Transforming Joint Air and Space Power
The Journal of the JAPCC

Edition 27, Autumn/Winter 2018

2018 was another eventful year for the JAPCC and I am very proud to be the new Assistant Director of NATO's catalyst for the improvement and transformation of Joint Air & Space Power. On 15 August 2018 I took over the responsibilities of the AD from my predecessor Air Commodore Madeleine Spit, who very capably ran the JAPCC for four years. I hope to emulate her energy and success and we all wish her the best in her new assignment. Our annual JAPCC conference, which took place on 9–11 October in Essen, was the first major task I encountered in my new position. With the outstanding support of my JAPCC staff and the very enlightening contributions of our panellists and our distinguished guests we accomplished a very successful conference and were able to examine 'The Fog of Day Zero'.

I am excited to present you with issue 27 of the JAPCC Journal of Air and Space Power, the first issue I have had an opportunity to contribute to as editor. It is my great pleasure to open Issue 27 with an interview of the Air Chief of the Czech Republic, Major General Petr Hromek, who provides us a with a very informative and sincere view of the challenges his Air Force is currently encountering and the ambitious goals they want to fulfil in the future. Our cover attests to the main focus of this edition, with articles on 'Space Resilience' and 'Responsive Launch of ISR Satellites' covering a wide field of future space challenges. 'Will the Aircraft Carrier Survive?' takes a critical look into the future of fixed-wing aircraft carriers and 'Aerial Tanking 2035' provides a conceptual look into the future of Air-to-Air Refuelling. 'Challenges of Future SEAD Operations' and 'Electronic Warfare – The Forgotten Discipline' inspire renewed thought about a capability, EW, that has long been taken for granted and neglected, but now needs to be substantially revitalized. 'Autonomous Weapon Systems in International Humanitarian Law' provides thrilling thoughts on the challenges and conflicts of these unmanned systems.

The Journal then moves on to different View Points. A review of '100 years Royal Air Force' outlines the value added by the RAF to current Air Power Strategies and the article 'Light Attack Aircraft' takes a view on a more budget-friendly way of projecting Air Power. 'Rotary Wing Unmanned Aerial Systems' emphasizes the usage of UAS in maritime operations; and last, but not least, 'The Future Role of Artificial Intelligence' examines a number of important considerations in this critical and rapidly developing capability.

Thank you for taking the time to read this edition of our Journal, and thanks to our authors for their contributions. I hope you find this offering as informative and thought-provoking as I did, and we at the JAPCC greatly appreciate any feedback and thoughts you may wish to share. Please visit our website at www.japcc.org, like us on LinkedIn or Facebook, or follow us on Twitter or send us an e-mail to contact@japcc.org to give us your opinion.

Ciao and good reading!

Giuseppe Sgamba
Brigadier General, ITA AF
Assistant Director, JAPCC

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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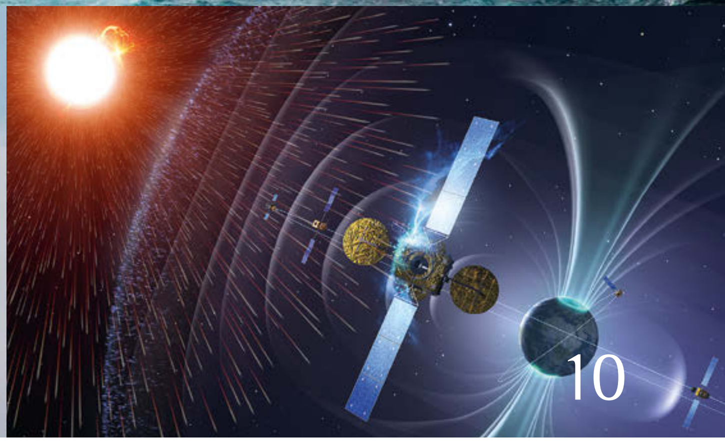
The Journal of the JAPCC Römerstraße 140 | D-47546 Kalkar | Germany



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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.

Czech Air Force – Now and in the Future

The JAPCC's Interview with Major General Petr Hromek, Commander of the Czech Air Force

On 1 May 2018, Major General Petr Hromek became the new Commander of the Czech Air Force. He replaced Major General Jaromir Šebesta. Despite the fact that the Czech Air Force may be thought of as a small one, commanding it still remains a truly demanding job. We asked General Hromek for an assessment of the Czech Air Force and his vision for its future.

Sir, congratulations on your promotion and new position. Considering that the Czech Air Force's capacity and capability may not be well understood by a broad audience, could you give the readers of the JAPCC Journal a sense of what your new command will entail?

Being a Commander of the Air Force is a great honour and responsibility for me. The Czech Air Force is composed of six major components. The 21st Tactical Air Force Base harbours the main combat power of 14 supersonic JAS-39 C/D fighters supported by two squadrons of subsonic L-159 Advanced Light Combat Aircraft (ALCA). The 22nd Helicopter Air Force Base with squadrons of Mi-171 and Mi-35 helicopters provide transport and fire support to land forces as well as search and rescue services. The 24th Transport Air Force Base operates a fleet of Airbus A-319, CASA C-295, indigenous L-410 and Challenger C-601 aircraft, as well as W-3A Search and Rescue (SAR) helicopters. The 25th Air Defence Battalion operates various Ground Based Air Defence (GBAD) assets, such as modernized SA-6 systems, short-range RBS-70 systems, and older, but still capable, SA-13 systems. The 26th Command and Control Battalion is the node responsible for continuous Recognised Air Picture (RAP) production and distribution, air traffic services, and NATO-connected Control and Reporting Centre (CRC) operations, which manage the Quick Reaction Alert (QRA) forces. Lastly, the Training Centre in Pardubice provides a broad scale of support to the Air Force units, including an education programme for beginner pilots and preparation in several simulators.

How do you assess the state of the Czech Air Force?

I think I took over the Air Force in very good shape. Looking back, our membership in the North Atlantic Treaty Organization (NATO) brought extensive technical upgrades and a much more significant shift in knowledge and training levels. Such progress provided fundamental performance improvements as well as an increased level of flight safety. Our NATO Allies confirm the high standards of the Czech Air Force achievements on joint exercises and foreign missions. All units are engaged in real-world operations and the operational tempo we are experiencing now is really impressive. A pair of QRA JAS-39 permanently contributes to NATO's integrated air and missile defence system and we additionally support NATO Allies in the Baltic region and Island air policing missions on a rotational basis. In addition to homeland search and rescue services, our helicopters were deployed to the International Security Assistance Force (ISAF), supporting a long-term Afghani Air Force training mission. An air advisory team is also deployed to Iraq, providing assistance to the Iraqi Air Force L-159 ALCA operations. One of our transport C-295 CASA

Portrait: © Vladimír Marek, Background: © Tomáš Soušek

aircraft is also part of a long-term commitment to support the United Nations' Multinational Force and Observers (MFO) mission on the Sinai Peninsula. Other elements contribute to the NATO Response Forces (NRF) and the European Union Battlegroup (EUBG). The Czech Air Force is hosting significant NATO exercises in support of Allied improvements in Close Air Support (CAS), Joint Fires, and Air/Land Integration. Our appetite to support training with opposing 'Red Air Forces' is well known and we support many exercises and evaluations with this capability.

What are your priorities?

The first priority I always highlight is my attention to the Air Force personnel. The goal is to stabilize Air Force manpower.

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After decades of declining defence budgets and relocations of several units, it is now time to switch from 'capabilities survival mode' to 'recovery and development' mode. Set objectives require younger, well-trained, and highly motivated personnel – almost a new generation. Air Force leadership has provided extra effort focused on recruitment, education and training. The most urgent situation prevails in the GBAD units, which bore the full weight of budget cuts in the last economic crisis. Our recruitment tempo ensures we are filling open positions with high-quality personnel, and it allows us enough time to train them for challenges unlike any we have seen before. Additionally, we intend to tailor and accelerate the training syllabus so the fresh personnel can reach full operational status earlier in their careers. New national legislation has dictated reaccreditation of many university study programs, including the Czech University of Defence. We have taken this as an opportunity to closely cooperate with academia to meet contemporary national defence demands. Speaking about human resources, it is important to realize that pilots, system operators, or air traffic controllers are only the tip of the iceberg. The less visible volume of manpower required to support the flying mission also deserves the best care. In summary, my aim is to rejuvenate people and enhance proficiency.

What are the main challenges facing the Czech Air Force?

The modernization process is not fully completed and strategic level procurement programmes are a long-lasting challenge. Since the development authority rests outside of the Air Force structure, it can sometimes be difficult to procure an asset that is needed quickly. The most urgent requirement is the procurement of modern, NATO-compatible, three-dimensional (3D), mobile Air Defence (AD) radars. Our ageing radars have passed their projected technical life multiple times already, and the art of life extension is reaching its limits as the unique, irreplaceable core parts wear out. We are minimizing our dependence on Russian hardware, which will eventually require the replacement of assets like our Mi-24 helicopter fleet. We are continuing to scan the market for western-built counterparts. A positive step forward is the near-future enlargement of our Spanish-made CASA C-295 fleet resulting in the retirement of our Russian-made Yak-40s.

How do you see the future?

