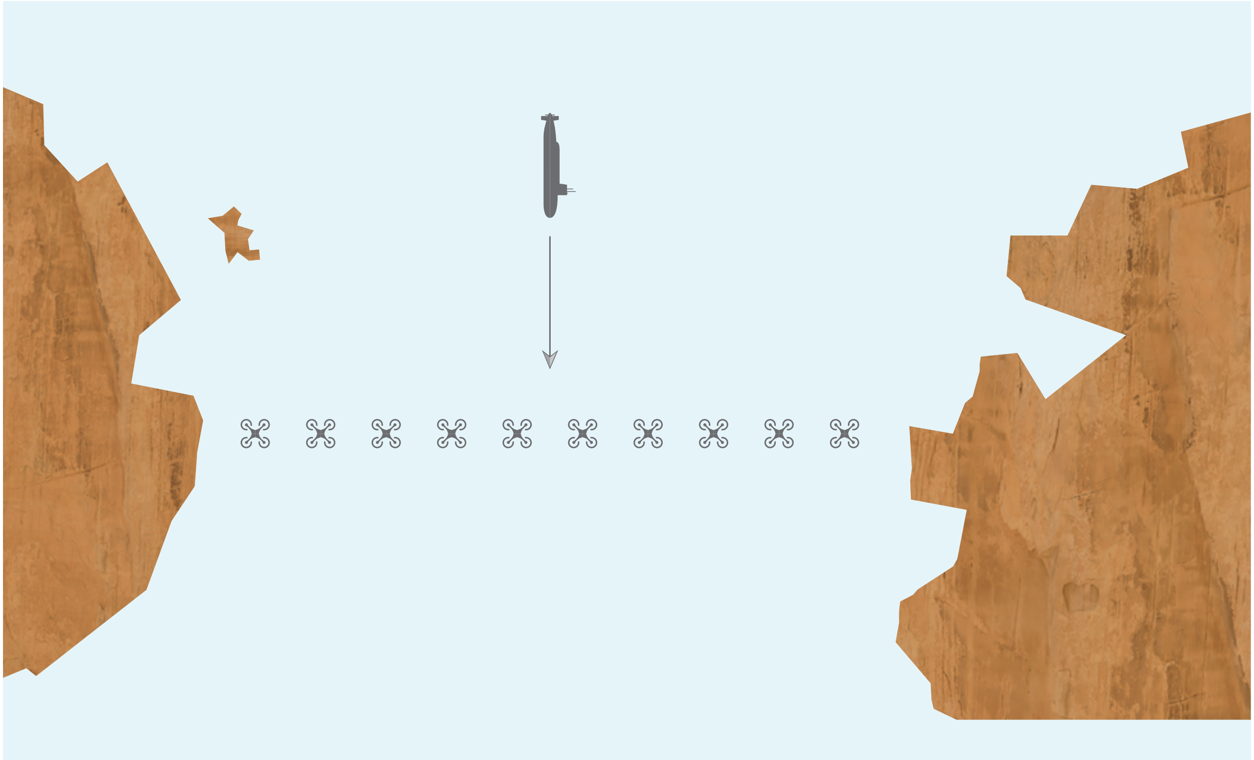

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Figure 2: Long duration unmanned aircraft systems monitoring a chokepoint.

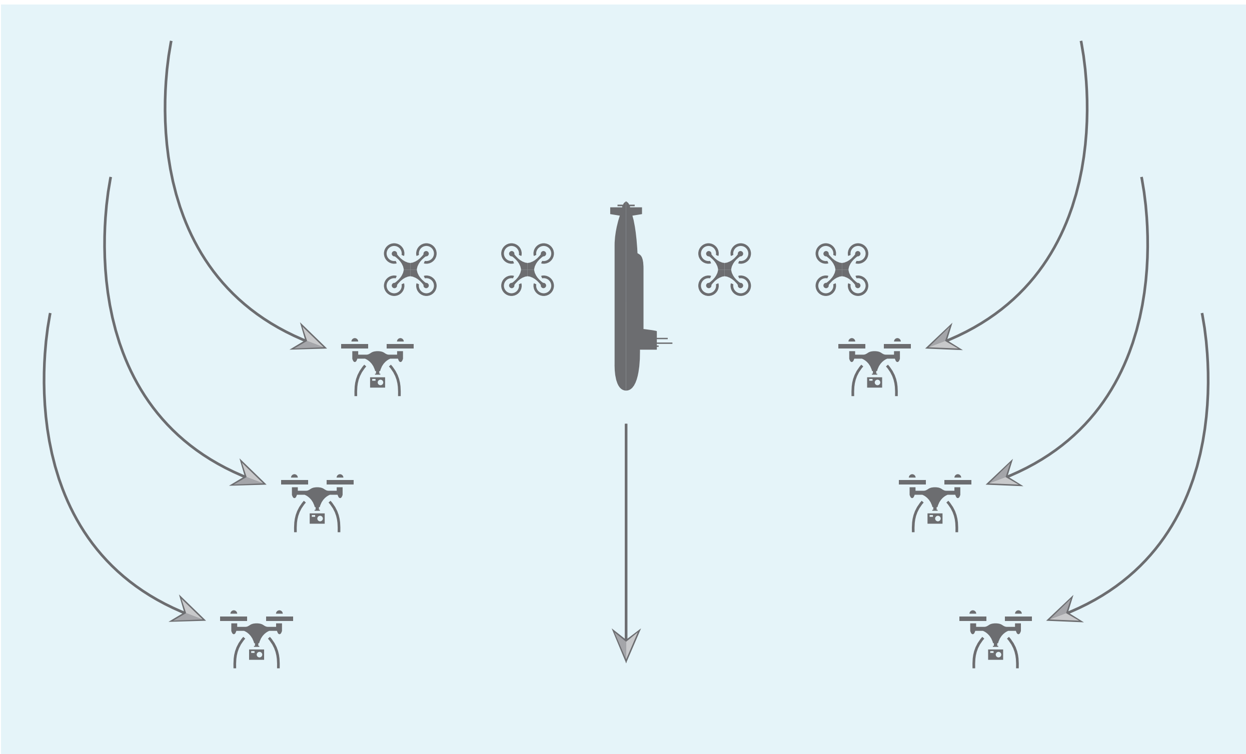

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Figure 3: As the submarine passes through the choke point, the network reorganizes in the direction of travel to maintain consistent coverage.

remain ahead of the direction of travel to allow other elements time to reposition or to be prepared to adapt to a change in submarine course. A network of 25 or so of these systems could maintain proper tracking geometry even on evasive submarines as outlined in the notional diagrams in Figures 1–3 on the preceding pages.

There are a few technical challenges to this vision. First, the network must be able to communicate amongst itself to effectively organize. Secondly, the network must be able to communicate to an off-board command & control (C2) element to inform of the presence and movement of the submarine so a decision can be made regarding the next step of prosecution. Thirdly, the network must be able to communicate with off-board sensors as well, even unmanned systems operating on above and below the surface. This requires the development of a robust communications network. NATO's Centre for Maritime Research and Experimentation in La Spezia, Italy, is focused on exploring solutions to this challenge

'New technology for swarming systems as well as potential developments in a reliable high-bandwidth optical link capability make the future of unmanned aerial systems a viable near term solution for aiding in the ASW mission.'

for undersea systems, as the water provides some challenges to data transmission not seen in airborne linked networks.

To address the ability of these types of unmanned systems to communicate outside their local network, a new type of data transmission might be required. Dr. Wolfgang Griethe and Dr. Markus Knapek discussed the potential for optical datalinks and their applications for use by unmanned systems. They conclude that a compact micro-laser datalink terminal might be a viable solution to enhance airborne communications.[6] In the case of the quad-copter above, building

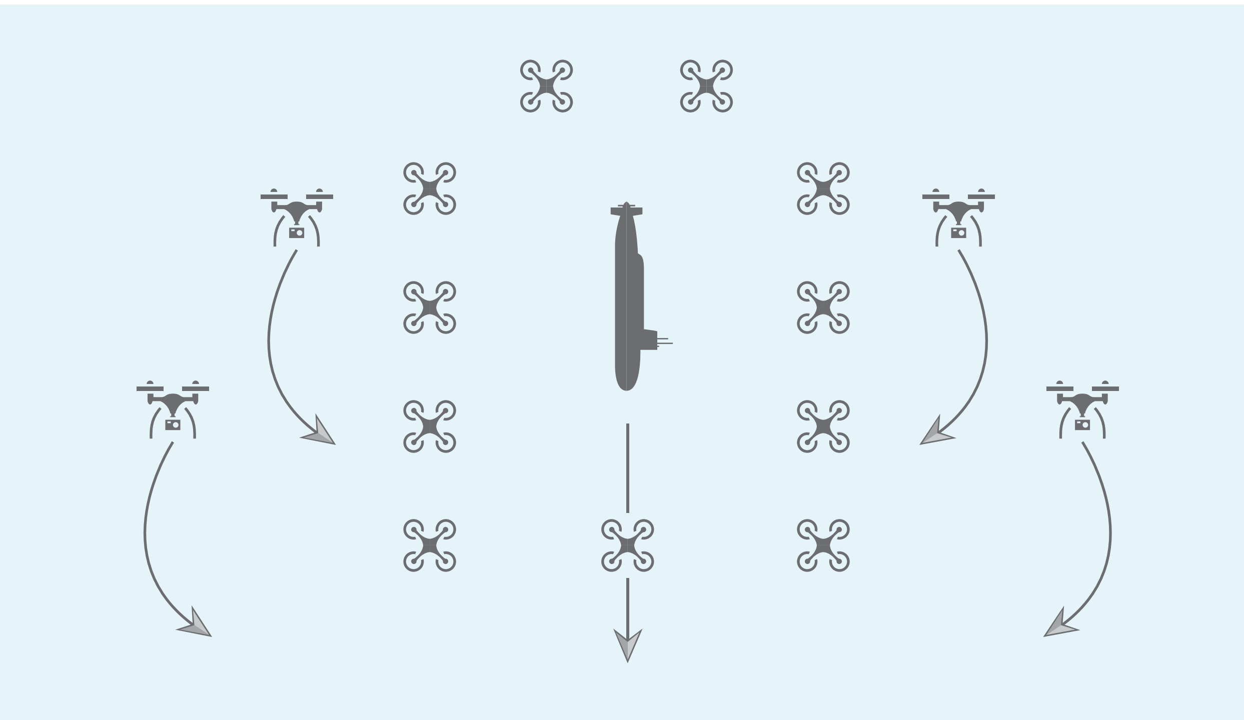

Figure 4: Some elements of the swarm are airborne conducting repositioning, some elements are on the surface conducting tracking. This process continues for every course change and can endure as long as the UAS power supply lasts.

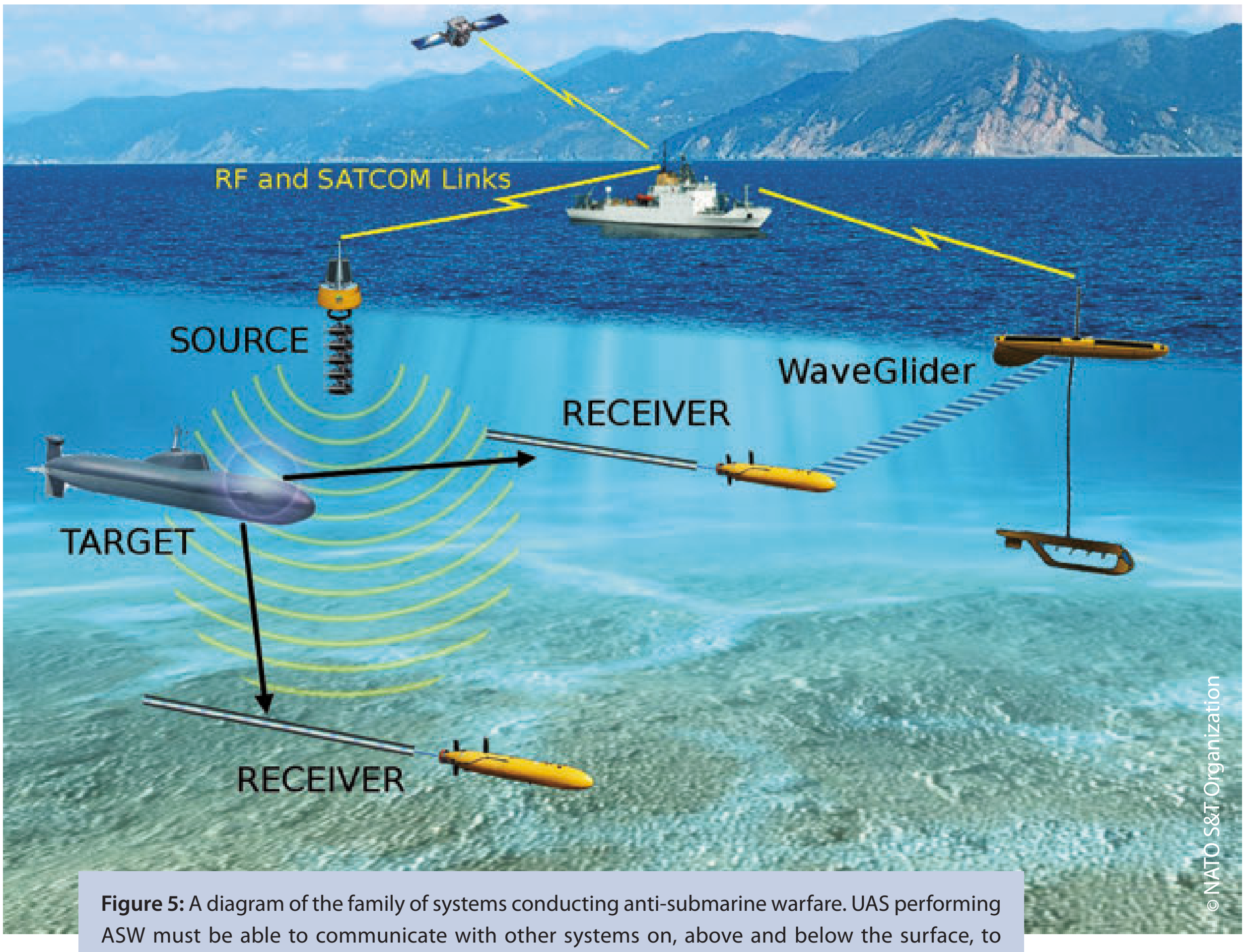

Figure 5: A diagram of the family of systems conducting anti-submarine warfare. UAS performing ASW must be able to communicate with other systems on, above and below the surface, to effectively conduct this mission.

Figure 6: An MQ-8 Fire Scout could be adapted with ASW sensors and serve in a similar role as a Hawklink-equipped MH-60R ASW helicopter.

one of these into each of the individual platforms is not necessary, rather a separate type of unmanned system, such as a long duration UAS, could orbit overhead the swarm as part of their local communications network and then further disseminate information via an optical datalink to ashore or afloat C2 nodes.

Although this article is using the aqua-quad as an example of a type of technology which could be leveraged in this manner, it is not recommending procurement of one particular system or design over another. Research would need to be conducted into the best design model which captures this potential. As an example of other types of airframes which could serve this function, the MQ-8 Fire Scout could be further adapted with a dipping sonar and torpedo delivery capability, similar to the function manned ASW helicopters perform today, while being remotely piloted from the ship in the same manner it is flown for its ISR mission. Furthermore, the diagrams on submarine tracking in Figures 2–4 are notional, and once a system was constructed, detailed analysis would be required to develop tactics for optimal organization and patterns for various submarine speed and depth regimes.

Conclusion

Unmanned systems technology offers potential applications for use in the ASW mission area. Although there are some systems in existence today, most of their sensors are directed at an intelligence-gathering mission and have limited direct application to ASW, although innovative use of tactics to exploit sensor capability should continue to be explored. However, the future is promising for development of unmanned systems which are specifically devoted to the ASW mission. ASW as a mission requires extended sortie durations and sensor dwell times as well as data fusion and data dissemination early in the prosecution, then requires options for submarine engagement when the situation requires. New technology for swarming systems as well as potential developments in a reliable high-bandwidth optical link capability make the future of unmanned systems a viable near-term solution for aiding in the ASW mission. Regardless, there will remain a requirement for unmanned systems to integrate with other elements in the ASW domain, including ships and manned aircraft. While unmanned systems are well suited for detection and tracking phases of prosecution, manned aircraft will, in the near-term, likely remain necessary for torpedo delivery for lethal effect.

1. Derived from comments made by Dr. Kevin LePage at 2017 Undersea Defense and Security Conference, 8 Mar. 2017.
2. A pod mounted on an aircraft using advanced imaging in the visible and infrared spectrum, processing hyperspectral imagery to provide real time submarine detection. Challenges with size of area scanned and processing capability (leading to long time delays for detection) challenged this system in development.
3. Kyle Mizokami. 'The Pentagon's Autonomous Swarming Drones Are the Most Unsettling Thing You'll See Today'. Popular Mechanics. 9 Jan. 2017. Available at: http://www.popularmechanics.com/military/aviation/a24675/pentagon-autonomous-swarming-drones/
4. Cheyenne MacDonald. 'The submarine-hunting drone that takes off and lands on water: US Navy reveals new breed of amphibious solar UAVs'. Daily Mail. 7 Apr. 2016. Available at: http://www.dailymail.co.uk/sciencetech/article-3528556/The-submarine-hunting-drone-takes-lands-water-VERTICALLY-Navy-reveals-new-breed-amphibious-drones.html
5. Cheyenne MacDonald. 'The submarine-hunting drone that takes off and lands on water: US Navy reveals new breed of amphibious solar UAVs'. Daily Mail. 7 Apr. 2016. Available at: http://www.dailymail.co.uk/sciencetech/article-3528556/The-submarine-hunting-drone-takes-lands-water-VERTICALLY-Navy-reveals-new-breed-amphibious-drones.html
6. Dr. Wolfgang Griethe and Dr. Markus Knapek, 'Optical Data Links for Aerial Applications – Promising Technology for Future RPA Operations'. JAPCC Journal 23, Winter 2016. Available online at: https://www.japcc.org/optical-data-links-aerial-applications-promising-technology-future-rpa-operations/

Captain (N) William Perkins

is designated as P-3 Orion Weapons & Tactics Instructor (WTI) and on his seven deployments he has flown combat missions in every operational theatre in which the P-3C operates. In 2012, then Commander Perkins completed a successful aviation squadron command tour as Commanding Officer of Tactical Air Control Squadron 11. A prolific author and strategist, Captain Perkins' work has been published in Jane's Defence Weekly, Jane's Navy International, US Naval Institute's PROCEEDINGS, Joint Warfare Centre's Three Swords and in the Journal of the JAPCC. In addition, while assigned to the JAPCC from 2015–2017, he wrote three strategic level studies on NATO maritime and air integration challenges. Captain Perkins is currently serving as the Director of Fleet Operations (N3) for the Pacific based US SEVENTH Fleet.