Our near-term objectives are set. The gradual rise of our defence budget ensures the procurements of strategic importance should not be disturbed. New radars are truly essential for production of a high-fidelity, 3D air picture that we can distribute to national and NATO systems. Land forces will receive advanced day and night multi-role support once new helicopters become operational. We are still analysing the appropriate size of our air transport fleet. We are considering joining some of multinational, capacity-sharing programmes in addition to expansion of our CASA C-295 fleet. The intended procurement of the Brazilian-made KC-390 Embraer is still beyond the fiscal horizon. We have well-defined milestones on our road map to the future. The current JAS-39 contract will terminate in the timeframe 2025–2027, and we must make the extremely important strategic decision about how to proceed well in advance. All options, as well as numbers, are still open, to continue with the current JAS-39 C/D, upgrade to the JAS-39 E/F, or possibly change to a new generation of fighters. The solution we choose will affect our entire Air Force as well as the entire Alliance. The future role of L-159 squadrons, infrastructure, and ammunition stockpiles are just a few examples of what we have to adapt in the next long-term planning cycle. The second significant milestone is the unavoidable replacement of the current GBAD systems. Despite extensive modernization, our Air Defence awaits technological steps forward. We are working to increase interoperability, mobility, and maximum engagement range of all assets. Additionally, we are seeking investment in Counter-Rocket, Artillery, and Mortar (C-RAM) and Ballistic Missile Defence (BMD) capabilities. My responsibility today is to support selection of the best possible solutions while engaging in education and training to continue building a highly-capable, modern Air Force.

Closing Remarks

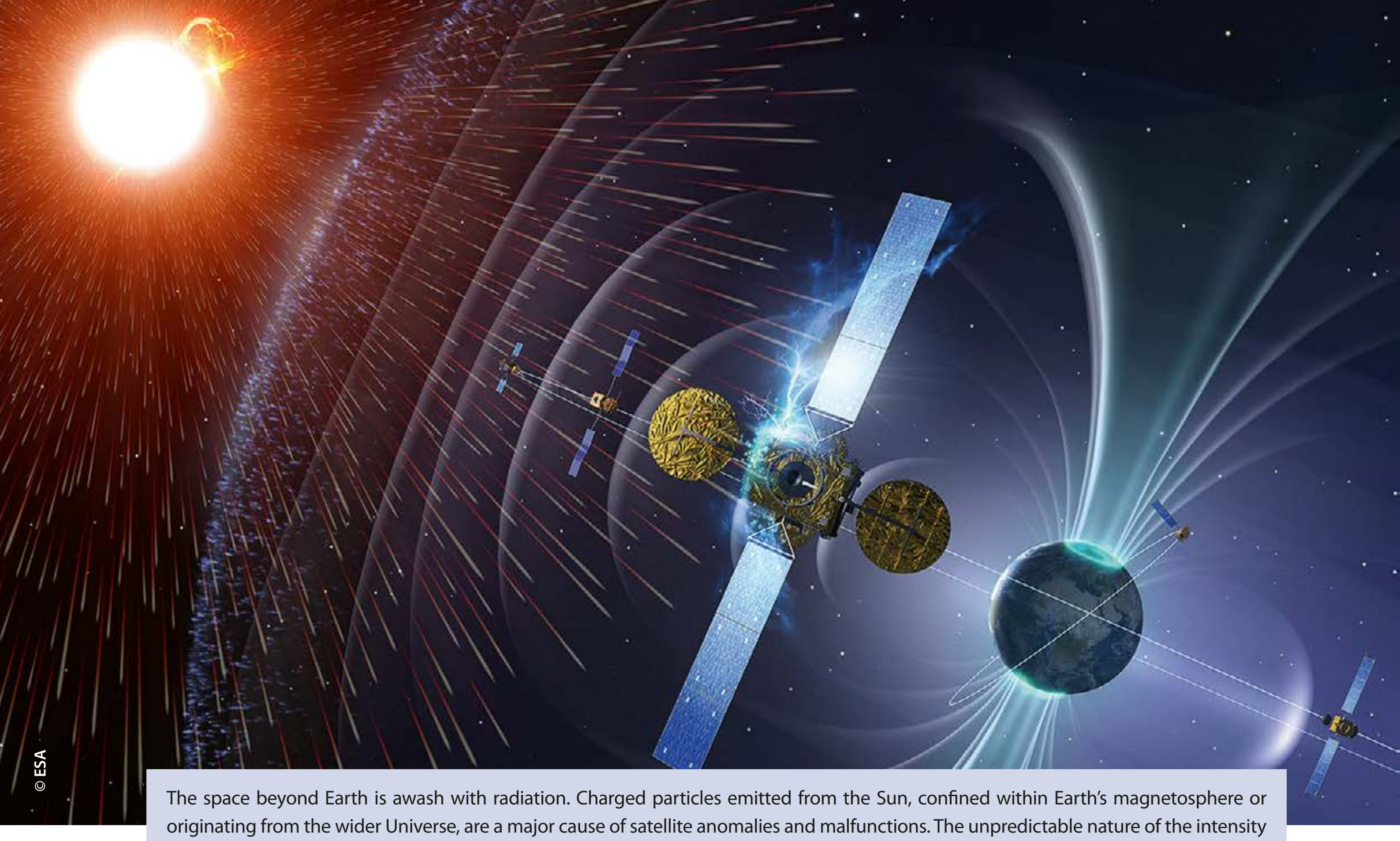
I always emphasize reliable and safe execution of Air Force duties. The Czech Air Force will continue to work hard to prove that we are a reliable and credible NATO ally. Air Policing, CAS, Short-Range Air Defence, and multinational interoperability training are the highlighted calls we are happy to answer. In today's unpredictable security environment, the credibility, reliability, and sustainability of our forces are essential. The future is in young and highly-trained professionals, combat-ready and interoperable equipment, and reliable and sustainable support.

Sir, thank you for your time and your comments.

Major General Ing. Petr Hromek

was born in 1963, in Krnov, Czechoslovakia. His fighter pilot career started in 1986 where he began flying MiG-23 and MiG-21 aircraft. The General became a Squadron Commander in 1994. His staff tour started in 2000 at the NATO Allied Air Command Headquarters (HQ) in Ramstein. In 2004 he began leading the Czech Joint HQ Air Force branch in Olomouc, and in 2013 he assumed command of the 21st Tactical Air Force Base in Caslav. Major General Hromek assumed the role of Deputy Air Force Commander in 2016, and assumed Command of the Czech Air Force in May 2018.

General Hromek graduated from the US Air War College in 2011 and the Czech Air Force promoted him to the rank of Major General on 28 October 2018.



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The space beyond Earth is awash with radiation. Charged particles emitted from the Sun, confined within Earth's magnetosphere or originating from the wider Universe, are a major cause of satellite anomalies and malfunctions. The unpredictable nature of the intensity of those radiations over time suggests the need for an improved resilience.

Space Resilience – Why and How?

The Importance of Space Resilience and the Current Approach

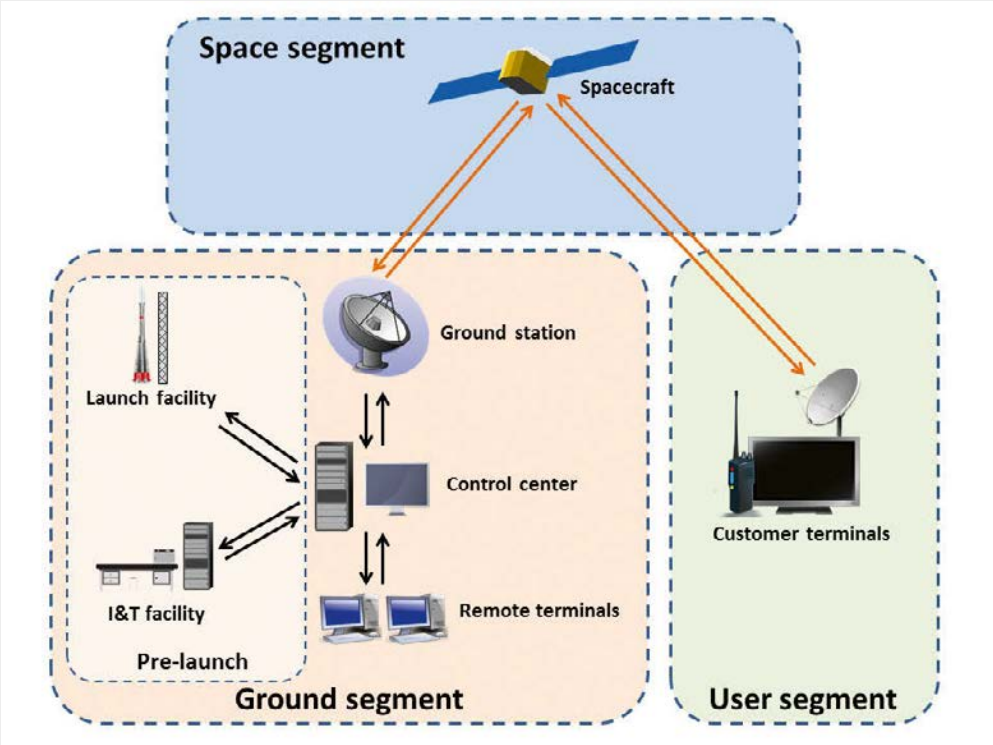
By Lieutenant Colonel Andrea Console, ITA AF, JAPCC

Introduction

Modern warfare is highly reliant on Space. From GPS-guided munitions to Communications and Intelligence, Surveillance and Reconnaissance (ISR), Space is almost ubiquitous when high-tech military applications are involved. The relevance of space-based services for military operations has grown to a point that NATO admits its substantial dependency on the domain.[1] For these reasons, most commanders assume the presence of space support in any operation, yet only a few have a clear understanding of its contributions, let alone the consequences of an interruption or significant degradation of any of the space services. In this context, raising awareness across the Alliance of its dependency on Space remains a challenging task, and thus a primary objective for the NATO space community.