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The extremely congested European airspace.

Ensuring Military Cross-Border Air Operations in Europe

Civil-Military Air Traffic Management in a 'Single European Sky'

By Lieutenant Colonel Edgar Reuber, German Air Force, EUROCONTROL Official

Introduction

In 1999, the European Commission (EC) launched the 'Single European Sky' (SES) initiative to solve the European Air Traffic Management (ATM) system's inability to deal with increasing congestion of the fragmented European airspace. Bolstered by subsequent European Union (EU) legislative packages, SES aims at a pan-European airspace independent of national borders as well as tackling future air transport demands regarding safety, capacity, efficiency, and environmental protection. SES ATM Research (SESAR) is the supporting programme developing future ATM capabilities and technology necessary for safe, efficient, and effective airspace utilization.[1]

To safeguard the ability of combined packages of military forces to operate and train across national airspace

As providers and consumers of Air Traffic Services, the military uses the same Instrument Flying Rules as does General Air Traffic.

boundaries in Europe, NATO Air Power must rely on coordinated civil-military ATM for airspace organization, allocation, mission planning, execution, and control. The military has therefore been involved in SES and SESAR since their inception, as a user, service provider, and in some cases even as a regulator. On the civil aviation side, the EU has gained ATM rulemaking authority across Europe. However, military matters often remain a national responsibility, and European ATM solutions have been only adopted based on the nature of national requirements and the peculiarities of airspace constraints. This has led to fragmented organizations, regulations, service provision, and civil-military coordination arrangements, with consequential shortfalls in the facilitation of military cross-border air operations.

EUROCONTROL is an intergovernmental European civil-military organization which supports the EC, the European Aviation Safety Agency (EASA), and National Supervisory Authorities in their regulatory activities. EUROCONTROL is committed with its partners to deliver the ATM performance required to build SES, which will also feature projects and activities to address specific military needs.

European Operational Air Traffic Rules (EUROAT)

As providers and consumers of Air Traffic Services (ATS), the military uses the same Instrument Flying Rules (IFR) as does General Air Traffic (GAT). In addition, most governments have developed national rules and services to meet specific IFR requirements for their mostly military 'Operational Air Traffic' (OAT).[2] To appropriately facilitate OAT and its interface with GAT in the SES environment, EUROCONTROL published in 2013 a set of 'Specifications for harmonized Rules for OAT under IFR inside controlled airspace of the European Civil Aviation Conference (ECAC) area'.[3] The agreement, referred to as EUROAT, is the first military deliverable of the European ATM Master Plan and intended to become a single reference for OAT in a 'single sky' ranging across all 44 ECAC member countries.[4] The aim is to provide a regulatory framework for OAT-IFR in controlled airspace on a European scale and to appropriately facilitate the interface between OAT and GAT, while minimizing the impact on military operational procedures or aerial tactics as much as possible. This is accomplished by adhering to three principles:[5]

1. Whenever possible, the same definitions, rules and procedures specified by the International Civil Aviation Organization (ICAO) and the Standardized European Rules of the Air (SERA) for GAT flights shall be applied.

2. Required rules for OAT, in addition to, or deviating from ICAO/SERA provisions are detailed within the EUROAT.

3. Where operational requirements of a flight are incompatible with either of the above, these requirements should be met by using an Airspace Reservation (ARES) of appropriate type and dimension, or methods that are considered sufficiently safe and which have been approved by the appropriate national authority.

National implementation of the specified rules and procedures will underpin OAT-IFR harmonization and standardization in the controlled airspace of all nations that have chosen to implement EUROAT. Ideally, EUROAT should apply to all aircraft flying under OAT-IFR, but national constraints may result in deviations from the specifications within their sovereign airspace. In any case, military and other State aircraft[6] will still require a valid diplomatic clearance when crossing national borders.

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OAT Transit Service – Providing Short-Term Solutions

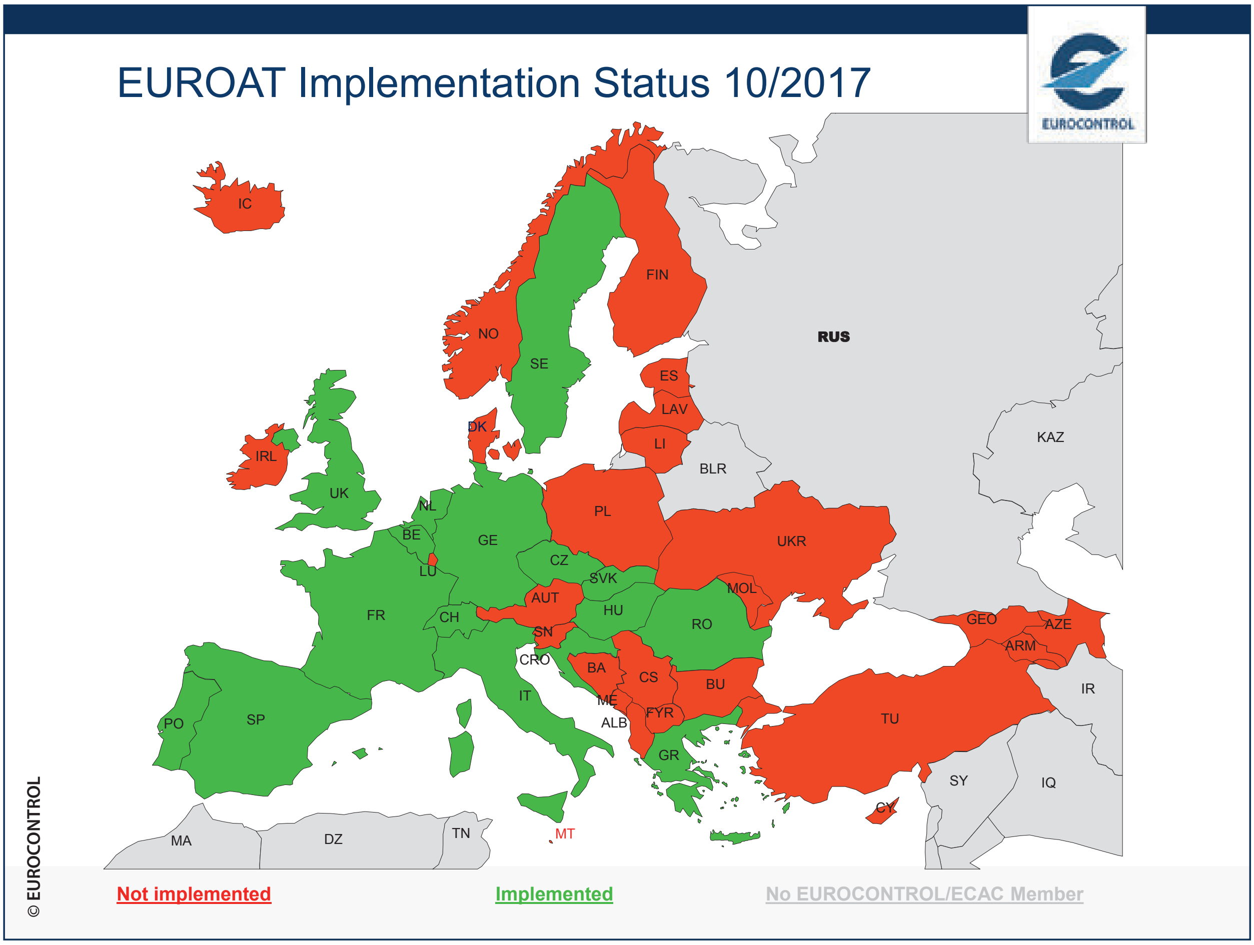
As long as the shortfall of harmonized OAT-IFR services for transit across Europe persists, military cross-border traffic will continue to use GAT IFR rules not satisfying military OAT specific needs like being provided in EUROAT principles. However, those GAT rules and services were not designed to address specific requirements for OAT transit in non-segregated airspace (i.e. without segregation using an ARES). Issues could be:

- Day to day management by service providers of potentially confidential trajectory data for military OAT-IFR transits.

- Military high priority missions (such as Quick Reaction Alert, Medical Evacuation, or any other type of time-critical flight mission) cannot be subject to Air Traffic Flow Management since their flight profile is not negotiable.

- Handling of military transit flights may require special procedures, skills and training. It can be in support of training packages or for executing en route Air-to-Air Refuelling (AAR) with limited aircraft manoeuvrability. The handler should be familiar with constraints and contingency procedures for Remotely Piloted Aircraft (RPA) or flights with live weapons and to be able to ensure safe separation, with minimum impact on GAT traffic.

- Military avionics and specific military Communication, Navigation and Surveillance (CNS) systems may require rule derogations, special provisions, and highly secure interfaces to civilian net-centric ATM solutions.



- In the event of operational or technical outage, the provision of ATS and CNS services needs to be transferred to the most appropriate centre or service provider.

These issues further highlight the systematic consideration of military requirements needed to integrate military cross-border operations into the European ATM network. While EUROAT provides the respective baseline, its effective implementation across the ECAC area will probably take many years. This has led to the foundation of the OAT Transit Service (OATTS) to safeguard the effectiveness of military operations by connecting national structures and arrangements with each other to facilitate short-term civil-military ATM solutions. OATTS is a combination of air navigation services and their supporting services provided either by military, civil, or civil-military Air Navigation Service Providers (ANSPs). While OATTS started as an initiative among the 17 EUROCONTROL member states who have committed so far to implementing EUROAT, it aims to develop a pan-European OATTS to ultimately implement OAT-IFR (EUROAT) on a wider ECAC scale.

OATTS implementation initially requires an agreement on its concept and on harmonized procedures. Some technical changes are also needed to share all necessary information, from the planning to the execution phase. OATTS enablers should address all types of mission needs and technical gaps. However, a realistic approach would be to target progressive implementation, starting with initial hand-over procedures (e.g. sharing of cross-border entry/exit and navigation points) as well as sharing and processing all requisite aeronautical information and trajectory data.

Improved OAT Flight Plan (iOAT FPL)

In the past, military flight plan (FPL) formats were not harmonized on a European level and information was not disseminated throughout the ATM network. This lack of awareness about military traffic intentions impacted ATM network performance, flexibility, and interoperability in particular when dealing with cross-border exercises. To solve this, OATTS created the 'improved OAT FPL' (iOAT FPL), an enhanced military flight planning system. Based on the ICAO 2012 FPL format and the EUROCONTROL Integrated Initial Flight Plan Processing System (IFPS), OATTS provided harmonized rules for the description of trajectory elements as a first step toward implementing the Mission Trajectory detailed concept previously developed by EUROCONTROL as the best means of accommodating military flights in the future Trajectory Based Operations (TBO) environment. TBO is one important objective of SESAR activities to overcome the deficiencies of static flight plans which have been used until present in the ATM environment for both civil and military users.

For military air operations, the iOAT FPL will constitute the initial description of the 'Mission Trajectory' (MT). Once delivered it would become an initial Shared Mission Trajectory (iSMT). It would then be continuously updated with more accurate and current data as mission planning progresses. In this way, the iOAT FPL allows the appropriate authorities to see the MT from planning to execution via the responsible national Wing Operation Centre (WOC). The iOAT FPL will also allow sharing ARES information and military activity intentions with the Network Manager and the relevant partners, including Area Control Centres (ACCs).

Summary

The full implementation of the OATTS would be a concrete demonstration of civil-military partnership and collaboration to support all operational requirements at minimum cost. The benefits are:

- Accommodating harmonized requirements for cross-border OAT-IFR transit.
- Service adaptation to military avionics constraints.
- Facilitating the management of unexpected events like mission abortion on the ground or in the air due to technical failure or flight weather conditions.
- Facilitating a variety of trajectory profiles, including transition from low-level Visual Flight Rule (VFR) to high-level IFR, like slow speed transit for RPA, en route AAR, long-endurance surveillance flights.
- Enhanced data consistency achieved through a harmonized FPL format and content for OAT-IFR flights in controlled European airspace.
- Full awareness of OAT-IFR flights for both military and civil ATCs through dissemination of respective iOAT FPL data to all parties concerned.
- The Network Manager and ANSP are better aware of OAT operations including the planned and allocated ARES for individual missions.
- Ensuring confidentiality by distribution to military and civil ATC centres only on a need-to-know basis.
- Provision of certified aeronautical information and more options to military planners and airspace users.

Having said this, it must be noted that practicable solutions such as the OATTS are only interim steps on a still long way to go. A main obstacle to fully workable civil-military arrangements for future European ATM is a continuous lack of common agreed military positions amongst the nations. This is partly a result of not enough understanding and support from national politico-military authorities.[7]

Conclusion

Constantly implementing new ATM requirements – using verified and validated collaborative mechanisms – demonstrates just how willing the military community is to strike a balance between the growing challenges in complying with very demanding SES requirements and the military's natural commitment to its security and defence responsibilities. In fact, these two sets of obligations form the foundation on which all future integration processes should be developed in civil-military ATM cooperation and coordination.

The SES, in one way or another, will be achieved and will create both challenges and opportunities for European military forces. Awareness, proper analysis, and use of existing expertise for making informed decisions to adapt where necessary are major prerequisites underpinning NATO Air Power training and execution in European airspace.

1. Remus Lacatus. 'Preparing for a "Single European Sky"'. In JAPCC Journal 23, p. 79–84. Online at: https://www.japcc.org/preparing-single-european-sky-military-prompted-adapt-future-air-traffic-management/
2. Operational Air Traffic (OAT) is an agreed term applied in Europe to all flights which do not comply with the provisions stated for General Air Traffic (GAT) and for which rules and procedures have been specified by appropriate national authorities (EUROCONTROL EATM Glossary of Terms).
3. EUROCONTROL. 'Specification of harmonized Rules for Operational Air Traffic (OAT) under Instrument Flight Rules (IFR) inside controlled Airspace of the ECAC Area (EUROAT)', Edition 2.0. 18 Sep., 2013.
4. The ECAC is an intergovernmental organization established in 1955 by the International Civil Aviation Organization (ICAO) and the Council of Europe. The ECAC has meanwhile 44 members, including all 28 EU, 31 of the 32 European Aviation Safety Agency member states, and all 41 EUROCONTROL member states.
5. Ibid 3, Par 1.3.4.
6. For ATM purposes and with reference to article 3(b) of the Chicago Convention, only aircraft used in military, customs and police services shall qualify as State Aircraft. EUROCONTROL: Provisional Council session 11, 12 Jul. 2001.
7. Ibid 1.

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is an active German Air Force officer currently employed at EUROCONTROL in Brussels. He holds a MSC in HF engineering and looks back at a 27 year career qualifying him as a Senior Military Expert in Air Traffic Management. Mastering all career steps through German Air Force ATM patterns, he took over responsibilities for civil and military personnel in different assignments including Head of Training and Head of Section in Air Traffic management. In EUROCONTROL he enlarged his field of expertise to SES and SESAR and Remotely Piloted Aircraft Systems (RPAS). As a project manager in R&D for SESAR 1 and SESAR 2020 he supports the safe, efficient, and effective airspace utilization satisfying specific military airspace user needs.

Future Battlefield Rotorcraft Capability

Operating in the Land and Littoral Environment Anno 2035

Part 2: Analysing Future User Requirements

By Colonel Wim Schoepen, BEL AF, JAPCC

This topic was the subject of an essay paper the author wrote under supervision of the University of Lincoln, UK. For the purpose of JAPCC Journal publication, the essay has been divided into three parts split over the previous issue (Edition 24), this issue (Edition 25), and the issue to come (Edition 26). An overall introduction to the topic was published in Edition 23.[1]

Introduction

Part 1 of the 'Future Battlefield Rotorcraft Capability' trilogy was published in the previous edition of this journal. The article analysed different aspects of the 'Future Operating Environment' and how these will directly impact the Future Battlefield Rotorcraft Capability (FBRC) in terms of technology requirements.[2] In summary, the FBRC will likely have to consist of both manned and unmanned (remotely piloted or autonomous) platforms of purely military design that allows for the effective integration of the full range of protective equipment needed to operate and survive in extremely hostile environments. The next step in the analytical process is to evaluate how future user requirements are likely to shape the FBRC.

FBRC Roles

Air Transport. The foremost important role for rotorcraft[3] is, without doubt, air transport in all its forms and shapes. Rotorcraft have the unique ability to hover, land practically everywhere and overcome virtually

A sea-based FOB for rotorcraft.

any natural or artificial obstacle across the battlespace while moving at least ten times faster than ground assets. This has made rotorcraft an indispensable asset for warfighters at all levels of command over the past few decades.

'Specialized tactical transport rotorcraft will remain of strategic importance.'

Medical Evacuation (MEDEVAC), Special Forces (SF) and Personnel Recovery (PR). Next to the classic rotorcraft role of transporting troops and goods across the Area of Operations (AoO), we have witnessed the development of specialized transport rotorcraft in support of MEDEVAC, SF and PR operations. Although these specific operations are being conducted at the tactical level, they often are of strategic importance[4], and will continue to be so with the FBRC.

Sensor-and-Shooter. A further role is that of the 'sensor-and-shooter' for which rotorcraft, such as the Apache or Tiger combat helicopters, have been specifically developed to provide augmented Situational Awareness (SA) and precise Fire Support (FSp) to support ground forces in the pursuit of their objectives. Despite their very effective and efficient contribution to operations in the land environment, it is only fair to state that rotorcraft share this role with manned combat aircraft and Remotely Piloted Aircraft (RPA), each with their inherent advantages and disadvantages. Although in the past some rotorcraft have been designed to exclusively execute Reconnaissance and Surveillance (R&S) missions, there is evidence to believe that these variants will no longer be found on the battlefields of the future, and that their missions will be executed by combat helicopters teaming up with RPA as it is already largely the case in the United States Army.[5]

FBRC Core Missions

The vast majority of FBRC operations will take place in the commitment phase[6] of any operation where the more static Forward Operating Bases (FOBs) are linked to temporary Forward Operating Locations (FOLs), out of which tactical operations will be planned and launched by rather small units. Depending on the characteristics of the AoO, these FOBs could be land as well as sea-based.