Space Support as a Requirement – Space Resilience as Deterrence

When confronting a space-capable, near-peer adversary, an absence of space support would result in a dangerous technological gap, because of the unavail-



An example of generic space system architecture. Orange arrows denote radio links; black arrows denote ground network links. It is worth noting that different system breakdowns into segments are possible. For instance, military documents usually list the communication link as a separate component (i.e. the link segment).

ability of many types of military equipment that require some form of space-based product or service. Consequently, being prepared to operate in the absence of space support is important, but it is not enough. In fact, the ability to go 'back to basics' (i.e. to employ 'old-style' Tactics, Techniques and Procedures (TTP) when it is the only available option) is a necessity because it allows operations to continue even in a highly degraded space support environment; nevertheless, it also implies some degree of capability deterioration that, in some cases, could be unacceptable for the effective conduct of operations.

Not only is space support critical to military operations, but it is also an important element of deterrence, as vulnerabilities in space support to operations seriously impair deterrence. An opponent aware that Alliance high-technology capabilities depend on an exposed space infrastructure will be, in fact, encouraged to undertake hostile actions, primarily against such infrastructure. A clear commitment to preserving military space support through the improvement of its resilience, therefore, should be a priority.

Unfortunately this is not an easy job, because satellites operate in a condition of intrinsic fragility: they orbit at an incredible speed (up to 28,000 km/h) in a high thermal and electromagnetic stress environment, with limited capability to manoeuvre, and under the constant threat of collision with other natural and man-made space objects. Moreover, from a military point of view, satellite systems have an additional vulnerability. In fact, unlike most military assets, nations need to deploy their satellites and their respective ground segments and put them into service well before they can be effectively employed in any military operation. This means that an adversary has the time to thoroughly study all system characteristics, understand behaviours, find weaknesses, and determine the best way to neutralize a key space-based service. Space systems are usually very expensive and take years for governments or industry to develop and make operational; furthermore, they are difficult to defend and take a long time to replace. In a nutshell, they represent a low-risk/high-reward military target. In addition, the wide spectrum of all possible threats to space systems, from cyber-attacks to kinetic attacks, to the use of Directed-Energy Weapons (DEW), allows the adversary to escalate and de-escalate the aggression intensity quickly and effectively.

Consequently, it is quite reasonable that space services should be acknowledged as a predictable day-zero target, because an adversary can clandestinely prepare space assets as targets during peacetime, then rapidly attack them, when required, to provide heavy impact to the Alliance forces and achieve significant surprise effect. An attack on dual-use or civil space systems would be highly disruptive as well. Today, for example, the sudden loss of satellite-based Position, Navigation and Timing (PNT) services or of satellite communication would paralyse most of the financial, commercial, and transportation systems and associated activities.[2]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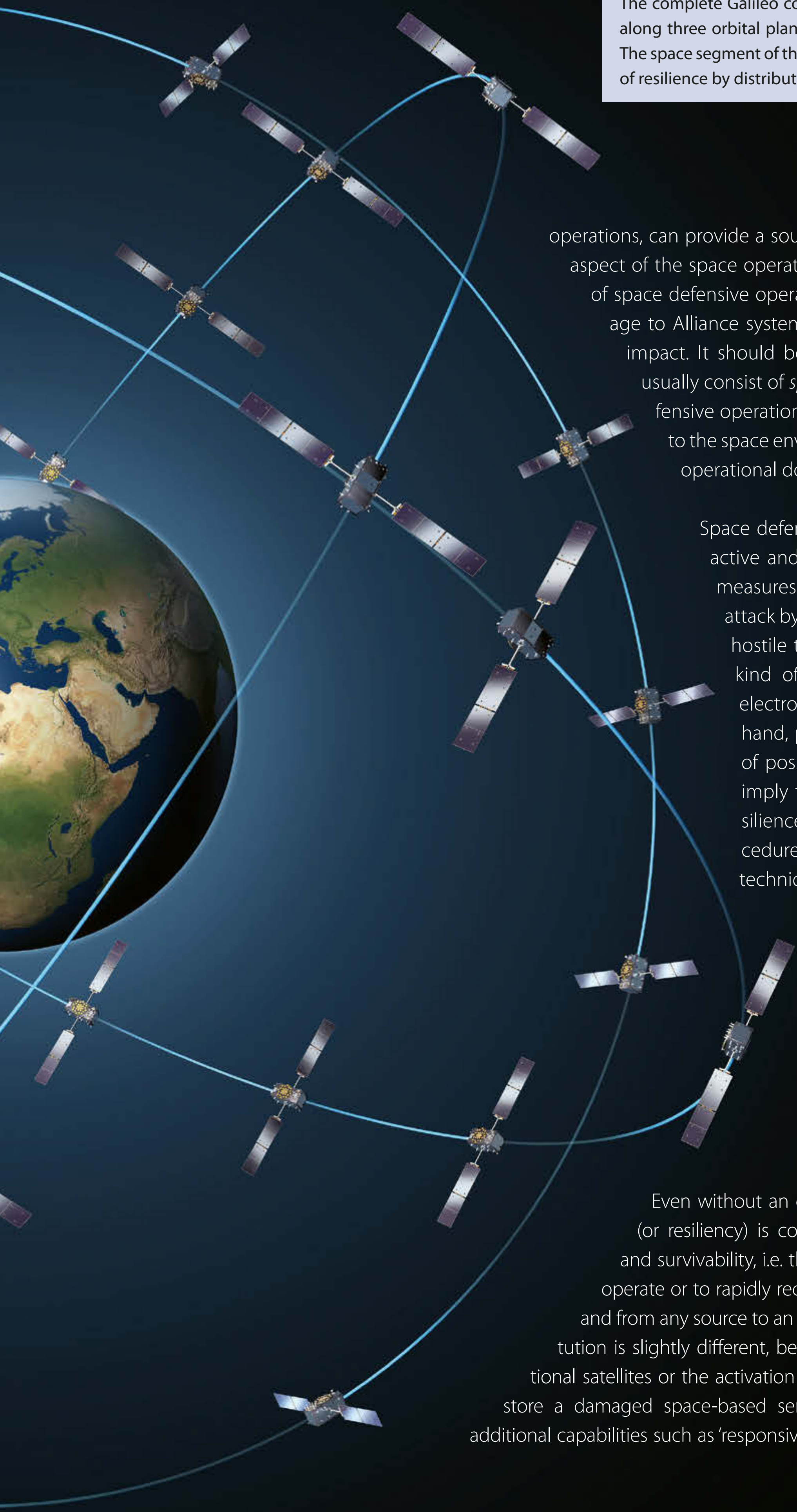
Resilience: Current Techniques

Once one accepts that space-based services are an indispensable but vulnerable military resource, and that they represent a high-profile military target for an opponent, the next question is how to pursue the desired level of mission assurance despite this constant threat.

The military answer is straightforward: defensive operations. However, since NATO has not yet recognized space as an operational domain nor released a space policy, NATO space doctrine remains, predictably, incomplete, and in particular regarding space defence. Nevertheless, the well-developed NATO doctrine for air and space operations, specifically for Defensive Counter-Air (DCA)



The complete Galileo constellation will consist of 24 satellites along three orbital planes, plus two spare satellites per orbit. The space segment of the Galileo system gives a good example of resilience by distribution and proliferation.

operations, can provide a source of inspiration for this particular aspect of the space operations doctrine.[3] Specifically, the aim of space defensive operations is to reduce the risk of damage to Alliance systems, both in terms of likelihood and impact. It should be noted that, since space systems usually consist of *space, ground* and *user segments,* defensive operations for space systems are not limited to the space environment, but can occur in multiple operational domains.

Space defence, as with air defence, comprises active and passive defence measures. Active measures aim at reducing the likelihood of an attack by destroying, nullifying or reducing a hostile threat. They imply the use of some kind of weapon, including kinetic, laser, electronic or even cyber. On the other hand, passive defence refers to a long list of possible countermeasures that do not imply the use of weapons. It includes resilience improvement, reconstitution procedures, and concealment and deception techniques.