In the future, both FOBs and FOLs will be manned with less personnel and equipment than is currently the case, as is described by the British House of Commons Defence Committee in its Future Army 2020 plan.[7] The NATO Research and Technology Organisation (RTO) confirms that this trend will endure into the considered timeframe (2035 and beyond). In its Joint Operations 2030 Final Report the RTO clearly states: 'In the future, military operations will increasingly be the domain of small units and teams … that must generally execute autonomous, independent missions for considerable periods of time.'[8] So what kind of core missions will this commitment phase generate for the FBRC and how will they shape the FBRC in terms of size and performance?

Routine logistic resupply. The first mission is routine logistic resupply where all kinds of consumables will need to be transported. In particular, when it becomes virtually impossible to effectively and efficiently resupply by means of ground convoys, due to the nature of the terrain, road infrastructure or threat, these missions will become a priority for the FBRC and might become very resource consuming. Consequently, they will more than likely be executed by remotely piloted, or even autonomous, rotorcraft thus liberating the manned rotorcraft for more time-sensitive or complex missions where maximum flexibility and quick thinking is required.

MEDEVAC and Quick Reaction Force (QRF) Stand-by. Second, there are the tactically and strategically crucial 24/7 stand-by missions for which dedicated rotorcraft and crews will be put on very short notice-to-move. Both the MEDEVAC and Quick Reaction Force (QRF) stand-by missions will remain priority missions, albeit at considerable cost in terms of platform and crew allocation. Given the nature of these missions, it is fair to believe that they will be executed by manned rotorcraft and escorted by unmanned ones whenever required.

'Combat rotorcraft will continue to share the fire support role with manned or unmanned combat fixed-wing aircraft.'

Direct support to tactical level operations. Third, there are the missions in direct support of a specific operation at the lower tactical levels. Generally, these operations will generate a series of missions and tasks for the FBRC. It all starts with the insertion of a tailored Task Force (TF) into the Engagement Area (EA) by transport rotorcraft while combat rotorcraft provide augmented SA and FSp. After the insertion, and in addition to the aforementioned standby missions, assets will need to be ready to execute R&S, FSp as well as punctual or emergency resupply missions for the duration of the engagement. Here again, some of those resupply missions could be conducted by unmanned rotorcraft. Finally, the operation ends with an escorted extraction of the TF from the EA back to the FOL or FOB for reconditioning. Even though it is at this moment quite impossible to predict the exact number of soldiers in those future smaller units and teams, it would be safe to assume that tailored-to-the-mission TF elements would range from specialized teams of 4 to 6 soldiers to sections of 10 to 15 soldiers to platoons of 30 to 45 soldiers.

A first observation is that for considerations of effectiveness, three types of transport rotorcraft would be required, as it is the case today. By lack of a better definition, they will henceforth be referred to as 'light', 'medium' and 'heavy'.[9]

A second observation is the continued requirement for combat rotorcraft, able to escort the transport packages while providing them with superior SA and precision FSp. Furthermore, these combat rotorcraft should be able to command and control RPA to significantly add reach, persistence, SA and FSp to their intrinsic capabilities.

Weight and Size Considerations

In many of the aforementioned FBRC missions, the expected total weight of transported personnel and equipment is a factor that requires special consideration. Combat patrols operating in Afghanistan and Iraq over the past decade saw soldiers carrying personal equipment loads of approximately 58 kg.[10] In the future, our forces will have to be able to operate even more independently and for considerably longer periods. This will translate into increased loads of equipment and supplies soldiers will have to carry. New technology in the form of exoskeletons may reduce the soldier's burden but, at the same time, allow him to carry even more. By consequence, the average total weight to be transported will increase dramatically. As a guideline for future rotorcraft capability development, the NATO Army Armament Group assesses an average weight of 150 kg per soldier should be taken into consideration.[11] In addition, extra capacity should be foreseen to cater for collective equipment such as larger portable weapon systems or remotely controlled air and ground vehicles, to name just a few. All of this might well add up to a total weight of 200 kg per capita to be internally transported. Additionally,

it is to be expected that even larger pieces of equipment or cargo might need to be transported externally, especially by the medium and heavy transport rotorcraft. This will obviously come at a considerable cost with regard to aircraft performance.

When combining these cargo load requirements with the sizes of the different future TF elements, it becomes quite obvious that the cargo load thresholds related to the currently used 'light, medium and heavy classification', as well as the current NATO capability codes,[12] will need serious revision. However, within the context of the development of an entirely new capability, this is only to be expected.

Speed and Range Considerations

A lot of attention is being given recently to what the speed of the next generation of battlefield rotorcraft should be. Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) have been extremely challenging for helicopters, in particular for those in the MEDEVAC role, due to the nature and especially dimensions[13] of the AoO. During OIF, but even more so during OEF, bases were very isolated and operations were often dependant on the availability of MEDEVAC helicopters, and the distances they could cover, to be able to respect the famous medical 'golden hour' rule.

The paramount importance of the MEDEVAC mission in any future operation has prompted US Army medical planners to perform a capability analysis[14] associated with the Future Vertical Lift program. Their findings are based on zero-risk planning assumptions and

A modified image showing specialized exoskeleton equipment which significantly increases the overall weight an infantryman can carry.

'A revision of weight categories and capability codes will be required.'

on rather ambitious future AoO dimensions[15] for their Brigade Combat Teams (BCT). To be able to respect the golden hour they concluded that for a 300 x 300 km square AoO (90,000 square km), a speed of 350 knots would be required. For a 'more conventional' 150 km radius AoO (70,650 square km), a speed of 250 knots would do the job. Set against the OEF background, this would have meant that the number of MEDEVAC facilities could have been reduced from 13 to 8 when the speed is doubled from the 'current 125 knots' to the 'future 250 knots'. Although the advantages of higher speeds are obvious with regard to logistic footprint and the total number of assets required for one specific theatre, one should not overestimate its importance compared to other, and perhaps more important, requirements. These requirements include manoeuvrability and survivability in the complex, confined areas that will be found in the mega-cities of the future. A similar line of thought can be followed for range, especially when considering the potential future requirements for SF and PR missions. The classic trade-off between cargo and range can, however, be partially offset by means of additional internal or external fuel tanks.

Additional Resource Demands

For obvious reasons, rotorcraft have always been instrumental in successful Humanitarian Assistance and Disaster Relief operations, and there is no reason to believe that this will change in the considered timeframe.[16] Especially during ongoing military operations, this combined requirement for potentially scarce resources might put a lot of pressure on the FBRC.

A third observation is an enduring requirement for sufficient numbers of rotorcraft to satisfy simultaneous military and humanitarian needs.

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In military operations, MEDEVAC helicopters are often the only means allowing to save casualties within the 'Golden Hour', which in emergency medicine refers to a time period during which there is the highest likelihood that prompt medical treatment will prevent death.

Conclusions and Outlook

Forces that will operate in the land and littoral environment of 2035 and beyond will require the continuing support of a robust rotorcraft capability able to execute a variety of missions. The nature of these missions dictates the requirement for several types of platforms in sufficient numbers to satisfy the needs of the military as well as non-military customers, all with their specific demands with regard to availability and capability. Similar as in many other military domains, quantity will definitely constitute a quality of its own in the FBRC.

Technological evolutions can be expected that increase speed and range significantly. But both planners and developers should be careful not to let these requirements prevail too much. Other specific platform requirements need to be considered simultaneously, such as manoeuvrability and survivability at low speeds and heights in megacity environments, or personnel and cargo load capacities in support of the various, previously mentioned missions.

Although synergy in design is to be expected, the FBRC will need two or possibly three manned transport types; a combat variant of one of those types and two unmanned transport types to satisfy specific needs. While budget rationality dictates to keep rotorcraft as simple and modular as possible, a one-solution-fits-all trend as observed in the fixed-wing fighter domain would be very unrealistic for the FRBC due to the variety in roles and missions.

The final part of this essay will be published in JAPCC Journal Edition 26. It will aim to describe the FBRC following the standardized NATO DOTMLPFI outline[17], while the main focus will be on Organisation, Material and Interoperability.

1. Szabo, M. 'The Future NATO Rotorcraft Force'. In JAPCC Journal Edition 23, 2016, p. 57–61.
2. Schoepen, W. 'Future Battlefield Rotorcraft Capability. Part 1: Analysing the Future Operating Environment'. In JAPCC Journal Edition 24, 2017, p. 28–32.
3. Within the context of these articles, the term 'rotorcraft' will encompass all types of aircraft that have helicopter-like flight profiles regardless of the lift and propulsion system they use. Consequently this includes all types of contemporary lift and propulsion systems such as single rotor helicopters (e.g.: UH-60), twin counter-rotating intermeshing rotor helicopters (e.g.: K-MAX), twin counter-rotating co-axial rotor helicopters (e.g.: Ka-52) or counter-rotating tandem rotor helicopters (e.g.: CH-47) as well as tilt rotors (e.g.: MV-22). Also, any kind of future or even futuristic types of propulsion yet to be developed may fit into this definition.
4. Joint Air Power Competence Centre (2014) Present Paradox Future Challenge. Kalkar, Germany: The Joint Air Power Competence Centre.
5. Gilbert, E. (2016) Apaches, UASs soon to replace OH-58s. IHS Jane's Defence Weekly, Nr 128, 12.
6. Considering an operational phasing consisting of the strategic deployment phase, including Reception, Staging, Onward Movement & Integration (RSOM&I), the actual commitment phase and the strategic redeployment phase including reverse RSOM&I.
7. House of Commons Defence Committee (2014) Future Army 2020 – Ninth Report of Session 2013–14. HC 576. London: The Stationary Office.
8. North Atlantic Treaty Organization (Research and Technology Organization) (2011) Joint Operations 2030 – Final Report. Neuilly-sur-Seine, France: NATO Research and Technology Organization.
9. Although this classification bears a strong resemblance to the already 'abandoned' ATP-49 helicopter weight classification, it only serves the purpose of differentiation between the yet to be defined different rotorcraft of the FBRC.
10. White, A. (2016) Reducing the Burden – Managing Combat – Loads Carried by Dismounted Soldiers. Military Technology, Nr. 6, 76–80.
11. North Atlantic Treaty Organization (NATO Army Armament Group) (2009) NATO Staff Target for a Future Heavy Transport Helicopter. Brussels, Belgium: NATO Headquarters.
12. Light Utility (Transport) Helicopter: capable of lifting 5 Fully Equipped Combat Soldiers, or up to two litters or 0,5 tons of equipment, min 100 kts, 2,5 hrs combat radius 150 km at 85 % of max gross weight – Medium Transport Helicopter: capable of lifting 12 Fully Equipped Combat Soldiers, or 3 tons of equipment, min 120 kts, 2,5 hrs combat radius 150 km at 85 % of max gross weight – Heavy Transport Helicopter: capable of lifting 33 Fully Equipped Combat Soldiers, or 10 tons of equipment, min 120 kts, 2,5 hrs combat radius 150 km at 85 % of max gross weight.
13. Afghanistan approximately 650,000 square km; Iraq approximately 435,000 square km.
14. Bastian, N., Fulton, L., Mitchell, R., Pollard, W., Wierschem, D., and Wilson, R. The Future of Vertical Lift: Initial Insights for Aircraft Capability and Medical Planning. Military Medicine, Vol. 177, 863–869. (2012).
15. 90,000 square km roughly equals the surface of the State of Maine (US), 70,650 square km roughly equals the surface of Belgium and The Netherlands together.
16. Ministry of Defence (2015) Strategic Trends Programme, Future Operating Environment 2035, First Edition. London, UK: Ministry of Defence.
17. Doctrine, Organisation, Training, Material, Leadership, Personnel, Facilities, and Interoperability.

Colonel (GS) Wim Schoepen

joined the Belgian Defence in 1990 after having completed his academic studies at the Royal Military Academy. He received his helicopter pilot wings in 1992, became an instructor pilot in 1996 and cumulated more than 3,000 hours through different assignments in training units and operational squadrons. His operational experience started in 2000 with operation KFOR and has grown over the years with multiple EUBG, NRF and VJTF commitments. Additional staff and academic assignments have given him a solid background in education, training, operations, doctrine and policy. He also has a keen interest in strategic security and defence issues. He joined the JAPCC in 2016 as a Subject Matter Expert on Helicopter Operations.


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Compared to other RW assets, maritime helicopters have more requirements such as blade and tail folding systems to reduce their footprint, and reinforced landing gear and fuselage hard-points for securing them on the flight deck. Furthermore, their electromagnetic compatibility with the naval units must be tested to prevent undesired triggering of ammunition and cartridge activated devices on-board the helicopter.

Maritime Rotary Wing

The Importance of Helicopters for both Naval and Joint Operations

By Commander Paolo Florentino, ITA N, JAPCC

Introduction

Spurred by a desire to extend their influence in the world through sea power, many nations recognized in the early 1900s airborne assets would become a fundamental component of maritime warfare. Consequently, many traditional maritime powers have celebrated the 100th anniversary of their Naval Aviation services within recent years, starting with the UK Royal Navy in 2009, the French *Aeronavale* in 2010, the US Navy in 2011, and the Italian and German Naval forces in 2013.

While air power is relevant in every domain, maritime air assets are crucial as Fleet defence tools primarily. They are under the command and control (C2) of the Maritime Component Commander (MCC) as an organic element to fulfil his mission. However, maritime aircraft are multi-role assets that could also support each of the other Single Service Commands (SSCs) and the Joint Commander. In fact, they are especially adept at doing so when coordinated by proactive inter-service liaison elements.

Mobility and Access in the Maritime Domain

The main advantage of naval forces is mobility and access. Worldwide mobility is guaranteed by the 'freedom of navigation' (to include overflight) in international waters, a principle that has been codified in international customary law[1]. Taking into account that the Earth is covered mostly by water and that 80 per-cent of the world's population lives within 100 miles of the coast[2], naval forces and their naval aviation assets have easy and legal access to almost any potential crisis region worldwide as well as the right to stay in close proximity.

Such capability may be considered key to success in many military operations. Warships with flight deck capabilities can be quickly deployed forward and act as mobile airbases with the advantages of faster response times and lower fuel requirements due to their proximity to the target area. Furthermore, operations can be conducted with relative safety, since the stand-off distance of the units afloat makes them less vulnerable to incursions and terrorist attacks compared to a land-based Deployed Operating Base near or inside the crisis zone. Furthermore, offshore flight preparations and activities may be less susceptible to enemy intelligence operations, thus providing higher levels of covertness.

Utility of Organic Embarked Maritime Rotary Wing Assets

The utility of Maritime Rotary Wing (RW) assets for naval and joint operations is sometimes overlooked. Apart from being the 'long arm' of their mother warships, these assets can be employed in many ways in support of the other SSCs, while their peculiarities must be carefully considered.

Anti-Submarine Warfare (ASW). Although submarine inventories were initially reduced globally after the end of the Cold War, there is a growing trend of non-Allied submarine operations in all sea areas relevant to NATO operations. In recent years, almost every nation claiming a submarine capability has expanded its current inventory with more advanced and less detectable submarines. The protection of a maritime force against submarines consists of 'defence-in-depth' and close coordination among friendly ships and submarines, helicopters, Maritime Patrol Aircraft (MPA), and

SH90 Maritime ASW Helicopters as depicted here are best suited for defending the Fleet against submarine threats.

shore-based facilities. Maritime ASW helicopters, in particular, have increased in importance due to the decreasing number of MPA available in NATO[3]. These helicopters are equipped with maritime radars optimized to detect submarine snorkels or periscopes. Integrated dipping sonars and dropped active/passive sonobuoys can be used to detect and track contacts. Electronic Support Measures (ESM) technology and mounted Magnetic Anomaly Detectors (MAD) are able to confirm the presence of submerged threats, while data link capabilities provide real-time information to the Fleet. Last but not least, ASW helicopters can be fitted with air-launched torpedoes, which allow them to attack and destroy enemy submarines.

Anti-Surface Warfare (ASuW). ASuW involves action against adversary's ships to achieve sea control or sea denial, to disrupt their sea lines of communication, or to defend against a surface threat. For ASuW missions, helicopters can rely on maritime radar, advanced forward looking infrared (FLIR) systems, ESM receivers, and data link to inform about adversary contacts located over-the-horizon, i.e. beyond the range of sensors implemented on their mother ships. For identification purpose, contact data can be cross-referenced with information available on open source vessel traffic services, such as the Automatic Identification System (AIS) used for collision avoidance on merchant ships. When fitted with anti-ship missiles, maritime helicopters can attack enemy vessels directly while chaff and flare dispensers are used for self-defence.

Support to Joint Intelligence Surveillance Reconnaissance (ISR). The usual types of NATO maritime helicopters (e.g. EH101/Merlin, SH90, MH60R) serving on carriers, escort units, or other independently operating warships, are both ASW and ASuW capable while equipped with well-performing sensors capable of collecting intelligence not only for naval purposes but also to satisfy joint or other services' ISR collection requirements. However, these assets are limited in range, altitude and endurance compared to other collection platforms such as Maritime Patrol Aircraft.

Anti-Air Warfare (AAW). In a joint operation, maritime AAW is part of the overall Air Defence (AD) effort. US and French catapult-assisted carriers use E-2C aircraft for Airborne Early Warning (AEW), while other NATO Navies with Short Take Off and Landing (STOL) carriers rely on dedicated Helicopter Early Warning/ Airborne Surveillance and Control (HEW/ASaC). These are equipped with sophisticated radar pickets, capable

Maritime helicopters with Assault and Resupply missions are the backbone of Amphibious Operations.

© ITA Navy

Inside the cockpit of EH-101/AW-101. Since 1999 the Italian Navy has been using this helicopter in various configurations for different roles to include ASW, ASuW, HEW, utility, and amphibious support.

of accurate detection and automated tracking of aerial threats to the Fleet. While the E3-AWACS provides AEW and C2 capabilities much superior to those of HEW assets, their availability cannot always be promptly granted for many reasons, as evidenced in the first five days of Operation Odyssey Dawn in Libya[4]. Apart from this, HEW/ASaC radars can also observe suspicious ground movements in support of friendly land forces ashore, and direct friendly air, sea or ground forces to intercept the enemy, as UK forces did with devastating effect during the fighting in southern Iraq in 2003[5]. HEW/ASaC may therefore at times become the best alternative option for naval or joint commanders, or possibly the best option for supporting amphibious operations.

Sea-based Joint Personnel Recovery (JPR). Most NATO Navies operate maritime transport RW assets to support Amphibious Operations with troop lifts and other logistic missions. Usually, these medium-to-heavy lift helicopters can also be fitted with material and litters for Medical Evacuation (Medevac) purposes. Maritime RW in the amphibious assault configuration therefore constitute the backbone of a sea-based JPR capability, as already implemented by NATO forces with great effect during Operation Unified Protector[6]. These assets have also been widely flown by many NATO nations in different land-focused theatres such as Kosovo, Iraq, and Afghanistan, providing Combat Support and Combat Service Support to land troops and Special Ops units.