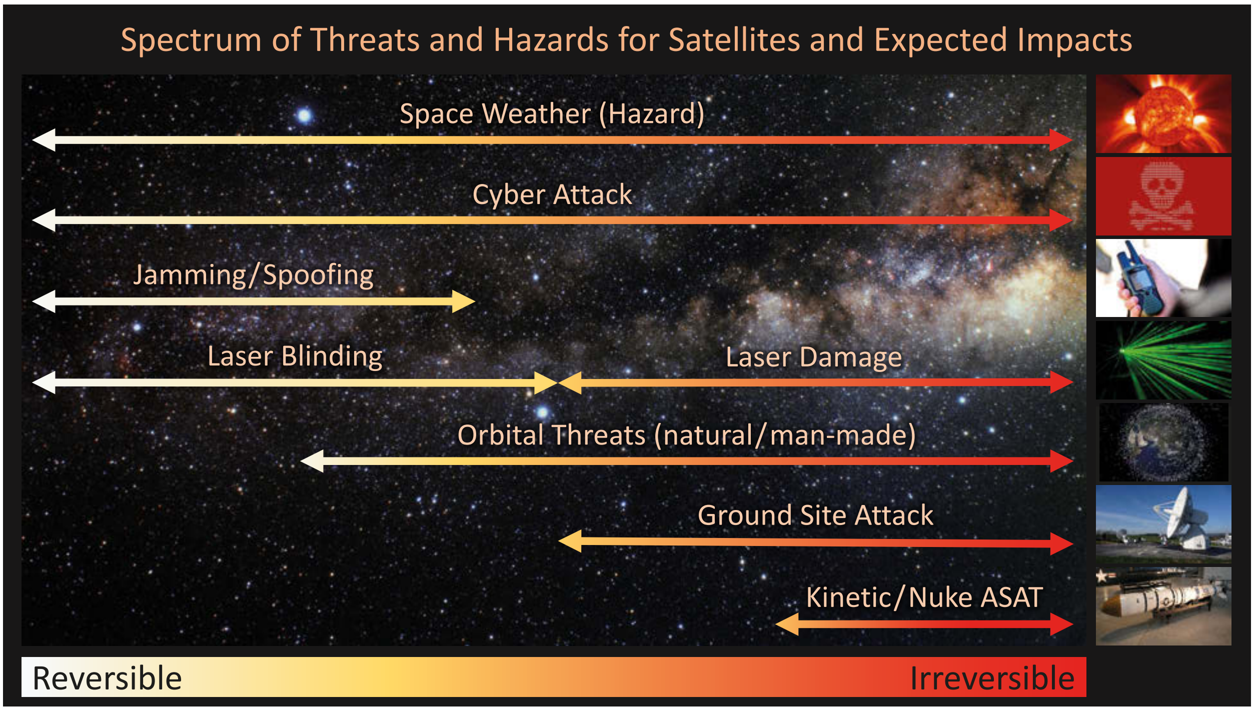
Even without an official definition in NATO, resilience (or resiliency) is commonly understood as robustness and survivability, i.e. the ability of a system to continue to operate or to rapidly recover after a disturbance of any kind and from any source to an acceptable level of service. Reconstitution is slightly different, because it implies the launch of additional satellites or the activation of additional ground stations to restore a damaged space-based service, and thus it requires specific additional capabilities such as 'responsive launch' (for more on this topic see the article 'Responsive Launch of ISR Satellites.'). In this sense, there is a sort of trade-off between resilience and reconstitution. For a given mission assurance requirement, the better your capability to promptly reconstitute a system, the less resilience you need. Concealment and deception methods, which include various techniques to hide assets and capabilities or to mislead the opponent, are outside the scope of this article.

Resilience can be achieved through several complementary approaches. The list below aims at identifying and defining the currently available options according to prevalent nomenclature. It is not the only possible set of definitions; it simply serves to illustrate specific concepts related to resilience to provide a sufficient conceptual framework for analysis.[4]

Disaggregation[5, 6] is the allocation of different missions, functions or sensors across separate subsystems, in space or on the ground (ground and user segment). In this way, targeting a single element of the system will only partially affect the capability. Additionally, its reconstitution will be faster and cheaper, since governments or industry can easily install lightweight subsystems as additional hosted payloads on larger satellites. In short, disaggregation improves deterrence because it increases the effort required of the attacker to bring down the whole system. Disaggregation also facilitates repair and upgrading because the system owner can intervene individually on component subsystems of a larger disaggregated system.

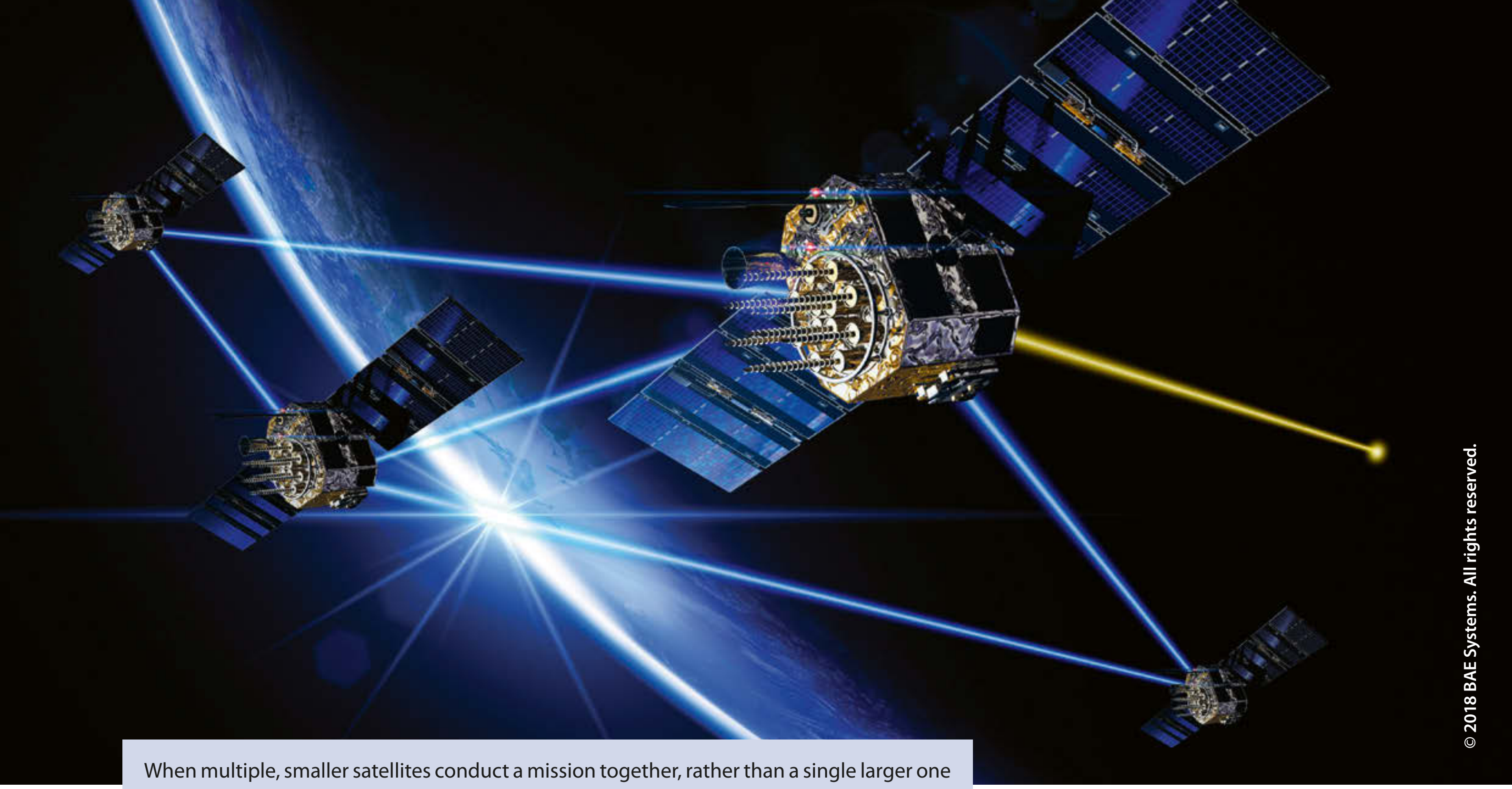
Distribution is similar to disaggregation but, in this case, the separate subsystems perform the same mission and collectively behave as a single system. The US Global Positioning System (GPS) is a good example of a distributed system. Attacking a single satellite only slightly decreases the overall system performance (graceful degradation) and all the original system functions remain available. Distributed systems improve deterrence by increasing the cost/benefit ratio for an aggressor: they represent an expanded target – thus harder to destroy – and they are relatively easy and fast to reconstitute.

Diversification is the ability to contribute to the same mission/function in multiple ways. Commercial, civil, or international partners can achieve it by using different



Since Space systems provide a tremendous military advantage to NATO, an opponent will probably attempt to disrupt, deny or degrade friendly forces' access to space capabilities. This diagram shows a list of the most common hazards/threats and the relevant severity.

[M] Right Column, 3rd Pic: © US Air Force, Tech. Sgt. Nicholas B. Ontiveros; 6th Pic: © ESA, C. Lezy; Any Other: © Copyrighted; Background: © NASA



When multiple, smaller satellites conduct a mission together, rather than a single larger one operating solo, odds of success are greatly increased.

platforms, orbits, systems, and/or capabilities. A good example of diversification is the possibility to obtain PNT services from different sources, such as GPS, Galileo, the GLobal Orbiting NAvigation Satellite System (GLONASS), etc. It is worth noting that diversification can also take advantage of alternative- or cross-domain solutions. High-Altitude Platform Systems (HAPS), for instance, can be deployed quickly in the case of sudden space system unavailability to substitute for or integrate into a space-based Global Navigation Satellite System (GNSS), or to contribute to long-range communications. Enhanced LOng RAnge Navigation (E-LORAN),[7] with its dedicated receiver, is another alternative-domain solution for navigation, while Inertial Measurement Units (IMUs) can provide independent positioning and navigation, even if their precision degrades in the long-term.[8] In short, diversification is focused on improving the resilience of a service rather than of a specific system.

Proliferation is the distribution of multiple units of the same system (or segment, or component) to provide technical redundancy to handle an event like a failure or an attack. Proliferation can be applied not only to satellites but also to components of the ground and user segment. In a nutshell, since any redundant element can individually ensure the required capability, it is harder for the opponent to tear the entire system down.