Command and Control of Maritime Air Assets

Organic maritime air assets are under the control of the Maritime Component Command (MCC). While their sorties are planned and tasked through the MAOC (Maritime Air Operation Centre), all air missions must be coordinated with the joint level and appear on the Air Tasking Order (ATO) issued by the Joint Force Air Component Command (JFACC). This is to ensure overall air space control and coordination and minimize the risk of fratricide or interference with the overall air defence plan. Therefore, the MAOC is required to file an 'ATO feeder', which identifies planned maritime air sorties, with the JFACC. When not all maritime air assets are required for the MCC's daily mission, the excess capacity can be declared available for sorties in support of the other single service components (SSCs) as directed and apportioned by the Joint Force Commander (JFC) as well as coordinated by the JFACC.

Joint Planning of the air campaign at the operational level, and the coordination between the MCC and the JFACC, is reached through the presence of liaison elements. The MCC provides a Maritime Liaison Element (MLE) and, for all air-related issues, a Maritime Air Liaison Element (MALE) to the JFACC. Conversely, the JFACC sends an Air Liaison Element (ALE) to the MCC. The coordinated execution of current air operations is implemented at the tactical level through the presence of a Maritime Coordination Element (MCE) and a Maritime Air Coordination Element (MACE) in the JFACC. The JFACC will conversely detach an Air Operation Coordination Centre Maritime (AOCC-M) to the MAOC. These air and maritime liaison entities report to and remain part of their parental command structure, but become functionally part of the headquarters to which they are attached.

The quality and competencies of the liaison elements representing the MCC at the JFACC and JFC are of utmost importance. The MLE and MCE must be able to communicate the maritime operational picture and coordinate joint operations with their parental headquarters. As well, MALE and MACE personnel must have deep knowledge of the capabilities of available maritime air assets, to include the utility of RW assets as described above, to recommend their appropriate employment in support of the other SSCs.

The support provided by maritime liaison entities during recent NATO crisis operations was critical. Maritime advocacy repeatedly proved its significance for the success of the joint effort. However, this comprehension often came late. Joint and service commanders experienced considerable difficulties in collaboration during the early phases of NATO operations since virtually none of the coordination instruments are common knowledge and no such liaison elements are implemented amongst the SSCs during peacetime. Not surprisingly, limited joint interaction and SSC 'stove-piping' could be observed in this regard during recent major joint exercises such as Trident Juncture 2015[7]. The peacetime liaison issue has also been recognized as a shortfall during the Maritime Air Coordination Conference[8] held in Northwood (UK) last spring.

Conclusion

The nature of potential conflict zones and the likely scarcity of feasible military airbase facilities ashore may make maritime air assets a key enabler in future Alliance operations. Maritime forces can be quickly deployed, have free mobility, and can easily gain access to the area of operation.

While the use of embarked air assets, especially RW, is essential for the MCC to ensure its own defence and project (amphibious) power ashore, excess capacity can be made available to support the Joint Commander and fellow SSCs in their missions. The knowledge of the particular capabilities of these flexible and highly effective assets and how to efficiently plan and direct their contribution within the joint environment is crucial.

A strong proactive liaison can help reduce friction and confusion in coordinating air and maritime air asset employment during the early stages of future Alliance operations. Therefore, NATO should examine the feasibility of implementing standing peacetime liaison elements at the operational level between AIRCOM and MARCOM, and between the JFACCs and MCCs standing-by as part of the NATO Response Force (NRF). This might substantially contribute to better preparation through education, exercise, and training, thus ensuring and increasing professional decision-making in this field, and therefore considerably strengthening NATO deterrence.

1. United Nations Convention on the Law of the Sea, 1982, Article 87(1) a & b.
2. NATO Alliance Maritime Strategy (2011). Online at http://www.nato.int/cps/en/natohq/official_texts_75615.htm, accessed 29 Aug. 2017.
3. Cdr Perkins. Alliance Airborne Anti-Submarine Warfare, Joint Air Power Competence Centre, 2016.
4. Karl P. Mueller. Precision and purpose, Airpower in the Libyan Civil War, p. 126. RAND Corporation, 2015.
5. UK Royal Navy. http://www.royalnavy.mod.uk/the-equipment/aircraft/helicopters/sea-king-mk7, accessed 29 Aug. 2017.
6. Karl P. Mueller. Precision and purpose, Airpower in the Libyan Civil War, p. 225. RAND Corporation, 2015.
7. Peter Hudson. A Maritime Commander's reflections ahead of the NATO Warsaw Summit. RUSI Newsbrief vol. 36, 2016.
8. The MACC is the Bi-SC annual conference dealing with Maritime and Air Components integration challenges. It is co-chaired by JAPCC Assistant Director (for ACT) and COM MARAIR (for ACO).

Commander Paolo Florentino

graduated from the Italian Naval Academy in 1991, was trained by the US Navy, and qualified as Naval Aviator in 1994. He flew ASW/AsuW Helicopters such as AB212, SH3D and EH101. He had appointments as Flight Commander on several warships, staff officer of the Italian Fleet Air Arm, Commanding Officer of the 2nd Helicopter Squadron and later the 3rd Helicopter Squadron. As a Navy line officer he commanded the ITS Tirso. He participated in Operation Enduring Freedom as Navy Liaison Officer to ComUSNavCent, and has been awarded for NATO Operation Sharp Guard and the Italian operations related to the Albania crisis and supporting UNIFIL. Since August 2016 he serves the JAPCC as a Subject Matter Expert for Maritime Air/Embarked Rotary Wing.

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Increasing Interoperability in NATO's Air-Delivery Cargo Fleet

By Lieutenant Colonel Edwin Markie, Jr., USA AF, JAPCC

The emphasis on air integration is very important to us. We know that we are never going to fight alone – it's always going to be joint, it's always going to be combined. Which is why on the combined side it's a NATO exercise, and on the joint side we want to fight in all domains and practice that integration. That means air, sea and land …

***US Navy Vice Admiral Christopher Grady, Commander, Naval Striking and Support Forces NATO (2017)*[1]**

Introduction

As current world events shape the future operating environment, NATO must take great care with how it intends to project power. The strongest approach is presenting a united coalition front, demonstrating a strong alliance. Turning this political commitment into action requires the operational ability to work together, or be interoperable. Shrinking national budgets coupled with rising tensions and NATO's increasing presence in global affairs makes the answer to the interoperability question vital to NATO's future success.

The term interoperability means different things to different people; is it the ability to operate together, the ability to use the same governing guidance, or the ability to replace one completely with the other? The Concise Oxford English Dictionary 12th Edition (2011) defines interoperable as *'able to operate in conjunction'*[2] while NATO offers a more Alliance centric definition: *'The ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives.'*[3] While NATO specifies the term interoperability, it further offers the term military interoperability as *'the ability of military forces to train, exercise and operate effectively together in the execution of assigned missions and tasks.'*[4] It is within this framework of military interoperability that possible solutions for the future will be explored.

to carefully choose what size and type of transport aircraft they purchase, whether they primarily have large strategic aircraft or smaller tactical aircraft. Gone may be the days of large mixed fleets of strategic and tactical aircraft belonging to a single country, replaced instead by pooling and sharing of resources to increase the synergistic effects of NATO members.

Perhaps the biggest driver of how to spend those limited defence budgets is national priorities. As Lieutenant General Hodges stated in 2014, nations are going to protect their own defence industries and ultimately purchase the systems that make the most sense for them at the time. The construct of NATO does not allow for the alliance to force a country to purchase a specific capability let alone a specific piece

Each nation, including our own, has its agendas. Every nation, including the US, is going to protect its own defence industry.

Lieutenant General Fredrick 'Ben' Hodges, Commander, NATO Land Command (2014)[5]

The first stumbling block toward greater interoperability is shrinking defence budgets.[6]

Stumbling Blocks

With defence dollars so hard to come by since 2008, purchasing new equipment for the sole purpose of being interoperable is a difficult proposition.[7] This fiscal constraint levied on NATO members must drive innovation and what is commonly referred to 'out-of-the-box' thinking, solving the interoperability problem without new procurement. The shrinking budgets have had the added consequences of limiting fleet sizes or aircraft types, cancelling programmes, extending the service life of more expensive systems, and foregoing recapitalization.[8] This forces countries

of hardware; what a country purchases is a national decision aligned with its own priorities. All NATO can do is make a case for a country to purchase something that is in-line with a broader NATO plan.

Way Ahead

It is clear that a top-down approach within NATO will have limited success when it comes to forcing nations to purchase equipment or adopt specific tactics, techniques, and procedures (TTPs). But progress toward increasing interoperability has been and will continue to be furthered through lower-level groups such as those described below. Each of these groups focus on interoperability; however, they each have a different lesson to teach.

A-400M Operational User Group (OUG). The A-400M OUG is a group headed by the European Air Transport Command (EATC) with the goal of increasing interoperability across all the nations wishing to procure the A-400M, even those outside the EATC umbrella. The overall goal is to achieve *'efficiencies of operation through co-operation, standardization, and harmonization of procedures'*.[9] This working group includes the United Kingdom, an OUG member outside the EATC highlighting the strength, reach, and importance of working groups. The OUG shows a proactive approach to the interoperability issue by gathering the interested parties during the requirements and design phase of the project versus waiting until the aircraft is fielded to try and blend the different national requirements. While the A-400M OUG focuses on a single airframe during the procurement phase, the remaining examples are focused on increasing interoperability by developing TTPs and operational parameters to work together no matter what platform is being used.

EATC Cross-Para Team. The EATC Cross-Para team is striving to simplify the process of dropping one nation's paratroopers from another nation's aircraft. This is a vital step forward, as NATO STANAG 7190 states *'airdrop of personnel is a key element of airborne operations. The potential for combined airborne operations is extremely likely'*.[10] It is only logical to ensure NATO has the flexibility to operate no matter which nation provides the troops and which nation provides the aircraft. The Cross-Para team has done just that, in creating a set of standardized TTPs between paratrooper nation and aircrew nation. According to the Cross-Para Booklet, of the 154 different combinations of aircraft and parachute, 41 percent of them are approved with an additional 33 percent pending approval.[11] That is 74 percent of the possible combinations from six different nations either approved or pending approval showcasing how interoperability can be developed by a working group focused on a common end-state by modifying and adapting national TTPs after the appropriate technical compatibilities are accomplished.

European Tactical Airlift Centre (ETAC). The ETAC was designed to increase the tactical proficiency of European air transport crews. This centre, located in Zaragoza, Spain, manages different courses with three different syllabi (single-ship, formation and night vision goggle courses) dictating what TTPs will be used during the training. The focus of this training is to expose crews from different nations to a single set of TTPs to prove these TTPs work for all regardless of

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The Spanish Air Force celebrates the delivery of its first A-400M on 1st December 2016. The event took place at Zaragossa Airbase, which is also home of the European Tactical Airlift Centre (ETAC) recently founded to facilitate mutual interoperability of European transport aircraft.

aircraft type, breeding familiarity and acceptance of a single method of mission accomplishment. The other facet of this centre is a place where the different nations can gather and exchange ideas and methods. The true benefit of the ETAC is proving to the individual crews from separate nations that a standardized set of TTPs is not only workable, but desirable, thereby increasing interoperability and decreasing the likelihood of confusion during NATO operations.

NATO Air Transport Working Group (ATWG). The NATO ATWG is open to all members of NATO, and is open to Partnership for Peace Nations, other interested national entities, European agencies, and defence organizations in an observation role. The ATWG is a place where ideas can be shared, concepts formulated, plans coalesced, and agreement reached on a new set of TTPs. Because this group is comprised of the National representatives responsible for the creation of individual TTPs, this is the place to devise and develop a common set of NATO air transport TTPs and doctrine. The result is each nation takes the same TTPs to be their national TTP. This new national TTP is approved at home and a standard is created that matches the standard of other nations. This new standard is trained to and evaluated against creating a completely interoperable air transport fleet built from the nations up versus from the Alliance down thereby strengthening the Alliance as a whole. As the ATWG is the focal point for NATO air transport doctrine, it is the perfect place to incorporate a single set of TTPs into NATO's air transport methodology. As of the writing of this article, the NATO ATWG has created a NATO Standards Related Document incorporating the EATC's Cross-Parachute work and approved documentation as a first step to the creation of a standard NATO cross-parachute TTP.

Conclusion

Because NATO defines military interoperability as the ability to 'train, exercise and operate effectively together' and not the operation of the same equipment, nations have the flexibility to solve this problem without prescriptive procurement. While procuring the same equipment is a simple solution, the current fiscal environment simply will not allow it. This means a different more difficult solution must be found. This solution must, therefore, be adoption and adaptation of common TTPs and training. If a common set of TTPs cannot be realized, then the limited training venues

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Spanish paratroopers entering a German C-160 for airdrop training.

An aircraft challenged to react on surface-to-air missile fire during the European Advanced Airlift Tactics Training Course (EAATTC) 16-1 as conducted by the *European Tactical Airlift Centre (ETAC)*.

afforded to the nations must be utilized to the maximum extent possible to expose each other to different TTPs. This will allow for the proliferation of a common understanding of other nation's TTPs. Given enough time, with enough joint and combined training, new and common TTPs can be adopted and promulgated thereby increasing interoperability and decreasing the uncertainty of how other nations will react to the same situation.

Mandates alone from politicians or General Officers cannot increase interoperability. Likewise, not even our finest tactical-level subject matter experts can change entire systems by themselves. Increasing interoperability requires a 'system of systems' approach where the subject matter expert recognizes and propels strategic concepts at the tactical level while simultaneously being supported by the senior leaders above. The open-minded, mission-focused individuals at the working group level must translate between the strategic and the tactical. Groups such as the A-400M OUG, the EATC cross-para team, ETAC and the NATO Air Transport Working Group have proven this strategy. Ground level TTPs devised for individual nations in concert with each other allow for a smoother and easier international approval process. NATO wins with a common set of operating procedures enabling any group of nations or the Alliance in total to mass Air Power as a cohesive force making the whole greater than the sum of its parts. ●

1. 31st Fighter Wing Public Affairs. 'Ensuring Global Reach through Interoperable Partnerships'. 9 Jun. 2017. Online at https://www.dvidshub.net/news/printable/237063
2. Stevenson, A. and Waite, M., Concise Oxford English Dictionary, Oxford: Oxford University Press, Twelfth Edition 2011.
3. NATO provides a more Alliance centric view of interoperability as it applies to NATO and its operational mind-set in NATO AAP-06 Edition 2016 NATO's Glossary of Terms and Definitions (English and French). Online at http://nsa.nato.int
4. NATO further defines military operability as a sub-set of interoperability to provide further clarification and delineation as it applies to the conduct of military operations within NATO's purview. This information obtained from NATO AAP-06 Edition 2016 NATO's Glossary of Terms and Definitions (English and French). Online at http://nsa.nato.int
5. Nancy Montgomery. '"Maddening" mission: Keeping NATO's interoperability on track'. 2 May 2014. Stars and Stripes. Online at https://www.stripes.com/news/maddening-mission-keeping-nato-s-interoperability-on-track-1.281162#.WcJpQE0UmHs
6. Present Paradox – Future Challenge. The Joint Air Power Competence Centre, Germany. 2014, p. 66.
7. Sally McNamara, NATO Summit 2010: Time to Turn Words Into Action. Backgrounder No. 2498 10 Dec. 2010. Online at: http://www.heritage.org/global-politics/report/nato-summit-2010-time-turn-words-action
8. Sally McNamara, NATO Summit 2010: Time to Turn Words Into Action. Backgrounder No. 2498 10 Dec. 2010. Online at: http://www.heritage.org/global-politics/report/nato-summit-2010-time-turn-words-action
9. European Air Transport Command (2016) Interoperability Framework For the Atlas. Available from http://eatc-mil.com/107/Interoperability-framework-for-the-Atlas
10. North Atlantic Treaty Organization (2010) STANAG 7190 AT (Edition 2) – Procedures for Cross-Parachuting Authorization, p. 4. Online at http://nsa.nato.int
11. European Air Transport Command Manual: Cross Parachuting Booklet Version 1.0, 16 Jan. 2017, p. 13.

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Future Options for Surface-Based Air and Missile Defence?

By Lieutenant Colonel Andreas Schmidt, DEU AF, JAPCC

Introduction

France, in 1794, was the first nation to use aerial balloons for reconnaissance purposes. Subsequently, it took almost 100 years for the German military to realize that small cannons could be used to intercept those balloons. The 'Ballonabwehrkanone' using a 3.7 cm cannon mounted on a horse carriage can be considered the first active air defence weapon, albeit with a very low rate of success. Target tracking, aiming and firing the cannon was mostly based on the gunners' talent.

Technological advances over the last 100 years have helped to significantly improve air defence weapons and in parallel improved adversaries' air capabilities. However, in the latest iteration of this cat-and-mouse endeavour the most recent technological advances could elevate Surface Based Air and Missile Defence (SBAMD) systems to a whole new level; in effect, changing the 'game'. This article will illuminate how some new ways of system integration, and new means of target interception, might affect the effectiveness and efficiency of, and employment options for, SBAMD systems. Also, it will suggest options for national contributions to future SBAMD networks.

The German 'Ballonabwehrkanone' employed anno 1915 during World War I at an unknown location in Austria.

Fixed Sensor and Effector Combination

In general, surface-based air defence systems are designed to counter surface-to-surface or air-to-surface threats by either destroying the opposing effector (e.g. missile) in the air or by destroying the carrier of an aerial weapon before it can be launched. They can also be used to engage other enemy platforms delivering adversary non-kinetic aerial effects such as intelligence, surveillance and reconnaissance, electronic and cyber-attack, and airborne command, control and communications. In order to engage a potential aerial target several factors need to come together. The target needs to be found, identified, tracked and a suitable interceptor needs to be available that can be led to the target. After engagement, a kill assessment needs to be performed. This defines the so-called 'Kill Chain'. The invention of radar made automated, or at least supported, searching, identifying, tracking and kill assessment possible and enhanced overall situational awareness in the third dimension. Radar engagements progressed from helping to manually aim the cannon, to automatically creating a fire-solution for the canon, to automatically guiding an air defence missile to its target. This engagement paradigm is true for all kinds of potential tracks, such as airplanes, drones or ballistic missiles.

A Patriot Advanced Capability-3 Missile Segment Enhancement (PAC-3 MSE) interceptor streaks toward its target during a test at White Sands Missile Range, New Mexico, in December 2015. With the MSE, the PAC-3's missile reach was nearly doubled and its performance against increasingly sophisticated ballistic- and cruise-missile threats dramatically improved.

From Isolated AD Applications to Networks

Historically, various technical developments produced distinct sensor-interceptor combinations, which created their own independent equipment 'ecosystems', good examples being NIKE[1] and HAWK[2]. Those systems had multiple radars for various tasks, which, in turn, gave air defence units a large footprint on the ground. Later, systems like PATRIOT introduced multi-function radars, which combined all tasks in one machine, but still maintained the fixed inter-unit sensor-effector relationship.[3] The net result is that newer systems are smaller and harder to target, but even more effective.

Currently, two ideas are being used to describe the efficiency of surface-based air defence systems against ballistic missiles, and these are the footprint and the battlespace. The footprint is a two-dimensional correlation of ground impact points with calculated intercept probabilities, based on a certain threat from a certain direction that a system can defend. The battlespace is the three-dimensional space within the interceptor's range where it can effectively intercept targets, and is used to calculate the footprint. The battlespace, in addition to other variables, is limited by the parameters of the interceptor but also by the available track data being locally produced by the system's organic sensors. In other words, SBAMD systems can normally only shoot as far as they can 'see', which historically is a greater limitation than the actual range of the weapon. Future concepts should lead to a maximized battlespace for interceptors by networking sensors to allow earlier target acquisition and engagement. Such layered defence could not only create second shot opportunities but also allow interceptors to use their full potential since freed up from sensor constraints.

The development of tactical data link (TDL) networks, like Link-16, with sufficient reliability and reduced latency opened new possibilities for air defence systems. Connections between weapon systems and Command and Control (C2) networks allowed for changed responsibilities in the 'Kill-Chain' and for complex emission control patterns. Systems like PATRIOT can receive cueing data which optimize its own radar and interceptor capacities and maximize the overall battlespace. This is accomplished because cueing a radar helps to significantly reduce target search times for organic tracks. However, the actual engagement is still performed by the fixed sensor-interceptor complex.

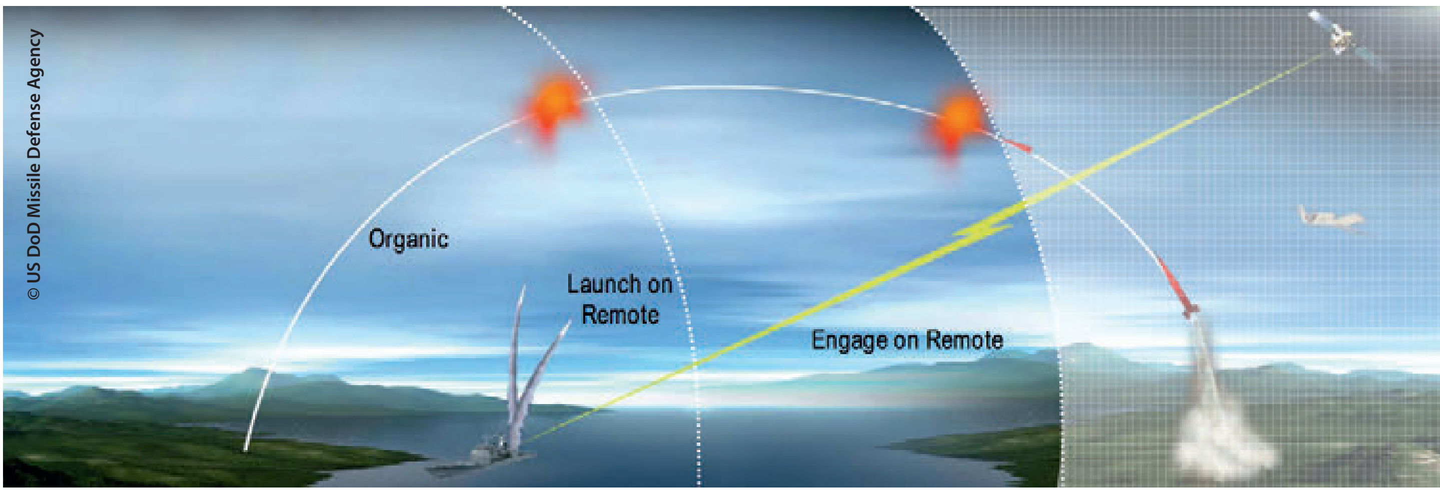
Launch on Remote, Engage on Remote and Missile Handover

There are three options readily apparent for exploiting networked sensors and C2 to expand the battlespace and in turn the footprint for modern SBAMD systems.

Launch on Remote (LOR). In this option, a unit fires a missile at a remote target it cannot yet see with its organic sensors based on cueing from the network. The only requirement is that the launching unit must have a local track during the final phase of the engagement, meaning launch must wait until the target is close enough to enter organic sensor range and allow terminal guidance of the interceptor. This concept pushes the boundaries of the battlespace, but is still limited to the maximum range of the organic sensors.

Engage on Remote (EOR). In this option, a unit fires a missile without available organic sensor track data, since it could rely on the interceptors capability of executing the final phase of the engagement automatically based on active sensors and highly accurate, very low latency remote target data. If EOR capability is implemented, organic sensor range and visible tracks

Organic radars co-located with the interceptors can support updates to the interceptor within line-of-sight. Some past testing has included longer-range intercept by passing information to interceptors from external sensors such as other ground-based radars and space-based tracking and surveillance satellites. These yet-to-be implemented 'launch on remote' and 'engage on remote' capabilities hold considerable promise to improve the defended area of the system.



are not the limiting factor anymore. Targets outside a line of sight (e.g. behind mountains) could be engaged without local radar coverage but with maximum interceptor range.

Interceptor Handover. A third option is to have the firing unit guide the interceptor to a point in space where a remote unit can take control over the interceptor and provide guidance updates to execute the last portion of the engagement. This option does not necessarily demand interceptors with an active sensor and still gives the option of exploiting the maximum range of the interceptor, however this also comes with its own limitations. Missile guidance communication is based on certain frequencies, protocols and, most likely, encryptions, which are unique to a weapon system, nation or the producing company, which may prevent, or at least complicate, a hand-over.

These concepts reallocate responsibility for certain parts of the 'Kill Chain' to various other systems. However, since a typical weapon system life cycle can easily be half a century from conception to its phasing out, it is not that easy to find a common technical basis for a shared 'Kill Chain'. Adding to the complexity are the administrative challenges for effective information sharing among nations or even different companies. Additionally, the usability of shared information via TDL networks is very dependent on the target set and the network update rates. E.g., target refresh rates over Link-16 are dependent on the network's technical implementation and management and can last several seconds.[4] For a high flying, slow-moving target this might be sufficient, but for ballistic missiles or future hypersonic targets with speeds of several kilometres per second, it is not.

Flexible Sensor and Effector Employment and Intelligent Networks

A vision for future SBAMD systems is to have standardized sensor and interceptor interfaces with reliable access to multi-layered, secure, low latency tactical networks with high update rates. These interfaces can be used to create a dynamic network of systems. However, standardized and disclosed system interfaces won't necessarily mean public access and standardized system architectures. The 'plug and fight' concept of the tri-national Medium Extended Air Defence System (MEADS) shows part of this concept on an intra-unit level.[5] The goal should be to have these features on an inter-unit, or possibly inter-system, level. This would allow several new approaches for air defence from contributing nations:

1. **Tailored to the Mission Environment:** The concept of a GBAMD battery could be defined in a new, task and mission environment-oriented way. For the past few years the idea 'Tailored to the Mission' has been used, where a battery only deploys the equipment needed for the mission, but still has the battery reference as a baseline. However, a preconceived battery construct is not necessary anymore. The battery size and construct is dependent on the mission needs in the operational environment. E.G. if a robust sensor coverage for the operation area is already present, a networked GBAMD battery does not need to have an organic sensor. If the interceptor density in the mission area is sufficient, a battery might only deploy sensor or communication equipment to support target acquisition and tracking. In effect, the GBAMD defence design can switch from a battery-centric approach to a capability centric approach. This could reduce redundancies and create a more balanced defence design overall.

2. **Allied Modularity:** Due to the many components and their tremendous technical complexity GBAMD batteries are a very expensive commodity and due to their life cycle require a long-term commitment in the defence budget. A modular, capability-centric approach would allow smaller nations to purchase only capabilities needed, in the context of an alliance, to fill gaps on the battlefield and to provide specific elements, instead of an entire GBAMD battery. That could mean purchase of a long-range search radar, a high precision fire control radar or just a launching section with 20 interceptors as part of a bigger network, instead of purchasing an entire THAAD, SMP/T or MEADS battery.

3. If an independent battery construct is needed, the battery could be comprised of any compatible components on the participating market. In this case the customer can choose from a far broader spectrum of product capabilities and is not bound to a single source solution.

4. Since the envisioned sensor, interceptor or communication interface will not be limited to ground based air defence units, the overall system might benefit from many other Army, Navy, and Airforce systems. A secure multi-layered network would allow controlled integration of alliance and non-alliance members, as well as civilian components.

Technically, an organic, local radar might still be the optimal sensor for a potential target engagement. But that does not mean that networked sensor data could not deliver sufficient target information for a comparable result. The flexibility within the defence design and the ability to adapt the design throughout the mission, perhaps due to damaged or destroyed equipment, bears significant potential benefits. An integrated system of systems could ad-hoc manage all connected sensors and shooters to identify the optimal fire solution.

Directed Energy Weapons

It is very likely that potential opponents have more ballistic missiles, air to surface missiles and other air targets than we have interceptors. This is especially true for ballistic missile defence or in a context of defence against dispensable low-cost unmanned aerials systems. In these cases, the highly complex missile based interceptors sometimes cost a multitude more than the systems they defend against. The more complex the target sets become, the more expensive the countermeasures, which leads to a less robust defensive posture in times of reduced defence budgets. With the available number of high-cost interceptors as the limiting factor, alternative ways of defending against adversary aerial targets need to be found.

'A vision for future SBAMD systems is to have standardized sensor and interceptor interfaces with reliable access to multi-layered, secure, low latency tactical networks with high update rates.'

There are multiple ways of successful intercept, which are heavily dependent on the targets' characteristics including size, speed, material, altitude or flight path. Overall, it is important to deliver an impact adequate to either fully destroy or sufficiently damage the target to negate the intended effect. Currently, it is necessary to be able to manoeuvre the interceptor during its flight to have an acceptable intercept probability. Recent developments in direct energy weaponry (DEW), such as laser or rail gun technology, are promising developments for the future. DEW have already proven to be able to intercept some targets like drones or artillery shells.[6] Since DEW project energy at the speed of light, target speed and manoeuvrability become a smaller issue that should be compensable by sufficient track data and flight path prediction. Once operational status has been reached, DEW will likely mitigate multiple problems, including:

- Cost per shot dilemma.
- Small number of interceptors (shots) available.
- Necessity of LOR, EOR or any kind of interceptor hand over.
- DEW will also significantly simplify the engagement process and allow concentration of effort on target detection, tracking and the network.

Obviously, DEW still has some obstacles to overcome, like the blooming effect, which defocusses a high-powered laser beam over great distances, or the fact that some targets are actually designed to sustain very high amounts of thermic energy, like ICBM re-entry vehicles. Also, it has to be taken into consideration that there is no way to stop or control directed energy after it has been released, which might have unwanted effects on other systems in the air or space, like satellites. Overall, it is very likely that DEW will be part of the future battlefield soon, starting with simple targets at short distances but encompassing more complex targets and larger distance over time.

Conclusion

Standardization of sensor data networks and interceptor interfaces can allow a much deeper integration of a variety of weapon systems. This will create improved flexibility in weapon system employment that is directly tailored to the specific mission needs and will create opportunities for smaller Allies and non-NATO nations to contribute to the overall defence. Easier integration of newer systems will also simplify the expansion of capabilities. Considering the rapid pace of developments in radar, networking and computer technology, it would be counterproductive not to take advantage of this progress. These developments

Ground-based High Energy Laser (HEL) systems such as this Rheinmetall 30kw laser defence turret have been successfully tested in shooting down artillery and mortar shells as well as adversary unmanned aerial vehicles. However, more research & development is needed to achieve a DEW capability that can produce the vast laser energy output required to engage a ballistic missile at the desired range.

give new options for target engagement, alternatives to tailor units to the mission environment and will allow us to leave old SBAMD paradigms behind, subsequently saving money and increasing effectiveness of our forces. The future should be a synergetic and effects-oriented network of C2, sensor and effector elements, with the inclusion of DEW or other methods of energy projection, to ensure a robust and always optimized defence for the Alliance and partners. ●

1. Federation of American Scientists (FAS). 'Nike Hercules (SAM-N-25) (MIM-14/14A/14B)'. Online at https://fas.org/nuke/guide/usa/airdef/nike-hercules.htm
2. Parsch, A. 'MIM-23', in 'Directory of US Military Rockets and Missiles'. Online at http://www.designation-systems.net/dusrm/m-23.html
3. Kable. 'Patriot Missile Long-Range Air-Defence System, United States of America'. Online at http://www.army-technology.com/projects/patriot/
4. Northrop Grumman. 'Understanding Voice and Data Link Networking – Northrop Grumman's Guide to Secure Tactical Data Links'. Online at http://www.northropgrumman.com/Capabilities/DataLinkProcessingAndManagement/Documents/Understanding_Voice%2BData_Link_Networking.pdf
5. MBDA Presse Release. 'Einzigartige MEADS Plug-and-Fight-Fähigkeit in Tests nachgewiesen'. Online at https://www.mbda-deutschland.de/pressemitteilungen/einzigartige-meads-plug-and-fight-faehigkeit-in-tests-nachgewiesen/
6. Dr. Kopp, C.. 'High Energy Laser Air Defence Weapons'. Online at http://www.ausairpower.net/SP/DT-Laser-ADW-2008.pdf

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. The main task of his first assignment was to conduct bilateral USA-DEU studies of Weapon System behaviour on a tactical level for the German Patriot Office. During his second assignment he was the Subject Matter Expert (SME) on Integrated Air and Missile Defence at the German Air Force Air Defence Centre. In between he had an assignment as the A3C in the former Air Force Division. Currently, he is the Ballistic Missile Defence SME in the JAPCC.

Unintentional Air Strikes during Dynamic Operations

NATO Views and Possible Fixes

By Lieutenant Colonel Andrea Olivieri, ITA AF, JAPCC
By Lieutenant Colonel Michele Ferrari di Valbona, ITA A.Avn., JAPCC

Introduction

Images of bombed hospitals stunned participants of the 2016 JAPCC Conference[1], as a Panellist raised the unsettling and poignant issue about how operations sometimes transcend military objectives. Specifically, the panellist expressed concern about *'recurring kinetic strikes against civilian and/or medical facilities and what is being done to prevent further occurrences'.* Discussion of the topic exposed significant differences in opinion about the reasons for, and prevention of, such strikes.

Subsequently, the JAPCC hosted a meeting of interested parties to further a better understanding of positions and attempt to find ideas for a way ahead that would minimize, if not eliminate, the problem.

The meeting and follow-on research revealed several areas where military and civilian organizations could improve training and preparedness to prevent such incidents in the future.

Recent Occurrences

Between 2012 and 2014, the International Committee of the Red Cross (ICRC) documented nearly 2,400 attacks against health workers, patients, and medical facilities and transport units, in just eleven countries. The vast majority of these attacks were against local medical facilities and personnel. In September 2015, the World Health Organization (WHO) reported 654 medical personnel had been killed since the beginning of the conflict in Syria, and that almost 60 percent of hospitals were either partially functional or completely out of service. Since 2015, nearly 100 medical facilities operated by Non-Governmental Organizations (NGO) have been bombed. The vast majority of these were in Syria, but facilities in Yemen, Afghanistan, Ukraine, and Sudan were also hit. It is extremely difficult to determine how many incidents were caused by NATO-led coalition assets versus the local government's or other nations' militaries.

These are only a few examples of fatal air strikes conducted by different entities against hospitals operated by NGOs:

Result of an air strike.

• Afghanistan, 3 October, 2015. The Kunduz Trauma Centre was heavily damaged in an airstrike conducted by a NATO asset.

• Syria, February 2016. An air raid hit the Maarat al-Numan Hospital. There is no clear evidence to confirm which nation or coalition is at fault.

• Syria, 27 April, 2016.The Al Quds hospital in the northern part of Aleppo was completely destroyed by an airstrike. There is no clear evidence to confirm which nation or coalition is at fault.

• Yemen, 16 August, 2016. A hospital was hit when the Saudi-led coalition conducted an air strike in the Abs district of Hajja province.

These tragic situations are every commander's worst nightmare. No one would argue that intentional strikes on such legally protected sites are permitted if they are used in violation of the laws of armed conflict, but the lack of awareness of the nature of the site and/or the alleged military use of the site can often result in devastation to civilian infrastructure and personnel. The confusion and stresses of dynamic targeting can often exacerbate this lack of awareness and/or confusion of enemy location, with fatal results.

Fictitious Example

Let us look at a fictitious but nevertheless realistic example. The situation is 'Troops in Contact (TIC)' and 'Danger Close' in the suburbs of a city, near a bridge on a winding river. 'TIC' means that our fellow fighters are being engaged, and the term 'danger close' is included in the call for fire support indicating there are friendly troops or positions within a given, close distance of the target.[2]

A powerful air asset is called to intervene, coming from a different part of the area of operations, making an already long flight even longer. It is late in the day for the crew. When the attack aircraft arrives, contact is established and the talk-on to the target begins. The aircrew is provided with coordinates on the ground (the friendly position, the hostile position, concerns positions) and other details. Unfortunately, the airplane's erroneous navigation system places the targeting pod's crosshairs somewhere on the river instead of on the target. Aircrew and ground troops start exchanging information, trying to manually guide the errant targeting pod to a valid, legal point on the ground. The building seen matches the building described. The relative position to the bridge checks. The aircrew obtains clearance from the ground and engages. A building is hit repeatedly, and hostile fire ceases on friendly troops.

Success? No, not entirely. While the hostile troops perceived the air-to-surface fire as a significant threat and stopped their ambush, the building that was just hit was not the one they were hiding in. Unfortunately, it was an unmarked hospital run by an unidentified NGO, and one that the crew of the attack aircraft was not aware of.

What happened? The truth can be complex. Perhaps there were two similar bends in that river, two alike bridges and south of those bridges quite comparable buildings matching the description just received. Such a constellation is plausible in many cities. The crew had little time to decide and act, and the troops on the ground were taking fire. There were no obvious markings on the building, no other building was briefed, and no one noticed differences. The crew did not doubt what looked right and engaged what they thought was the target building.