Protection embraces all passive measures that make the satellite system intrinsically more robust, such as physical or electromagnetic hardening. It also includes systems to protect the link segment from jamming and other forms of interference, as well as software techniques, like the encryption of the communication channel. Additionally, the availability of built-in capabilities for detecting and assessing possible attacks, as well as improved manoeuvrability to avoid them, can also be considered as protection-oriented features.

As stated, the above list provides a short overview of the possible approaches to a resilient design. Note that these measures are not mutually exclusive; on the contrary, the coupling of different approaches multiplies their effectiveness. For example, one can apply proliferation, diversification, and protection to a set of commercial and military systems to provide cost-effective, resilient satellite communications. It is also worth noting that some resilient approaches actually can facilitate the implementation of additional resilience measures. For instance, a disaggregated system easily can implement protection, diversification and/or proliferation measures, too, because it relies on simpler components that are easier to replicate or upgrade. In this regard, however, there is an essential constraint to keep in mind: in principle, the satellite owner may decide to implement some resilience measures, such as diversification and proliferation, at any time, but most of them can only be introduced during the initial design phase. For example, implementing disaggregation, distribution and protection after the launch is usually unviable – at least with respect to the satellite segment.

Resilience in the NATO Perspective

The 2016 'Warsaw Summit Communiqué'[9] and in particular the relevant 'Commitment to enhance resilience'[10] clearly attests that resilience is already a major concern for the Alliance. This means that NATO's space policy and strategy also should reflect this approach. Therefore, even if NATO is not expected to acquire its own satellite systems in the near future, it should exert its political influence to ensure that Alliance nations apply resilience concepts for the development of their space systems. On the strategic level, the approach should be slightly different. Since NATO is a space service/products consumer, its main concern is space resilience from a service perspective. Consequently, it should strongly foster the selection of resilient, redundant, and synergetic national space systems – commercial solutions included – to support NATO operations. The recent and long-awaited announcement[11] of an agreement on developing an overarching NATO Space Policy is a very promising first step in the right direction.

Conclusion

Today, space support to military operations is so essential that its assurance has become a critical factor of NATO deterrence. This means that resilience, which is already a central topic in NATO, needs to be addressed with respect to space-based capabilities, not only at national levels, but also by the Alliance as a whole. In this context, the simple abdication of a capability (the 'back to the basics' approach) should no longer be considered a valid 'plan B', but the last resort. In fact, it should be clear at this point, that failing to achieve the combined resilience of national assets could pose a substantial threat to NATO effectiveness. Henceforth, it is paramount to exploit any existing synergies between available national systems, both military and commercial, to improve the resilience of space capabilities provided to the Alliance. Moreover, NATO should bring nations together to consider space resilience as a fundamental design driver for future systems and foster the creation of new synergies, perhaps through the establishment of specific Standardization Agreements (STANAGs). ●

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Lieutenant Colonel Andrea Console

started his military career in 1995, joining the Italian Air Force Academy in Pozzuoli. During his career, he gained specific technical competence in multiple fields related to navigational aids and data transmission. From 2011 to 2015, he served in the Italian Defence Telecommunications Procurement Agency (TELEDIFE) in the Radar and Electro-Optic Space Systems for Earth Observation Section. Lieutenant Colonel Console holds a master's degree in Electronics Engineering and postgraduate II level University master's degree in Advanced Systems for Space Navigation and Communication. He is also officially recognized as a Projects in Controlled Environments (PRINCE2) Practitioner. Currently, he serves as a JAPCC Space Subject Matter Expert.

Launch campaign: In this contend the timeline for a launch campaign means the complete integration process of the SLV. This includes the full assembly of the launcher and the payload as well as the launch procedure. Currently a launch campaign lasts 25 to 180 days after the delivery of the full manufactured satellite.

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Responsive Launch of ISR Satellites

A Key Element of Space Resilience?

By Lieutenant Colonel Tim Vasen, DEU A, JAPCC

Introduction

NATO operations rely on Space Support provided by satellites, such as Satellite Communications (SatCom), Position, Navigation, and Timing (PNT), and Intelligence, Surveillance, and Reconnaissance (ISR), as a critical mission enabler. The services of ISR systems, in particular, have become more and more essential to NATO's decision-making and planning processes. However, NATO actually does not possess or operate Space systems; rather, it relies on services that member states provide. These same nations must protect their satellites, as well as the relevant infrastructure. Meanwhile, NATO's potential adversaries continue to develop and proliferate counter-Space technologies throughout the world. The process of protecting resources in Space includes enhancing both the data exchange mechanism and the level of redundancy in Space. The term 'resilience' defines the combination of enhanced data exchange and increased redundancy. Furthermore, resilience in Space includes the protection of the satellite itself, the maintenance of Space Domain Awareness (SDA), the protection of the related ground infrastructure, as well as timely restoration and sustainment.

There are two options to react to disabled satellites and their services in a timely manner. The first option is to provide on-orbit spares not used for ISR systems. (From the technical perspective, on-orbit spares gradually become obsolete at the same time as those satellites in use). The second option is to launch a new system to replace the disabled one. Keeping spares on the ground provides the option to keep the

GEO | Geostationary Earth Orbit. This orbit has an altitude of roughly 36.000 km above the equator. Satellites in these kind of orbit circle around the earth with the speed of the earth's rotation rate, what means that they could always be seen at the same position.

MEO | Medium Earth Orbit. Satellites in these orbits have usually an altitude between 15.000 and 25.000 km above the earth surface.

LEO | Low Earth Orbit. Satellites in these orbits have usually an altitude between 200 and 1.500 km above the earth surface.

Polar Orbit | A polar orbit is a special LEO that has an inclination of roughly 97° and covers nearly the whole earth surface.

Satellite Orbits.

systems technically refreshed. While Space-related services like SatCom or PNT normally require satellites in higher orbits, like Geostationary Earth Orbit (GEO) or Medium Earth Orbit (MEO), ISR systems are ordinarily used in Low Earth Orbit (LEO). ISR satellites in LEO usually circle the earth at an altitude between 250 and 800 km. This article focuses on responsive launch options for ISR satellites in LEO, systems for which the counter-space threat is greatest, and for which on-orbit spares are unavailable.

Current Situation and Limiting Factors

Modern ISR satellites are highly developed and very capable, but extremely expensive. The brief timeline between design and production does not permit incorporating all technical developments that are taking place in the meantime. The designed/calculated life expectancy of an ISR satellite is commonly five to ten years. To reach this milestone, satellite-providing nations choose orbit altitudes of 500 km and above as the most favourable. The drag of the Earth's atmosphere more negatively affects satellites at lower altitudes, and they would require a larger amount of fuel to sustain orbit altitude. The selected altitude determines the size limitations of the observation equipment, which is the major cost driver. On the one hand, decreasing the orbit altitude means reducing the satellite's lifetime due to the corresponding increase in weight of the additional fuel required. On the other hand, decreasing the orbit altitude enables either an increase to the maximum ground resolution or scaling down on the size/weight of the whole optical system. To reduce launch costs, the aim is to reduce the overall launch mass of the satellite itself, which also means also reducing the calculated lifetime. Satellites operate in a harsh environment. Completing radiation hardening of components and maintaining redundant sub-systems will help them reach their designed lifetime, but increase the production costs significantly. Smaller satellites, designed for shorter lifetimes, are less expensive, and provider nations can continually upgrade them with leading-edge technology, right up until they are launched.

Responsive Launch

Responsive Launch is characterized by the ability to launch a Space payload on short notice, and is defined as a function of the characteristics of the launch vehicle, the spacecraft, and the process.[1]

The idea of short notice, especially for military reasons or requirements, is to react quickly to developing situations. Process-wise, classical Space launch campaigns last from several weeks to even months, and conclude with the on-orbit checkout phase of the satellite, which satellite operators also must reduce significantly. The orbits where this capability gains the most advantages is LEO, and for the payload, ISR missions are the focus. A responsive launch capability requires already produced and preassembled Space Launch Vehicles (SLV), either produced or at least in assembly sets, and pre-produced satellites, all kept in stock and ready to deploy. If a critical satellite is disabled, either due to technical reasons or due to an opponent's counter-space activities, it provides a quick way to react to restore the mission.