Avoidance of Fratricide and Collateral Damage

The example above is a typical case of an Immediate Request for Close Air Support (CAS), which usually results from unanticipated or unplanned emergency needs on the battlefield and requires diverting or rescheduling aircraft from other missions.[3] CAS is air action against hostile targets in close proximity to friendly forces, which require detailed integration of each air mission with the fire and movement of those forces.[4] When executing CAS, risk assessment is a critical factor in preventing both fratricide and collateral

Field Hospital Aerial View.

damage. NATO doctrine prescribes due diligence should be applied in order to minimize, and ideally avoid, any loss of civilian life, injury to civilians, or damage to civilian objects.[5]

While this all sounds good in theory, the strain of dynamic operations in practice often exposes weaknesses in man and machine, which could lead to undesired effects. Factors such as unexpected developments, faulty systems and malfunctions, inadequate levels of training, human fatigue, and psychology may play a role. In addition, the value of a risk assessment before a strike is predicated on the aircrew having complete and accurate information about non-combatant groups and facilities in the area. In the absence of such information, there is no expectation of collateral damage or civilian casualties, and therefore no reason for the aircrew to assess alternative courses of action such as having friendly ground forces disengage and look for a new route.

Psychology's Treacherous Trio

In our example above, the erroneous decision made by the aircrew to engage the wrong target could also be explained with a phenomenon known as 'Psychology's Treacherous Trio'. It consists of three psychological tendencies that when mixed together form a potent recipe for ignorance:

- Confirmation Bias. A natural propensity to look for what confirms what we believe and ignore what contradicts our belief.

- Cognitive Dissonance. A state of tension that occurs whenever a person holds two cognitions that are psychologically inconsistent.

- Motivated Reasoning. The human tendency to accept what we want to believe with more ease and much less analysis than what we do not want to believe.

If the aircraft's navigation system was 'off' just enough to show only one bridge, the crew would have believed the building to be the correct one. Even if the targeting pod had shown both bridges, the crew may have assumed the system to be accurate. It could have been the 'psychological treacherous trio' that drove the crew to select targeting the bridge closer to the crosshairs.

How to Improve on the Military Side?

On the military side there are tools that could help prevent such errant strikes.

1. Make sure aircrews have detailed maps or charts available showing the locations of all known formal and informal hospitals in the Area of Operations, just in case they are diverted from a planned mission to answer a distress call from ground forces.

2. Increase the use of technical capabilities for networked exchange of information. Modern systems are capable of receiving a digital brief directly from the involved ground troops, similar to real-time traffic information fed into modern car navigation systems.

3. Implement more accurate navigation systems connected with the aircraft's targeting systems.

4. Improve crew training. While an accurate navigation and targeting pod system help zeroing in, it is still the human that makes the decision to engage. The best weapon kit may not be enough in a dynamic environment, where nothing is more important than human observation and intellect. Recurring training aspects could be:

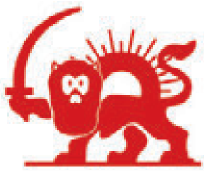
   a) Communication capabilities of the aircrew, i.e. the talk-on procedures to exchange more accurate details about the situation concerning the target.

   b) Psychological human factors as described above. Awareness of these dangerous proclivities may help prevent their unfortunate effects.

How to Improve Self-Protection on the Civilian Side?

NGO's and the ICRC can also help reduce the probability of medical facilities falling victim to an unintentional military strike. Under the international Law of Armed Conflict (LoAC), the Geneva Conventions Protocol I unmistakably codifies that medical units shall be respected and protected at all times and shall not be the object of attack. In the same context, the Protocol is very clear that Parties to the conflict are invited to notify each other of the location of their fixed medical units and shall ensure that medical units are so situated that attacks against military objectives do not imperil their own safety.

Therefore, besides carefully choosing the location of the medical facility, the use of distinctive, recognized, and clearly observable markings on the buildings is paramount in zones of conflict to safely protect qualified structures from military attack. Vertical signs, whether on the external building walls or free-standing, are usually not large enough to be visible to aircrews from above. Therefore, organizations need to put horizontal markings on the roof, or on the ground right beside the building, which are large enough to be seen by the naked eye or through a targeting lens from hundreds of metres in the air. In accordance with the Geneva Conventions, these could be the Red Cross, the Red Crescent, or the Red Lion, to name only a few examples. Some humanitarian organizations want to be recognized as non-aligned or non-affiliated and therefore prefer not to use those signs. In this case, the red diagonal on a white square background has been specially designed. Aircrew know and understand these signs, and they will not deliberately ignore them. If an aircrew observes such symbols on a targeted building, they will most likely seek more information about the nature and occupants of the building before deciding whether or not to execute the strike. Apart from the symbol itself, special attention should be given to its size and the type of paint. For best observation from the air, the sign should be put on flat portions of the roof and must be large. The edge length should be 2–3 metres at a minimum. The paint of such markings should also be observable at night with Night Vision Goggles or IR sensors. There

	**Red Cross** Convention (I) for the Amelioration of the Condition of the Wounded and Sick in Armed Forces in the Field. Geneva, 12 August 1949. Chapter VII. The Distinctive Emblem. Art. 38. As a compliment to Switzerland, the heraldic emblem of the red cross on a white ground, formed by reversing the Federal colours, is retained as the emblem and distinctive sign of the Medical Service of armed forces.
	**Red Crescent** Nevertheless, in the case of countries which already use as emblem, in place of the red cross, the red crescent and sun on a white ground, this emblem is also recognized by the terms of the present Convention.
	**Red Lion and Sun** Only used by Iran, recognized in 1922 and admitted in the ICRC and Red Crescent in 1923. The use of this symbol has been renounced on 4 September 1980.
	**Red Crystal** Protocol additional to the Geneva Conventions of 12 August 1949, and relating to the Adoption of an Additional Distinctive Emblem (Protocol III), 8 December 2005. This distinctive emblem is referred to in this Protocol as the 'third Protocol emblem'.

are paints that react with sunlight and therefore are more visible at night because they have retained heat, which will provide a different and improved response to sensors detecting white/black contrast.

Unfortunately, many NGOs are quite reluctant to contact and cooperate with Military HQs, for a number of reasons. First of all, NGOs tend to closely guard their independence and do not want to appear affiliated to any official or governmental agency or entity. Second, they often provide support to personnel without regards to status or nationality (i.e. NGOs may assist enemy combatants), which can put them at odds with 'friendly' troops. Finally, they often believe that the average military 'NATO' HQ is impenetrable and not permeable to discussions and cooperation. On the other hand, it also has to be said that sometimes coalition HQs treat NGOs with suspicion and are not prepared to share information and cooperate. One possible solution, to have a better understanding and mutual trust, could be to have regular meetings in a 'neutral' site to share information, programs/activities and maybe organize combined relief exercises which do not fall under a specific colour flag. This may require specific allowances for NGO sensitivities but could generate great dividends.

Furthermore, establishing contact with the military to report and stop an actual unintentional attack could be practical. A simple phone call might suffice but


© US Air Force, Senior Airman Christopher Hubenthal

Effects of a high ordinance explosion.

could also lead to a prolonged process to gain situational understanding and resulting in a delayed decision. The use of an emergency communication system is probably the better option. The Aeronautical market offers various solutions such as a radio transmitting on established emergency frequencies or an Emergency Locator Transmitter (ELT). Modern ELTs can be registered and given a 'call sign'. When the emergency occurs the device transmits a coded signal on the emergency frequency, audible as a beacon and broadcasting its own call sign. An aircraft crew engaged in an attack could be notified within seconds of the ELT activation and possibly correlate the activation with the engagement.

Conclusion

When countries, alliances, coalitions or factions engage in a confrontation, this may often result in devastating effects. Often, not only the engaged parties pay the price. This perception, however, does not liberate anyone from taking all appropriate measures to avoid collateral damage as well as unnecessary suffering in line with the provision of the LoAC.

On the military side, improvement of technical capabilities for the exchange of target information and precision strike is one obligation. The other one will be procedural training to include education about the psychological influences on human decisions. Despite the susceptibility of the human mind to mistakes, the human-in-the-loop's cognitive reasoning is often the last line of defence in confusing environments.

Nevertheless, it is important to note that military technology, procedures, and (mental) training are not the only critical factors when it comes to avoiding unintentional strikes on civilian targets. There is also a civilian responsibility. In particular, humanitarian organizations inside the zone of conflict should take the necessary precautions such as appropriately marking their medical facilities and establishing emergency communication with coalition forces' military headquarters.

Examples of portable Emergency Personal Locator Beacon.

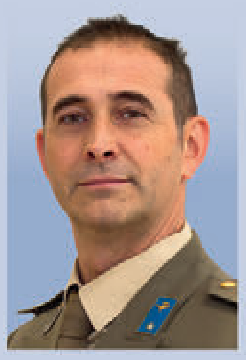
Maintaining neutrality does not require maintaining anonymity, and better self-identification could be a major step in self-protection.

Western air forces do not intentionally target known medical facilities in conflict zones, yet these strikes have continued to happen, with regrettable losses of dedicated medical personnel and their patients. Both the militaries involved in a conflict, and medical organizations attempting to impartially treat wounded civilians and combatants from both sides, can take steps to increase the awareness of hospital locations in order to reduce, or better yet, eliminate such accidents in the future.

1. 'Preparing NATO for Joint Air Operations in a Degraded Environment', Essen, 4–6 Oct. 2016.
2. 'Indirect Fire' Military Analysis Network [e-document], http://fas.org/man/dod-101/sys/land/indirect.htm
3. NATO 'ATP 3.3.2.1(C) Tactics, Techniques and Procedures for Close Air Support and Air Interdiction'. 17 Feb. 2011. Par. 0222.
4. NATO Glossary of Terms AAP-06, Edition 2016.
5. NATO 'ATP 3.3.2.1(C) Tactics, Techniques and Procedures for Close Air Support and Air Interdiction'. 17 Feb. 2011. Par. 0121 – 0123.

Lieutenant Colonel Andrea Olivieri

is a qualified Navigator/Weapon System Operator in the Italian Air Force. Since joining in 1989, he has trained in the USA Air Force SUNT (Student Undergraduate Navigator Training) program in Randolph AFB (TX) and subsequently graduated at the TTTE (Tri-national Tornado Training Establishment) in Cottesmore (UK). As an aircrew with 154 Sqn he participated in the flying Operations in Bosnia and Kosovo and the Ground Operations in Iraq. Between 2007 and 2014, he served as Chief Current Operations in the Italian AOC in Poggio Renatico and contributed, as an ATO Coordinator, to the Operation Unified Protector in Libya. He is currently stationed in JAPCC – Kalkar, as a Precision-Guided Munition Expert.



Lieutenant Colonel Michele Ferrari di Valbona

joined the Italian Army in 1989, trained first as an Anti-Tank infantry officer in the anti-tank company of the grenadier brigade. After three years he transited to the Army Aviation schools and graduated as fixed wing pilot in 1994. As an aircrew assigned to the school he operated as observer pilot for the artillery fires. In 1997 he transited on twin engines planes and assigned to the 28th Sqd.Gr. And participated in flying operations in the Balkans and ground operation in Lebanon. He served in the Balkan CAOC and as chief current OPS in the Army Avn School and as chief Ops at the 28th Sqd.Gr. He is currently stationed in the JAPCC – Kalkar, as the Air-to-Ground OPS expert.

While this is just an artificial rendering of a typical commercial of the shelf unmanned aircraft fitted with a machine gun, similar threats using even smaller UAS charged with explosives or other dangerous payloads are no longer a fiction.

Unmanned Aerial Systems Miniaturization

Chances and Risks of an Irreversible Trend

By Major Michel Busch, DEU Army, JAPCC

Introduction

The design of the first-ever Unmanned Aerial Systems (UAS) that appeared in the late 1970s and early 1980s was determined, and limited, by the payload size and weight of the sensors available. During that time the production of high-definition aerial imagery required a platform which today is called NATO class 2 UAS[1], weighing between 150 and 600 kg and requiring dedicated launch and recovery elements. Fielding such systems required an extensive amount of money, knowledge, personnel, and organizational structure, which was solely available to state actors. Additionally, those systems fell under proliferation and arms trade agreements, so the identity of producers and customers were well-known and easily monitored.

But times have changed. Commercially produced, small UAS for professional business or private usage are today freely available and affordable. At the same time, the evolution in UAS miniaturization allows even the smallest systems, such as micro UAS about the size of a fingertip, to carry high value and high-performance equipment.

The dangers from small Unmanned Aerial Systems (UAS) are very visible in today's media and actively discussed in the civil and military communities. Actual threats have included quadcopters coming within meters of politicians at public events[2], mid-air collisions with civil airliners, and the dropping of small explosives in current conflict areas. On the other hand, the military could benefit from the new technology, making efficient and effective use of the smaller systems for better situational awareness and a variety of other military tasks.

Evolution in Miniaturization

In recent years, three major trends have been driving developments in the UAS field. Those trends are automation, swarming, and miniaturization. All three are interrelated while miniaturization of UAS components is the main enabler of the others. These trends allow industry to constantly field new UAS generations to further optimize the trade-off between flight range, maximal altitude, and most importantly, the possibility to carry a specific, or multiple, payloads.

Traditional manned aircraft use mature technology for which even massive investments result in only limited capability improvements. The comparably young UAS business, on the other hand, is dealing with emerging low-cost technologies with innovation velocity much more responsive to even small investments. At the same time, the commercial UAS market is rapidly growing, promising huge revenues in relatively short term. Market researchers forecasted a UAS sales volume of 11.2 billion Euros in 2020[3].

Currently, the most challenging aspect of UAS miniaturization are electronics necessary to transmit and process command and steering signals. Those chips are still too big and energy consumptive compared to

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This awarded 3D print quadcopter design[6] provides an airworthy frame measuring less than 10 x 10 x 5 cm and weighting only 12 g, while still suited for payload delivery. Could such concept be copied and adapted by malign actors to print their own homemade UAS?

the overall system.[4] The increasing use of nanomaterials in the production of batteries and structural elements may be one solution to this problem, as recent research has found these materials will improve the weight-range-payload capacity ratio by multiple factors.[5]

Advantages to the Military User

Despite the security risk associated with the spread of increasingly smaller UAS on the consumer market, the development might be advantageous for the military as well. For example, remote-sensing service providers for farming and agricultural analysis have been using multi- and hyperspectral sensor suites for quite some time. Sensor weight and carrier system capacity required them to operate manned platforms at very high cost until the industry developed smaller, unmanned aerial platforms and smaller sensors to satisfy the customer's need for a more cost-efficient solution.

The benefit to the military is clear. Applications such as infrared, hyperspectral imaging, miniaturized for mini and micro UAS[7], enable the forces to use sensors previously only available in larger systems. For example, when searching roads ahead of convoys for planted Improvised Explosive Devices (IEDs), it would now be possible to use mini or micro UAS with miniaturized, multi-sensor suites as compared to the limitations of previous UAS fitted with only one single intelligence sensor. The speed of those systems and the increased endurance using new generations of fuel cells[8] should enable more robust and faster results compared to current detection and removal systems fielded as part of road clearance packages.

Another example of a capability originally developed for civilian users are miniaturized, automated, navigation systems allowing UAS to perform their functions with little or no GPS signal by utilizing terrain and object recognition.[9] Such signal-independent UAS

© Lockheed Martin

The Indago quadrator UAS provides military and civil users an eye-in-the-sky hovering capability for continuous 360-degree panning and multispectral imaging.

navigation could benefit the military extremely well when it comes to operations in a contested environment, i.e. where the reliability of satellite navigation might be reduced due to adversary electronic warfare or cyber measures.

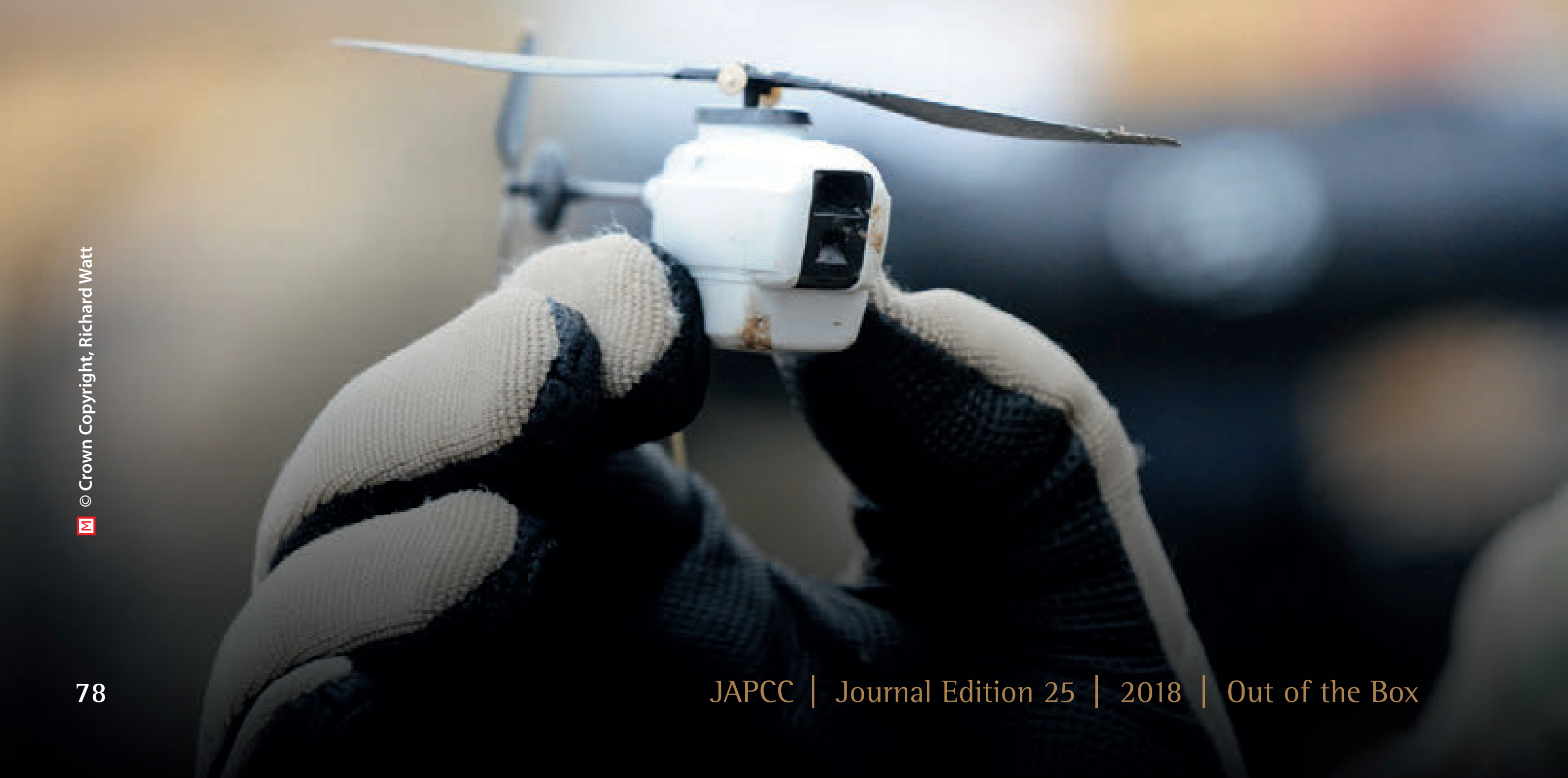
The shrinking size of UAS platforms and possible improvements of autonomous sense-and-avoid technology may further lead to changes with regard to pilot/operator qualification requirements pending respective airspace safety regulations. This means fewer 'certified pilots' (same qualifications as a manned aircraft pilot) are necessary as the smaller systems, which can be employed by a 'simple' trained operator, will substitute the currently larger UAS still requiring a fully certified pilot.