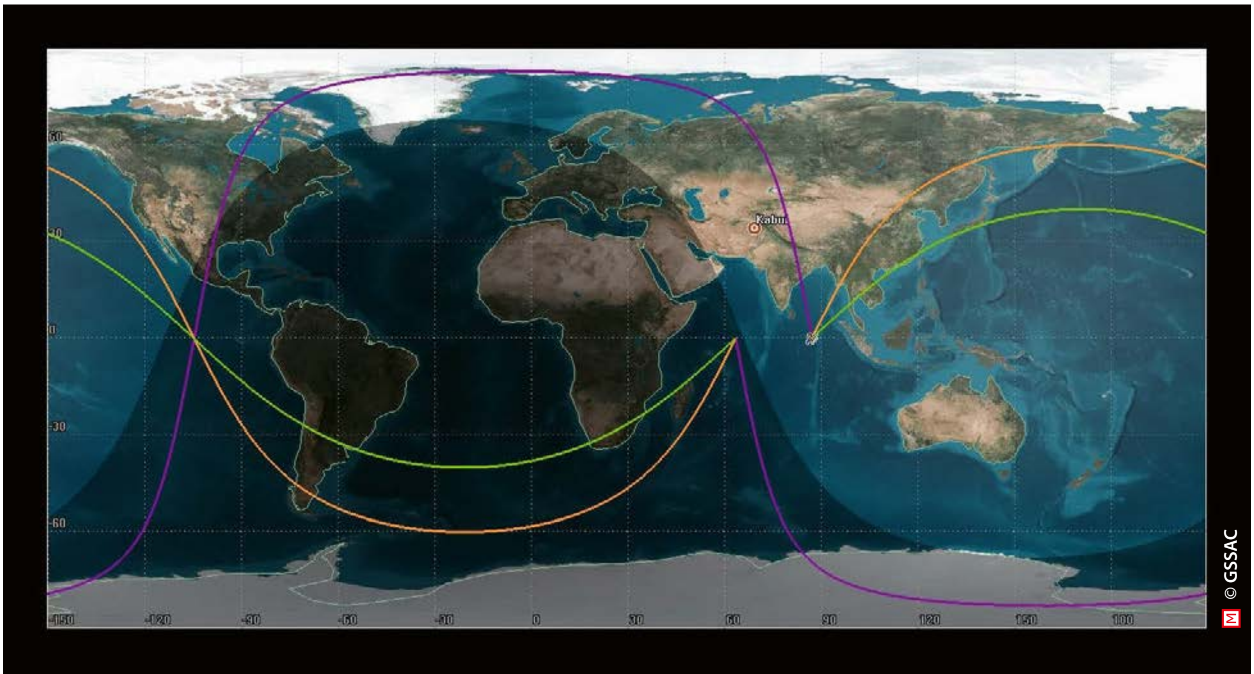
Operational Responsive Launch

In addition to adjusting orbits for the reasons cited above, nations could launch satellites to an optimized orbit to cover a special area of operations. This allows for the option to include the specific orbit design in the operational planning process. This approach is called 'operational responsive launch'. Operational responsive launches are determined by specific orbital parameters calculated for a specific mission. In particular, the most important factor is the inclination, i.e. the angle between the equatorial plane and the planned orbit of the satellite, because it defines the only latitude interval where a satellite can gather ISR data. An additional advantage is that the number of overflights in this area would be significantly higher. A satellite placed in a polar LEO orbit, for example, usually has 7 passes per week over Kabul, which is located 40° North (see picture 1). If the satellite is placed in an orbit of 60° inclination, the overflights will increase to 8, and if it uses a 40° inclination orbit, the overflight rate will rise to 19 passes per week. However, the use of low-inclination orbits might be limited due to the locations of the C2 ground infrastructure with which the satellite needs to communicate. Employing mobile solutions could be an alternative, but it would raise the system costs tremendously.

Requirements on Space Launch Vehicles (SLV)

The launch phase of a satellite is the most risky time-frame in spacecraft operations, but advances in technology have provided some benefits, including decreasing launch costs, that provide options worth a deeper look into the topic. The use of small satellites with a shorter lifetime in lower orbits will reduce the costs of the satellite itself. Since lighter payloads require smaller launchers, a new risk management approach can be employed. There may be a higher possibility to lose a satellite due to a launch failure, but it is more tolerable because of the decreased costs. This has opened the market for commercial launch services in recent years. From the military perspective, as well as a commercial perspective, the need for quick, responsive launches is universally acknowledged. From the technical perspective, small, solid-fuelled SLVs, based on Intercontinental Ballistic Missile (ICBM) technology, are the solution for ground-based systems. Additional options include air-launched solutions. Air-launched systems have fewer limitations (according to the designed inclination of

Figure 1: Ground tracks for a satellite in different orbits. Purple is a polar, yellow a 60° and green a 40° inclined orbit. The green one would be a specially designed orbit to support an operation in Afghanistan (Kabul is shown in the picture).



Ground-based Responsive Launch Capable SLVs
China, Russia as well as the USA have already these capabilities. India is currently developing a comparable capability.

Air Launched SLVs
Military wise only the USA have already developed this capability. There is currently a DARPA challenge in this topic ongoing. On the commercial site there are systems in development to be expected in the near future.

the orbit) than ground-based systems. These kinds of launchers permit the launch of a small satellite (by definition with a mass less than 500 kg) into LEO up to 500 km without the need for a long-term launch campaign. However, rapid availability of an SLV requires some form of standardized and pre-produced design. Pre-produced SLVs, in this case, include already assembled, storable, or modular systems that technicians can produce from components within a few days or weeks.

Requirements on ISR Satellites

As mentioned, nations do not use on-orbit spare satellites for ISR missions. Yet-to-be-launched, or 'ground-spare' satellites, offer several new opportunities. First of all, there is the option to launch just the right sensor type and capability to replace a specific space-based need that a commander has lost. Modular satellites provide this required capability[2]. This means that a company or nation has to pre-produce a functional satellite, but then take it into stock, disassembled in functional parts. In this case, the functional element of the satellite that has all components to allow it to operate in Space – the bus – can then be equipped with the required payload (electro-optical, Synthetic Aperture Radar (SAR) or Signals Intelligence (SIGINT)). Distinct subcomponents of the bus, specialized for the specific payload, also can be changed quickly. Another advantage is that 'ground-spare' satellites can be technically refreshed to keep them on the leading edge of technology.

Higher risk acceptance during both the launch and the operating phase offers a significant reduction in the costs. If the expected lifetime can be reduced due to operational means, one can use off-the-shelf components in the satellite. As mentioned before, radiation hardening, along with redundant functions, raise the costs for spacecraft. The combination of smaller spacecraft with shorter lifetimes offers the option to keep the capability of a deployed constellation in Space up-to-date, because nations can continuously regenerate it. Shorter lifetimes also allow the most recent technical refresh of the systems prior to a launch, especially regarding data transmission, data storage, and processor performance technologies, which means significant performance enhancement. For example, by current process standards, a highly developed satellite designed for a lifetime of 10 years can be up to two years behind the leading edge at the launch date, technologically speaking. Even if the 'quality' of highly developed and expensive systems is normally better, they lose their advantage during the time in Space, as technical developments are ongoing.

The storage of an already produced satellite or key components is a critical but solvable challenge. Nations that use off-the-shelf subcomponents could also lower storage requirements. In this case, training and education of satellite manufacturers must be kept on a certain level to facilitate quick, and generally standardized, assembly. To keep the satellite and the subcomponents in stock, nations and industry partners must sustain a continuous development and engineering process.

Conclusions

Highly developed ISR satellites, with maximum capability placed in polar orbits to allow permanent worldwide ISR collection, are currently – and will be for the future – a key element for decision-making. In a conflict where opponents have counter-space assets available that would allow permanent disabling of specific satellites, ISR satellites most likely would be the first target. This will become even more important as the development and proliferation of counter-space assets increases. To restore or reconstitute a degraded capability, as well as launch additional assets in specially designed orbits, small and rapidly ready-to-launch satellites will become more and more important.

Small, rapidly launched ISR satellites will never replace highly developed satellites, but they can take over their role in military operations or close gaps in coverage after technical failures or counter-space actions. To achieve this, provider nations require modular, pre-produced, or already fully manufactured satellites.

The integration of space-based ISR into military operations is increasing. People have already tested satellites that military forces can task on the battlefield. To provide a commander the maximum availability of ISR, the use of special orbits designed to focus on a certain area will become more and more important. To arrange this, small and flexible launchers must be available. To gain the maximum service restoration capability, air-launched SLVs will be vital. Additionally, military, technology-based, flexible, ground-based SLVs will be crucial for special orbits, even if the risk of the launch itself is higher due to shorter launch notifications, reduced assembly times, and storage challenges. In the case of a foreseeable launch to a specially designed orbit, small commercial SLVs could be part of the solution.

The overall design of larger constellations of smaller satellites is in an ongoing modernization and adjustment phase. Current and future launch systems will make this approach affordable from the perspective of the launch vehicle program. These modern approaches should provide a higher level of resilience in future military and commercial ISR architectures to meet the needs of NATO nations and commanders.

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- Orbit analysis as well as Figure 1 on p. 19 was made by the German Space Situation Awareness Centre (GSSAC).

Lieutenant Colonel Dipl.-Ing. Tim Vasen

began his military career in July 1994 as a conscript. After his officer training he served for several years in commanding and staff positions within the artillery branch, including a deployment to KFOR as company commander of the DEU ISTAR-company. After 2005, he took over positions as an intelligence officer, responsible for IMINT planning and technical assessments, including positions in the office of military studies as a senior analyst for Space systems. From 2013 to 2017 he was part of the German Space Situational Awareness Center (GSSAC) responsible for Space intelligence. Since October 2017 he has served in the role of a Space SME at the JAPCC.

Will the Aircraft Carrier Survive?

Future Air Threats to the Carrier (and How to Defend It)

By Commander Daniel Cochran, USA N, JAPCC

Introduction

Since the First World War, the importance of sea-based aviation has evolved, including the increasingly diverse mission sets aircraft carriers provide. Expert opinions on the future effectiveness of air power from the sea have also changed dramatically.[1] Decades ago, most experts in the field held the opinion that sea-based air power would be a critical piece of future conflicts, and that global powers should invest heavily in this core, military capability. More recently, many experts' opinions have changed, stating carriers will be kept from the battlespace due to the rapid increase in the capabilities of Anti-Access/Area Denial (A2/AD) integrated weapon systems.[2, 3]

Various state-sponsored and non-state actors, utilizing unconventional warfare tactics, pose a plausible threat to the force protection of any naval vessel. However, strategists consider China and Russia as the most likely potential adversaries to have peer capabilities, credibly able to threaten a Carrier Strike Group (CSG). While surface and subsurface systems also pose serious risks to the carrier, the lethality of air threats is growing at an exponential rate. This article will highlight the developments of air threats to aircraft carriers and how future countermeasures might ensure CSG survivability.