The tremendous trend of UAS miniaturization thus will create a huge amount of new and greater possibilities at lower cost. Since not only platforms and sensors but also associated components such as batteries will continue to shrink and become more efficient, even very small UAS may soon provide similar sensor performance and time-on-station capabilities as larger UAS can today. The speed of this development, however, creates the necessity to re-think the goals we want to achieve. In particular with regard to Intelligence Surveillance Reconnaissance (ISR), militaries must consider the quantity of data these systems will generate, which will require more and better educated as well as trained personnel to produce quality results, especially in near real-time processing and exploitation.

Increasing Asymmetric Threat

Most commercial off-the-shelf (COTS) UAS can easily be adapted for military use, especially when applying non-traditional tactics and means.[10] Unfortunately, the enemy has noticed the same. As demonstrated in current conflicts in Iraq, Syria and Ukraine, friendly forces may face an increased threat posed by small UAS employed by the enemy with unforeseen tactics, techniques, and procedures. Additionally, further developments in additive manufacturing (also known as 3D printing) may allow and encourage the production of homemade UAS, whose threat potential will be very difficult to predict. Relatively slow government procurement processes make it hard for the military to keep up with the current speed of those innovations as typical for the 'information technology cycle', relying on intuition as well as trial and error rather than perfect testing and safety considerations.

While Counter-UAS (C-UAS) capabilities are increasingly the focus of research, testing and fielding, the continuing trend of UAS miniaturization remains the greatest challenge for the developers largely due to detection and engagement difficulties. While the ever decreasing size of UAS is an important factor for detection, it is however not the only parameter to



consider. Target identification is an issue for many defence systems as well. For example, it can be extremely problematic for a radar sensor to differentiate between a small UAS and a swaying tree or other natural phenomena, especially when occurring in large numbers such as a swarm of birds or insects. Sophisticated UAS may even be capable of simulating the shape and movement of such creatures. This may not shield them from eventual detection; however, it complicates their categorization as an adverse object, which remains the most important step.

Apart from the object's affiliation there is a following challenge to determine its likely intent. Uncertainty whether one or more small UAS detected around a force will simply be used for intelligence collection, to deliver non-kinetic effects, carry lethal payloads or even function as so-called 'kamikaze drones'[11] trying to cause secondary explosions by serving as the trigger detonator[12], underlines the importance of permanent nearby airspace surveillance and flexible C-UAS response options.

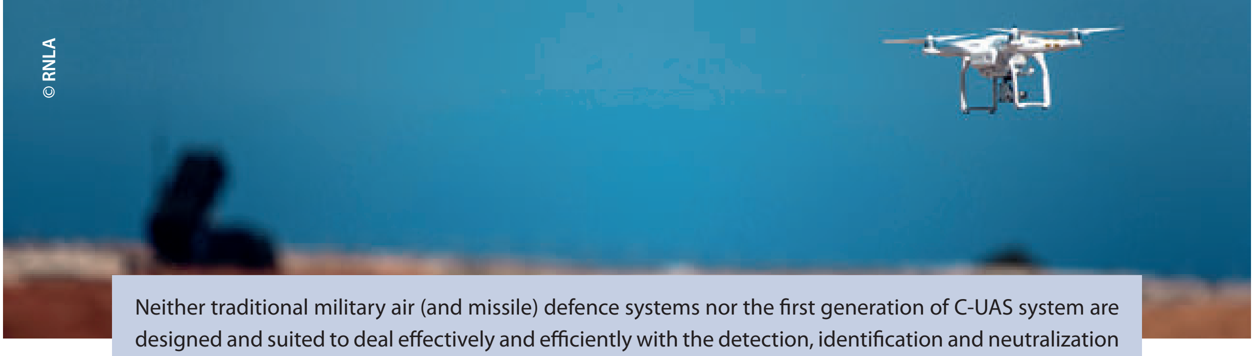
Given recent developments in light nano-explosive designs, which are able to create effects at least two times more powerful than heavier conventional explosives[13], friendly forces will have to dedicate additional resources to protect against this increased threat.

Currently fielded C-UAS systems can only provide effective surveillance and effective cover of a relatively small area around their employment location. Furthermore, engaging small-sized UAS with regular air defence weaponry will probably show little success. Given the advance in UAS miniaturization (including weapon payloads) and UAS swarming, NATO needs a comprehensive approach for dealing with these trends and subsequent threats.

Two stills from an IS video published in January 2017 showing a militant launching a Skywalker X7/8 fixed-wing UAV (COTS) fitted with two improvised munitions, and how such munitions were successfully dropped on Iraqi forces.

© Bundeswehr, Andrea Bienert

The German Army has purchased the AR 100-B 'Milkado' quadcopter as well as the PDR-100 PRS 'Black Hornet' nano UAS (p. 78) for local area reconnaissance.



Neither traditional military air (and missile) defence systems nor the first generation of C-UAS system are designed and suited to deal effectively and efficiently with the detection, identification and neutralization of small UAS threats of the upcoming years.

Conclusion

Recent years have shown that technological advancements and trends towards miniaturization of UAS are unlikely to stop. The associated chances and risks articulated in this article will continue to evolve. A clear understanding of those chances will enable users to leverage UAS advantages to the benefit of the Alliance and its partners. With regard to threats, however, the Alliance must recognize that neither stopping proliferation nor restricting the use of miniaturized UAS will be feasible. Consequently, UAS miniaturization will lead to a broader range of potential users, to include malign actors, which create threats that will not only have to be addressed by armed forces but, increasingly, by law enforcement agencies as well. Therefore, a comprehensive approach which encompasses a universal understanding of the threat, as well as the ways and means to counter it, should be embraced by the civil-military security community. In this regard, the JAPCC is currently participating in a C-UAS study run by the NATO Science & Technology Organization. This study includes military as well as civilian stakeholders.

In the days ahead, equipping friendly forces with effective and innovative C-UAS capabilities will be of utmost importance. A mere reactive approach will not be sufficient. Further C-UAS system development should encapsulate multiple sensors and effectors to make sure the entire spectrum of detection and engagement is available. This spectrum should include not only fencing, jamming, and kinetic engagement to destroy systems immediately threatening friendly personnel and assets on the ground. It should also encompass UAS communication tracking, since the ultimate goal will most likely be to identify the individual employing/using the miniaturized technology. Some of the C-UAS technology currently available or under development will be described in the following essay in this Journal edition. ●

1. NATO UAS Classification Table: AJP- 3.3 Ed.B V1. Allied Joint Doctrine for Air and Space Operations p. 71.
2. Wilkens, Andreas Nach Vorfall mit Merkel: Polizeigewerkschaft fordert Drohnen-Flugverbot, 2013. [Cited 1 Aug. 2017], Available from: https://www.heise.de/newsticker/meldung/Nach-Vorfall-mit-Merkel-Polizeigewerkschaft-fordert-Drohnen-Flugverbot-1960144.html
3. Ziegler, Michael, Studie: Drohnen-Markt wächst rasant, 2017. [Cited 1 Aug. 2017], Available from: http://www.drohnen-journal.de/studie-drohnen-markt-waechst-rasant-932
4. IHLS, Breakthrough in Drone Miniaturization, 2017, [Cited 1 Aug. 2017], Available from: http://i-hls.com/archives/77552
5. Hammes, X.T., Technologies Converge and Power Diffuses. The Evolution of Small, Smart and Cheap Weapons; in: Policy Analysis No. 786, CATO Institute, Washington, DC, 2016.
6. Design by Salva Serrano, winner against 218 other participants of the Fulcrum Generate Quadcopter Challenge in 2017. Online at: https://grabcad.com/challenges/the-generate-quadcopter-challenge/results
7. Hinnrichs, M., Hinnrichs, B., & McCutchen, E., Infrared hyperspectral imaging miniaturized for UAV applications. Infrared Technology and Applications XLIII. Anaheim, California, USA, 2017. doi:10.1117/12.2262125.
8. Pohang University of Science & Technology (POSTECH), Miniaturized fuel cell makes drones fly more than one hour. ScienceDaily 2016. [Cited 1 Aug. 2017], Available from: www.sciencedaily.com/releases/2016/03/160308105627.htm
9. Piermattei, L., Bozzi, C. A., Mancini, A., Tassetti, A. N., Karel, W., & Pfeifer, N., Multispectral data processing from unmanned aerial vehicles: application in precision agriculture using different sensors and platforms. 19th EGU General Assembly, (p. 13944). Vienna, 2017.
10. Ewers, E. C., Fish, L., & Horowitz, M. C., Drone Proliferation. Policy Choices for the Trump Administration: Center for a New American Security Washington, DC 2017.
11. Grohmann, Jan, The drone DragonFly: prototype weapons of the future 2017. [Cited 1 Aug. 2017], Available from: http://www.armadninoviny.cz/dragonfly-prototyp-zbrane-budoucnost.html
12. Ibid. 5.
13. Ibid. 5.

Major Michel Busch

commissioned to the German Army as an artillery officer in July 2003. His subject matter expertise comprises Unmanned Aerial Vehicles (UAV) and Imagery Intelligence (IMINT). In previous assignments he was deputy commander of a Tactical UAV (LUNA) company and Instructor for NATO Aerial Imagery Target Categories and Head of the Full Motion Video Section at the German IMINT Training Centre. Major Busch holds a university diploma degree in Social and Political Sciences from the Bundeswehr Universität München and a Master of Business Administration from the University of Applied Sciences in Kempten.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Detecting and Neutralizing Mini-Drones

Sensors and Effectors against an Asymmetric Threat

By Daniela Pistoia, Corporate Chief Scientist, ELT Group

Introduction

Small (15–150 kg), mini (<15 kg), micro (<66 J energy state) Unmanned Aerial Systems (UAS)[1] will drastically proliferate in the near future with rapidly advancing performance and functionalities. Progress in power storage, avionics miniaturization, materials and design methodologies, together with the availability of commercial or open source software applications, will enable increasingly smaller and cheaper platforms for a broadening range of possible uses. While such advanced technology means a huge opportunity for the military and industry, its alternative, sinister use for criminal and terrorist purposes is also no longer a fictitious risk. As many recent examples show, small UAS have become a real threat to both civil and military targets.

The detection, identification, and neutralization of such UAS flying near key infrastructure or sensitive areas (e.g. government buildings, high-profile event locations, prisons, military compounds) has therefore become a critical capability. So far, traditional countermeasures have demonstrated their weakness in this regard. Unconventional threats require more advanced solutions, and many industrial and government initiatives are rising to meet this new threat.

New developments such as advanced passive and active multispectral technologies seem most feasible to deal with the counter-UAS challenge. Multiple domain (electromagnetic, acoustic, electro-optic), multiple sensor (active radar, passive electromagnetic interceptors, acoustic sensors, infrared cameras), multiple jamming/deception system of systems, integrated via a dedicated command & control (C2) capability, are key elements within this approach. Last but not least, exploiting cyber capabilities is an important vector to counter the mini drone threat, though respective solutions are still immature. Superior knowledge, skills, and tools in the cyber domain will probably be the most decisive factor for a successful defence.

Too Small and Simple to be a Threat?

Drones are rapidly becoming 'tools of the trade' in many industries and could be categorized into segments of the market: Government (including Military), Enterprise (Corporations/Businesses) and Consumers (Personal/Hobbyist).

Since low-altitude drones fly only hundreds of feet above ground, they mostly operate outside traditional radar coverage used to track commercial aircraft. Also, military air defence radar systems are usually not designed to detect aircraft with such a small radar cross-section. In other words, there is an airspace segment neither under control of civil authorities nor military air power.

According to the 2016 Field Guide 'Drones Operating in Syria and Iraq' published by the Center for the Study of the Drones at Bard College (Annadale-On-Hudson, New York), *'there are more drones, made in more countries, and flown by more groups, than in any other previous conflict.'* Among the 38 different types of UAS, the institute counted at least eight recreational hobby drones and possibly six unidentified homemade models, asserting *'the conflict marks the first time that hobby drones have been modified with explosives and turned into flying improvised explosive devices.'*[2]

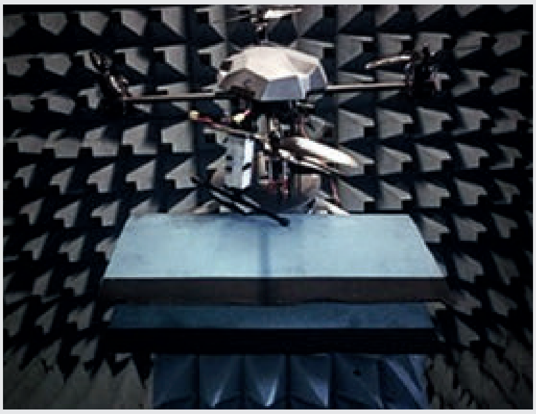
However, such use of mini-drones may not be limited to zones of war or conflict. The probability of threat proliferation to domestic areas combined with the inability of traditional airspace control and defence to effectively deal with such small and low-flying objects underline even more the pressing need for appropriate counter-UAS technology. Many companies have therefore created intense research & development programmes to provide effective solutions.

Drone Detection and Identification

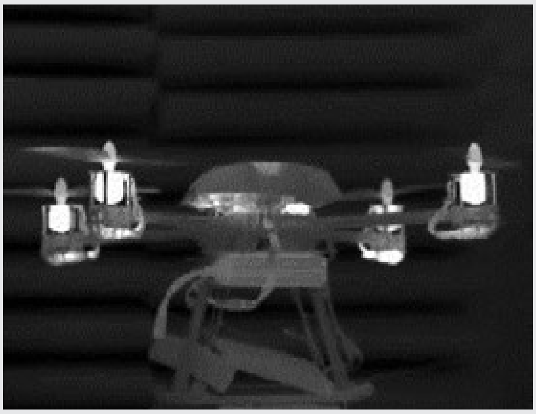
Defending against small UAV threats is a complex issue since it is not only about eliminating the drone to prevent it from completing its mission. Successful defence must ensure the immediate detection and identification of the object prior to neutralizing it in a secure framework for the safety of the people on the scene as well as minimizing collateral damage. Given the physical and kinematic characteristics of the drone and the typical modes of use, a multiple sensor approach is necessary to improve the detection capability. Several options, each with their own strengths and weaknesses are currently being tested:

Segment	UAS Application
Government Agencies	Homeland Security, weather, search & rescue (first responder), military air/sea/land applications (weaponized, surveillance, patrolling)
Businesses/Enterprises	Agriculture, photography, video production (movie, TV, documentary), infrastructure and building inspections (pipelines, cell towers, railroads, waterways, docks, locks)
Personal/Hobbies	Racing, personal photography, blogging, podcasts, video-blogging, experimental purposes, sports affiliated, videoing events (including live streaming)

Table 1: Types of mini-micro UAV Application.



Measurement of Radar and IR signature of mini-drones in ELT facilities.



Thermal hotspot on a small drone.

EM Sensors. Defence systems could exploit the sudden presence of radio signal used to send the commands from the pilot to the drone (uplink) and to send data and images from the drone to the command post (downlink). Those radio signals are transmitted on well-known and standardized frequencies, relatively easy to be intercepted with electronic surveillance in automatic mode, even though complex wave modulation is often superimposed to the carrier signal. Furthermore, passive geo-location techniques can be put in place to locate both the drone and the control station.

Active/Passive Radar. A sensor particularly devoted to the detection of aerial tracks is the radar. However, mini-drones are hard to detect and identify due to very low radar signatures (with a radar cross-section of the order of 0.01 m^2). Furthermore, it is a tremendous challenge to distinguish the target from other objects particularly in an urban environment, with a high probability of false alerts. The challenges increase when trying to use passive (bi-static) radar.

Infrared Sensors. Together with electromagnetic sensors, other promising devices could be thermal cameras, usable under low visibility conditions and at night. Infrared sensors could reveal drones even in the presence of strong lighting due to the ability to locate thermal hotspots generated by motors. Such hotspots, located in fixed positions in relation to the structure of the drone, also contribute to automatic object identification by making use of IR image reference libraries.

Acoustic Sensors. During flight, drones generate noise both in the audible frequencies and in the ultrasounds. Acoustic sensors reveal the presence of mini-drones as well as helping to classify the target based on noise characteristics specific to the drone model. However, the operational range of acoustic sensors is limited to a few hundred metres. At longer distances, drones are lost in background noise. On the other hand, radars have a blind spot at shorter distances. This means the acoustic sensor, made up of an array of microphones, is the ideal complement to radar systems to cover both long and short ranges. Being relatively cheap, acoustic sensors are efficient tools for the continuous surveillance of particularly sensitive areas.

Drone Neutralization

Detection and identification are essential, but they are only the preliminary steps in solving the problem of removing the drone from the scene of illicit action and/or its neutralization. 'Hard Kill', or physical destruction options are limited to combat zones or an

	EM Sensors (RF, COMM)	Active Radar	Passive Radar	Infrared Sensors	Acoustic Sensors
Capability of Detection	GOOD	GOOD	MEDIUM	MEDIUM	MEDIUM
Capability of identification	MEDIUM	POOR	POOR	GOOD	MEDIUM
Resistance to Interference	MEDIUM	GOOD	POOR	MEDIUM	MEDIUM
Applicability in Urban Environment	GOOD	POOR	MEDIUM	POOR	POOR
Installation Constraints	GOOD	MEDIUM	POOR	GOOD	GOOD
Life Cycle Cost/ Complexity	GOOD	POOR	POOR	MEDIUM	GOOD
Technology Maturity	GOOD	GOOD	POOR	GOOD	MEDIUM

Table 2: Suitability of Drone Detection Technologies (internal feasibility assessment).

open field, where the consequences of falling wreckage, ordnance, or other harmful items are generally irrelevant. In an urban scenario, a different approach aiming at a 'Soft Kill' is preferable. The following options have currently been proven as feasible and effective:

Jamming. A first option is to affect previously detected and identified radio signals, which would sever control of the drone from the operator. Then it could be forced to land in a safe area or to crash without risking collateral damage. The simplest technique is to generate jamming signals against the control link, delivering enough power to negate the use of the electromagnetic spectrum. According to the programmed modes, the drone then automatically enters into fail-safe mode causing it to land or return home. This 'brute force' approach, however, requires generating a huge amount of electromagnetic power and broad spectrum jamming of the whole area, which may also result in the undesired suppression of friendly communications. A more sophisticated and selective technique is so-called 'Smart Jamming', which consists of jamming the control signal only in some specific timeslots, according to the specific protocol used by the radio remote control. The challenge is again to successfully detect the particular UAS control/steering signal, whose waveform and encoding then need to be compared with available data for correct identification. To this purpose, a library of control signal protocols must be previously obtained by laborious reverse engineering based on vested intelligence, which may pose additional challenges to the friendly forces in countering the threat.

GPS Spoofing. The most effective albeit complex technique is Global Positioning System (GPS) spoofing, provided the targeted UAS is using satellite navigation.[3] Based on military capabilities designed to

© Cockrell School of Engineering, The University of Texas at Austin.

In 2012, a University of Texas at Austin research team led by Professor Tod Humphrey successfully demonstrated for the first time that UAV GPS signals can be commandeered by an outside source. In 2013, a similar team successfully spoofed a superyacht at sea.

deceive adversary precision-guided munitions, the technique consists of first, seducing the UAV's GPS receiver to recalculate its position and second, deviating its path in accordance with pre-planned countermeasures. To this end, a spoofing device transmits imitated satellite signals while deceiving the target with formally correct but false position data. This requires knowing the exact position and speed of the drone, which can be provided by a radar sensor. Precise scheduling of each spoofing phase is also needed to reduce the effectiveness of counter-countermeasures of certain smart, GPS-based guidance systems.

Direct Energy Weapons. In addition to these soft-kill techniques, weapons are being developed that produce a high-power microwave electromagnetic pulse which is highly effective against electronic equipment. With a specifically shaped antenna or emitter, the energy can be focused to produce effects within a confined area and limited range. Under certain circumstances such weapons could ideally complement the other techniques to neutralize small drones.

Sensors and countermeasures would need to be coordinated and integrated, so they interface via a Mobile Ad-Hoc Network (MANET) with a C2 station, typically with a man-in-the-middle, with an intuitive and easy to use interface.

Outlook

Michael Blades, research director at market research firm Frost & Sullivan, says that a year ago the anti-drone industry was too new to even offer a market estimate. But things have changed, and quickly. The anti-drone business is worth 'between $ 500 million and a billion dollars right now'. Blade isn't alone in his thinking; other market firms project growth rates as

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high as 26 percent, with market values hitting $ 1.5 billion by 2023. 'I think double-digit growth is a foregone conclusion', says Blades, 'just because they're starting from almost zero right now.'[4]

Many companies worldwide are proposing solutions in this emerging field, even if a lot of Research and Development activity is still ongoing and no vendor is able to demonstrate the maturity of a 'total weapon'. From US to Russia, including across Europe, announcements of new solutions and experimental results are published every day. ELT Group, the Italian EW house, is conducting trials of its solution named Anti-Drone Interception Acquisition Neutralization (ADRIAN), which includes hacking activity against the processor on board the threat.[5]

In any case, every proposed solution, modular and scalable according to the operational scenarios and the needs of the final user, is several times more complex than the threat, requiring a plethora of assets deployed. Controlling these assets will require highly-qualified and best-trained operators, whose mission preparation needs to be much more professional and sophisticated compared to the relative simplicity of the threat. The costs of the defence could therefore be magnitudes higher than the cost of the attack.[6] This is really asymmetric warfare.

1. According to the official NATO UAS Classification, small, mini and micro drones are subcategories of Class I. See Allied Tactical Publication ATP-3.3.8.1.1, 'UAS Tactical Pocket Guide'. Oct. 2016. Table 1, p. 1–2.
2. Dan Oettinger. 'Drones Operating in Syria and Iraq' (Field Guide). Center for the Study of Drones, Bard College. Dec. 2016. Online at: http://dronecenter.bard.edu/drones-operating-in-syria-and-iraq/
3. Miniaturization does not only apply to UAS platforms, but also on-board electronic equipment of any kind. Size reduction does therefore not limit the use of GPS technology, as shown on the open drone market, though other methods of navigation (e.g. based on recognized terrain and objects) for small/mini/micro drones have been developed.
4. Tim Wright. 'Anti-Drone Technology Could Become a Billion-Dollar Business'. 26 Jul. 2017. Online at: http://www.airspacemag.com/daily-planet/there-are-plenty-ways-stop-droneif-allowed-180964214/, accessed 26 Sep. 2017.
5. To hack the on board processor, a strong activity of reverse engineering is needed to discover the particular vulnerability that can be exploited pending the type of processor used. Exploitation of the vulnerability will require access to the functionalities of the target via the control link. Hacking UAS is difficult but possible, proven, and effective under certain conditions.
6. Counter-UAS system prices may vary between 250,000 € and 1,000,000 € depending on the specific configuration and features. A serious threat UAS may only cost between 5,000 and 25,000 €.

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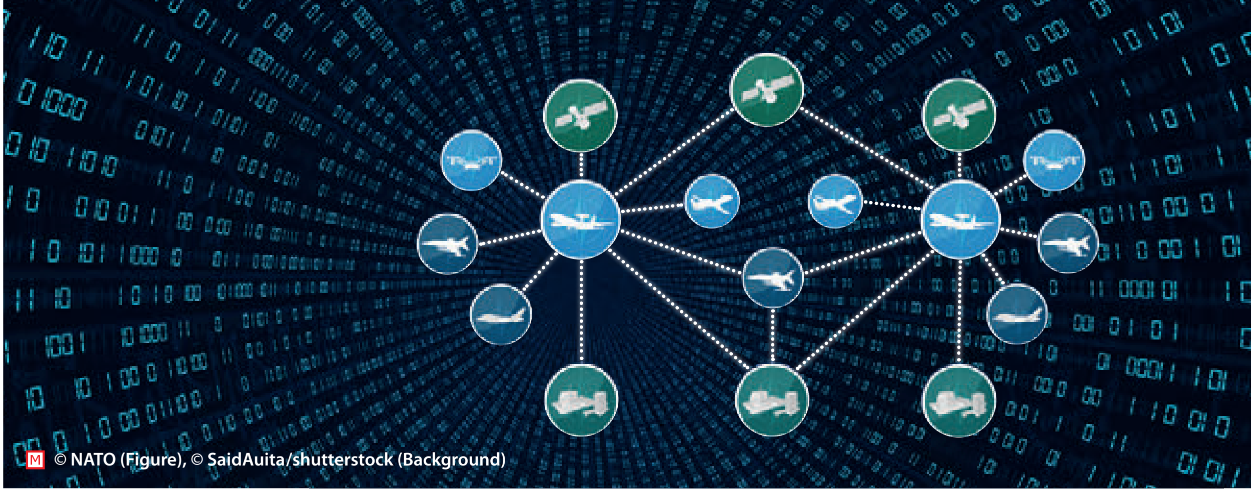
has a degree in Electronic Engineering and a diploma for Executive Management. In 1988 she began her career at Alenia Marconi Systems as an Engineer for Missile Systems and led the company's RF Sensor Simulation and Design Studies. Having worked from 2000–2002 as the Head of Advanced Concepts and System Studies in the Seeker Division of MBDA, she joined Elettronica (ELT) in 2003. As Vice President for Research and Advanced Systems Design, she developed and managed ELT's product portfolio related to cyber, EW, radar and electro-optical systems. Since 2013 she has been appointed as ELT Corporate Chief Scientist and Head of Product Innovation & Advanced EW Systems. She is author of numerous technical research papers and a regular speaker at international events.



© NATO (Figure), © SaidAuita/shutterstock (Background)

NATO Joint Air Power and Offensive Cyber Operations

In addition to Command, Control, Communications, Computers (C4), Intelligence, Surveillance, Reconnaissance (ISR), and Space Support to Operations, the successful projection of Joint Air Power relies heavily on Cyberspace for complex mission systems. Assets operating in the air and space environment must have freedom of movement, physically and in Cyberspace, to effectively deliver their function and, ultimately, secure air superiority, without which there is a grave risk to mission accomplishment. As a vital component in the projection of air power, Cyberspace has therefore surpassed its mark as an enabler, now recognized as not only critical to mission assurance but a domain of operations in itself.

Consequently, it is critical that systems operating in Cyberspace are secure, reliable and available. Defensive measures alone may be insufficient to ensure these criteria are met. It may be necessary to exploit the ability to attack those systems threatening NATO, to include an adversary's mission systems, and even as part of a joint effort to accomplish the mission. Ultimately, we must ask ourselves whether Defensive Cyberspace Operations (DCO) alone are sufficient, or whether this posture inhibits the adequate projection of Joint Air Power. A strong argument can be made that NATO must be able to request and/or exploit offensive Cyberspace effects.

In a recently published White Paper JAPCC looks back at the evolution of Cyberspace within NATO, from the initial use of Information Technology (IT) and Computer Information Systems (CIS) for basic digital communications needs, through to the declaration of Cyberspace as a Domain of operations. Lessons learned from key events as well as research papers that support are cited in an assessment that asserts Offensive Cyber Operations (OCO) are required to have the most effective Cyberspace posture, suggests how it might be applied in Joint Air Power scenarios, and offers that structural models already exist for how this capability can be incorporated into the NATO organization and processes.

E-Version: *https://www.japcc.org/portfolio/oco/*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NATO Helicopter Underslung Load (USL) Certification

One method of quickly employing forces is through airmobile operations. When employed by helicopter, equipment and materials can be transported as an Underslung Load (USL) underneath the helicopter. In NATO-led joint operations it is essential nations involved are interoperable in transporting equipment and materials of one nation with helicopters of another nation. Even though respective Standardization Agreements (STANAG 2445, 3542, 2286 and 2970) with minimum USL interoperability criteria had been developed and put in place, the responsible NATO Helicopter Inter-Service Working Group (HISWG), identified a significant deterioration of interoperability in helicopter USL operations in the last decade.

On request of the HISWG the Joint Air Power Competence Centre (JAPCC) conducted a study identifying the challenges for helicopter USL interoperability and provided recommendations on how to overcome these challenges to increase the effectiveness of joint helicopter operations. The main objective of the study was to assess the feasibility of forming a NATO-accepted USL certification system based on existing NATO USL standards. After evaluation of those existing standards and consultations with relevant agencies, a questionnaire was developed and distributed across NATO and partner nations to gain insight into the current issues that interfere with USL interoperability.

The JAPCC White Paper 'NATO Helicopter Underslung Load Certification' published at the end of 2017, provides an overview of current USL certification and interoperability practices across the responding nations. From the responses received, it can generally be concluded there is low or no acceptance of USL of other nations during operations and exercises, as a result of unclear procedures and differences in certification regulations, a lack of harmony between NATO STANAGS and national regulations, different training levels and currency requirements for personnel, Helicopter Underslung Load Equipment (HUSLE) variations, and the lack of documentation sharing between nations. The recommendations given identify a workable way forward for the future to improve USL interoperability in NATO operations and exercises.

E-Version: *https://www.japcc.org/portfolio/uslc/*

Think-Piece on Force Protection Command and Control (FPC2)

The Airbase of the future will likely be a location where multiple nations come together to operate a wide variety of different air platforms, in substantial numbers. Furthermore, the capability, scarcity and cost of fifth-generation air assets will make such platforms increasingly high priority targets. Joint Air and Space Power is NATO's asymmetric advantage and most likely what any future adversary will seek to degrade. Recent operations as well as future plans tell us that any airbase is also highly likely to be a headquarters location and a logistics facility, providing theatre enabling capability and quite possibly an operating base for other components. This combination of factors quickly creates a strategic asset that could very easily be the military Centre of Gravity (CoG). The inescapable conclusion is that the Airbase of the future will be a high priority, high-value target for any adversary, whether that adversary be a state or non-state actor. Given the strategic nature of airbases and the vulnerability of most, if not all of the assets grouped on them, it is apparent that the methods of protecting them will have to become much better. As a key component, this process will require dedicated, air-minded Force Protection (FP) forces that are specifically trained and organized for the task.

It should be robustly argued that too much focus is placed on the cost of Air FP, when the actual focus should be the significantly higher cost *(human, materiel, strategic, reputational etc.)* of a failure to adequately invest. That said, nations must make the most of what resources they have, and investing in intellectual development and critical thinking should be a priority if future adversaries are to be outwitted and ultimately out-fought. Few, if any, of our nations are now capable of 'going-it-alone' therefore, creating constructs to which all can contribute or *'plug and play'* is not just sensible, but essential.

The recently published Force Protection Command and Control (FPC2) Think-Piece is a collaborative work between the European Air Group (EAG) and the JAPCC. For the EAG it provides the 'Capstone Document' for their 'Standardization of FPC2 Documents' project. It also provides the generic start-point from which to develop over the coming years a multinational, air-minded, responsive, scalable and agile FP capability that will be effective yet resource-efficient. If embraced now, it will help make the participating nations 'Operationally Compatible'; moving forward and when fully-developed, it should deliver true interoperability.

E-Version: *https://www.japcc.org/portfolio/fpc2/*

Air Warfare Communication in a Networked Environment

The advent of technology which improves the method by which communication is achieved across the air domain offers an opportunity to shape the future of Air Command and Control (C2). In July 2017, the JAPCC published a detailed review of a future networked battlespace and the potential impact of near-unlimited communications on the disparate platforms which will operate in this environment.

Although 4th–5th generation aircraft interoperability is currently a focal point of future battlespace considerations, this study is about much more than that. It explores a vision of the future communications-networked battlespace and then identifies specific elements of coordination and communication necessary for operations in this type of hyper-connected environment. Soon, clusters of different types of platforms will be allocated and combined to function as specific force packages, organized by capability and hierarchy, and ideally irrespective of service, country, or degree of human presence. Unlimited connectivity is no longer a thing of the future, yet combined decision-making and data-sharing (what we do with the information) are not evolving at the same speed as technology. As technology continues to develop and improve communication (speed and amount), humans and artificial intelligence will have to develop new 'social contracts' in order to comply with and execute the Commander's intent.

The value in this study, and its subsequent relevance to NATO (both Allied Command Operations and Allied Command Transformation), is to define air platform behaviour in this future networked environment to inform the development of both the network and command structures so that they may evolve in concert with the likely evolutional behaviour of the assets over which they will exert control. Furthermore, the development of concepts such as Dynamic Airspace Synchronization, as well as the exploration of C2 adaptation, are designed with a more integrated, more joint and more connected battlespace envisioned than is currently executed today. The findings are designed to improve the Commander's operational decision tempo and will help shape the direction of research as multi-domain interoperability and communication among participants in a networked environment improves.

E-Version: *https://www.japcc.org/portfolio/air-warfare-communication-in-a-networked-environment/*

'Russia's Air-launched Weapons – Russian-made Aircraft Ordnance Today'

By Piotr Butowski,
Harpia Publishing L.L.C., 2017
Reviewed by:
Lt Col Ralf Korus, DEU A, JAPCC

Since Russia's economy has been affected by sanctions for several years, one could expect the ambitious modernization process of the Russian Federation military to be slowed down or delayed. Nevertheless, Russia is back on the international scene and underlining its global power claim through intervention in the Syrian civil war. The deployment of air and maritime assets into theatre, to include air operations from their single aircraft carrier as well as cruise missile launches from warships and submarines out of the Caspian and Mediterranean Seas could also be seen as test and demonstration of current Russian air force armament.

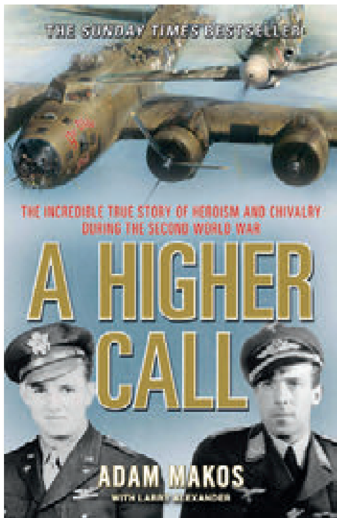
Russia's Air-launched Weapons is the third volume of a series of publications to describe Russia's tactical and strategic aircraft inventory and their possibilities employing air power. As a supplement to the previous books, this new issue describes the inventory of strategic weapons, tactical air-to-surface and air-to-air missiles (including helicopter-launched missiles), aerial bombs and rockets, guns, pods, and naval weapons, while not only detailing the history and current status of ordnance but also the prospective development of future generations. The book thus provides in depth knowledge of Russia's current and future military capabilities serving well the needs of military analysts to understand such worldwide development. This book is very valuable and should be of great interest to anyone generally interested in Russian military aviation. ●

'A Higher Call'

A Higher Call is the story of two World War II veterans, US Army Air Corps pilot Charlie Brown and German Airforce pilot Franz Stigler. They encountered each other by accident in the contested skies over Europe and still live today to tell their story.

Brown's flies his first WWII mission on 20 December 1943, heading together with around 475 other bombers towards the city of Bremen/Germany. Due to heavy flak over the target area his B-17 sustains heavy damage, his left waist-gunner is severely wounded, and his tail gunner dies. In addition, all but one board machine guns are frozen solid. Unable to keep up, Brown has no choice than to leave the formation and become a 'straggler'. When Luftwaffe pilot Stigler intercepts Brown's B-17, he is not engaged by any of the adversary gunners. Coming closer, Stigler notices the tail gunner is dead. Through the battered and torn sides of the B-17 he observes the crew is fighting for the life of their waist gunner. Remarkably, Stigler, decides not to attack but escorts the bomber safely along the coast through German air defences. Flak gunners on the ground are astounded to find a B-17 being escorted by one of their own BF-109's. Not a single shot is fired.

This episode would haunt both pilots well over 40 years until they eventually met face-to-face in 1990. Through the incident they have become attached for the rest of their lives. *A Higher Call* is a very well written book that immediately grips the reader. Just too difficult to put it away until finished. ●



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