Why Own an Aircraft Carrier?

The aircraft carrier's diverse mission set has been used regularly in conflicts and crises throughout the world over the last 100 years. Diplomacy, power projection, quick crisis response force, land attack from the sea, sea base for helicopter and amphibious assault forces, Anti-Surface Warfare (ASUW), Defensive Counter Air (DCA), and Humanitarian Aid Disaster Relief (HADR) are just some of the missions the aircraft carrier can accomplish.

To help one imagine how a 'maritime runway' could accomplish such a diverse number of missions, the 70/80/90 rule-of-thumb is useful: water covers about 70 % of the earth's surface, approximately 80 % of the world's population lives near the ocean, and about 90 % of all trade travels by sea. When a crisis occurs on or near a body of water, the aircraft carrier is unique in the speed at which it can arrive, and its independence once on station. Timely responses to emerging conflicts or disasters, even when the arriving force is small in scale, can greatly affect cost and outcome. In many cases, an aircraft carrier is the quickest, most credible military force available.

Too Valuable to Lose?

One of the advantages a carrier has over a traditional airfield is that it can move. Its biggest disadvantage is that an adversary can sink it. With improvements in anti-ship systems worldwide, the probability of losing this capital ship may be increasing. Therefore, in the face of credible threats to an aircraft carrier, pundits often argue that the potential loss of such a high-value asset (as many as 5,500 personnel and 70 aircraft) would be so great that very few scenarios would justify the risk. If so, it begs the question, what are the major threats to the aircraft carrier and what can be done to protect it?

Air Threats to the Aircraft Carrier

Anti-Ship Missiles. Russia has immense anti-ship missile capability and boasts the widest inventory of ballistic and cruise missiles in the world[4]. One example is the SS-N-26 Anti-Ship Cruise Missile (ASCM), with a 300–450 km range. Russia incorporated it into the land-based K-300P Bastion-P system in 2015, and it contains an active radar and infrared imaging seeker for target determination in the terminal phase. Considering Russian sea-based missiles, the SS-N-27B 'Sizzler' is very capable, with a 300 km range and state-of-the-art terminal guidance. It is currently deployed on Russian nuclear submarines and ships, and in September 2017, a submerged submarine fired one into Syria[5]. The ASCMs that the Russians currently have fielded and employed from the land, sea, and air, are the most capable element of the air component of their defence systems, and pose a significant threat to CSGs.

China has the most active and diverse missile development program in the world[6]. China's current Medium Range Ballistic Missile (MRBM), the conventional DF-21D[7], entered service in 2006[8], and has a range of approximately 1500 km, as well as a manoeuvring warhead. In 2016, China announced it had successfully test-launched 10 DF-21Cs[9] as a show of military might in response to a potential shift in US policy towards Taiwan and the 'One China' stance. China's next anti-ship ballistic missile will likely be a variant of the DF-26 Intermediate Range Ballistic Missile (IRBM), with a reported range of 3,000–4,000 km, and a nuclear option[10]. In addition to surface and land-launched anti-ship missiles, aircraft will also be capable of launching ASCMs and Anti-Ship Ballistic Missiles (ASBMs)[11], enabling a launch point thousands of kilometres from China. Providing accurate coordinates for a moving target at that range is currently very difficult; however, with future 5th generation platforms and other Chinese targeting sensors, one can assume China will have very long-range, anti-ship capabilities.

Drone Swarms. In the near term, the potential exists that capable adversaries will possess drone swarms able to perform a variety of anti-carrier tactics. According to a detailed UAV study conducted by *Project 2049 Institute,* 'The U.S. Navy should have particular concern because, according to several military-technical materials reviewed for this study, People's Liberation Army operational thinkers and scientists envision attacking U.S. aircraft carrier battle groups with swarms of multi-mission UAVs in the event of conflict'[12]. These UAVs will be inexpensive and may be transported to the open sea through a variety of methods including submarines, surface ships, or from stealthy UAV 'mother-ships'. The swarm of UAVs would work in concert, attacking soft targets on the carrier such as personnel, aircraft on the flight deck, ship sensors, and exposed ordnance. A soft-kill of the carrier is also possible by UAVs simply maintaining airborne positions near the carrier, consequently causing a mid-air collision hazard. Additionally, they may attach to the ship and serve as communication relay links, providing ASBM targeting data. In essence, only one's imagination limits the potential

USS Ponce conducts an operational demonstration of the Laser Weapon System.

uses of UAVs. They may not sink the carrier, but they can create ways to degrade effective operations. Therefore, carrier defences must be able to eliminate and/or defend against them.

Allied Maritime Counter Air Systems

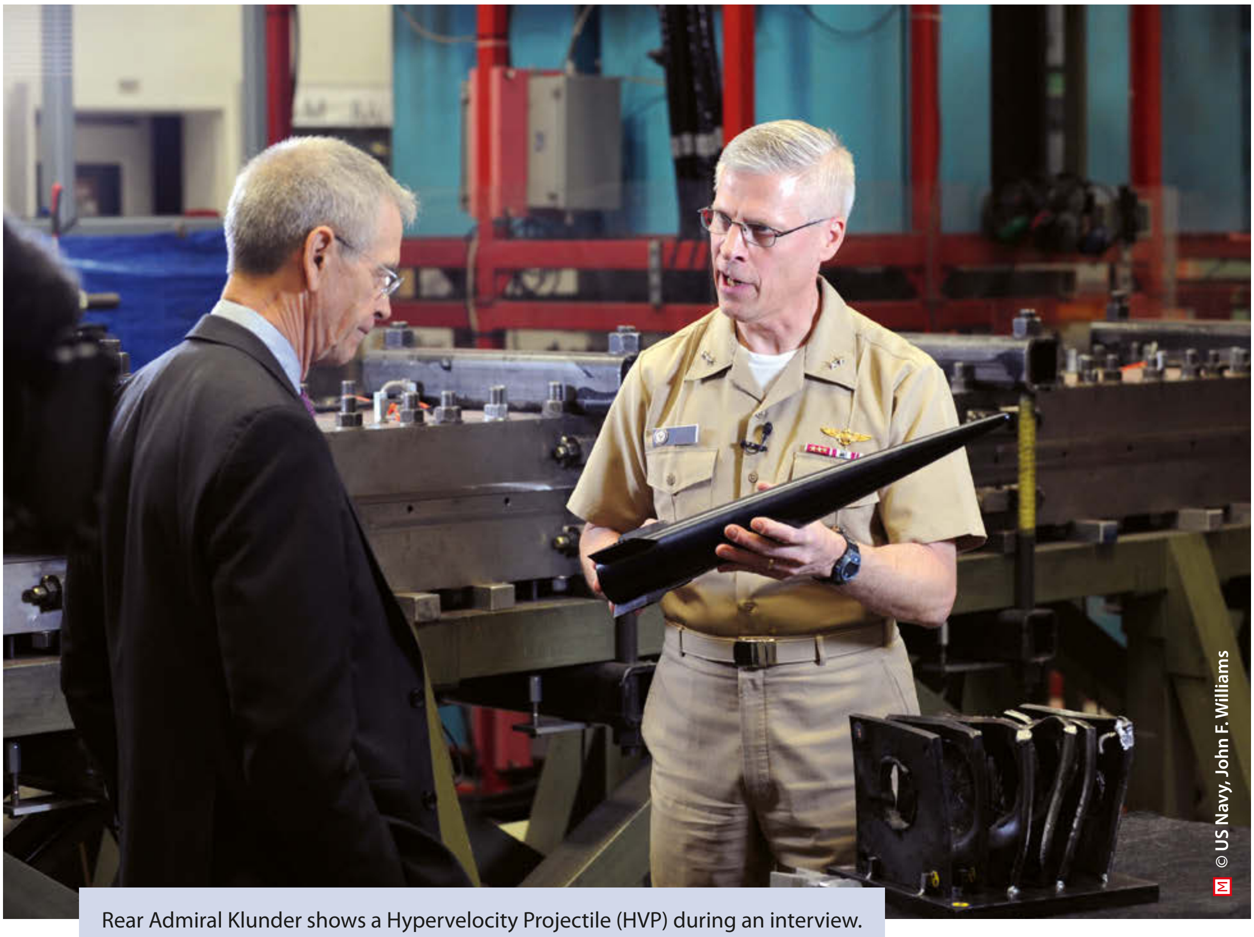
In light of air threat system improvements, several Allied nations are researching a wide range of future defensive capabilities.

Deployable Lasers. Shipboard lasers likely will be a significant component of ship defence in the near future. In February 2018, the US Navy awarded Lockheed Martin Aculight a $150 million contract to develop a deployable laser, called High Energy Laser and Integrated Optical-dazzler with Surveillance (HELIOS), for the Navy to integrate into resident systems on surface vessels. 'We've now reached the point in laser development [where] you can have effect on the adversary and the adversary's systems at an operationally important range', says Rear Admiral Druggan, Commander of the Naval Surface Warfare Center[13]. Engineers designed the HELIOS system to defeat UAVs and 'dazzle' incoming missiles and surface contacts, defeating their homing guidance. Lasers designed for hard-kills should be available within a decade, and will provide self-defence against ASCMs and ASBMs, including Manoeuvring Re-entry Vehicles (MaRVs)[14].

Even at today's power levels, the ability of the HELIOS system to defeat UAVs and dazzle incoming missiles will indirectly improve a CSG's missile defence by reducing the number of engagements that have to be met with the limited supply of standard missiles.

Electromagnetic Rail Gun and Hypervelocity Projectiles. In 2005, the US Navy began funding research for an Electromagnetic Rail Gun (EMRG)[15], a cannon able to launch hypervelocity projectiles (HVP) at speeds of 4,500 to 5,600 mph[16]. Although engineers originally developed the EMRG as a Naval Surface Fire Support (NSFS) weapon, it has promising potential for ship defence against ASCMs and ASBMs. Current prototypes have fired projectiles at energy levels of 20–32 megajoules, enough energy to launch projectiles 50–100 nm. The unguided projectile is designed to engage ASCMs and ASBMs once the missiles arrive in the vicinity of the ship. Due to technical issues, EMRG development has been slow, and some predict operational capability will not occur for a decade or more. With delays to the EMRG system, the US Navy is shifting its focus to employing HVPs from existing 5-inch and 155 mm powder guns[17]. When a powder gun fires the HVP, it only achieves a speed of approximately Mach 3, but that is still twice the speed of conventional 5-inch shells, and will greatly expand the anti-air engagement options against current and emerging threats, including ASCMs[18].

Surface-to-Air Missiles. Naval Integrated Fire Control-Counter Air[19] (NIFC-CA) is the newest sea-based Integrated Air and Missile Defence (IAMD) system employed by Allied forces. NIFC-CA is a networked IAMD system utilizing extended target detection and tracking from various sensors, including 5th generation platforms and the Aegis Weapon System. Furthermore, the SM-6 – the newest and most capable multi-purpose missile to date – is included in NIFC-CA, and it is an outstanding new contributor to IAMD at sea. In August 2017, a pair of SM-6 surface-to-air missiles destroyed a MRBM in the terminal phase. A very versatile



Rear Admiral Klunder shows a Hypervelocity Projectile (HVP) during an interview.

missile, the SM-6 has demonstrated an ability to target aircraft, cruise missiles, ships, and most recently, ballistic missiles.

The SM-3 also can defend the CSG from ASBMs. A dedicated ballistic missile interceptor, the SM-3 is designed to intercept ballistic missiles during the midcourse of their flight profile. The newest of this series of missiles, the SM-3 Block IIA Ballistic Missile Defence (BMD) interceptor, with an unclassified range of 2,500 km, receives target cueing from many sources, including satellites, and is capable of 'engage-on-remote'[20]. In addition to Aegis ships fielding the SM-3 Block IIA missiles, the US Navy plans to deploy these missiles to Aegis Ashore sites, including Redzikowo, Poland[21]. 'We will continue developing ballistic missile defense technologies to stay ahead of the threat as it evolves' said US Air Force Lieutenant General Sam Greaves, Director of the Missile Defense Agency (MDA)[22].

The Best Defence is a Good Offence

Another option to increase survivability is to create long-range offensive weapons, enabling the CSG to remain outside of the A2/AD environment[23]. Continued improvements in surface and maritime air-launched weapons, such as hypersonic missiles, are imperative to accomplish this. Air-launched *supersonic* missiles have an approximate range of up to 500 km, only marginally more than the S-400's current reported range of 400 km. Air-launched *hypersonic* missiles, however, could cover a range of approximately 1,000 km, keeping the launch platform outside the envelope of threat systems. Industry experts are on pace to attain operational readiness of air-launched, hypersonic cruise missiles within 20 years,[24] and these could be critical in disabling systems creating an A2/AD environment.

Long-range strikes carried out by stealth aircraft will also be paramount. Combining the F-35's long combat radius of over 600 nm[25] with carrier-launched unmanned air-to-air refuelling aircraft[26], the aircraft carrier would be able to perform long-range strike missions with a range up to 1,000 nm. Additionally, F-35s have the ability to obtain target locations of key


© US Navy

The Arleigh-Burke class guided-missile destroyer USS John Paul Jones (DDG 53) launches a Standard Missile 6 (SM-6) during a live-fire test of the ship's aegis weapons system.

An F/A-18E from Strike Fighter Squadron TWO SEVEN (VFA-27) conducts an arrested landing on board the USS RONALD REAGAN (CVN-76).

A2/AD nodes while operating inside threat envelopes, then pass them to systems operating outside threat envelopes[27] that can engage the targets.

Conclusion

The capabilities of the next generation CSG will be essential in the event of peer conflict. It will provide robust maritime air power and contribute to the IADS network through state-of-the-art airborne early warning[28], 5th and 4th+ generation fighters, and missile defence ships operating advanced versions of the Aegis Weapons System. While air threats to the CSG are becoming increasingly capable, if the Alliance invests in the right defensive (and offensive) capabilities, the CSG will survive against a peer adversary, and remain a viable, valuable asset in the Joint Force Commander's portfolio. ●

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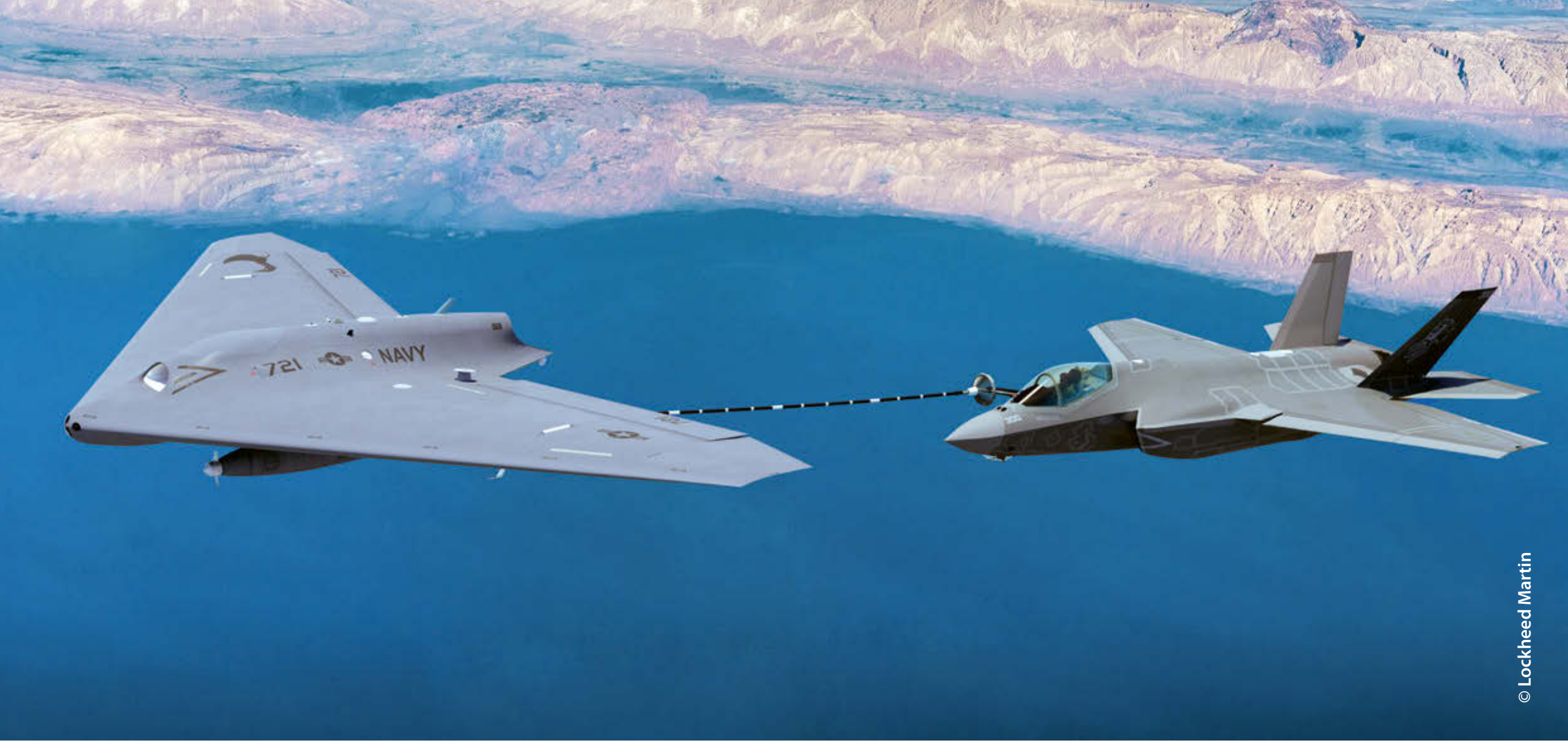
Commander Daniel D. Cochran

graduated in 1998 from Rensselaer Polytechnic Institute with a Bachelor's Degree in Materials Science and Engineering. He was designated a United States Naval Aviator in 2001. He is a distinguished graduate from the Air Force Institute of Technology earning a Master's of Science in Aeronautical Engineering. He also graduated from the United States Naval Test Pilot School and has served as an instructor there. Commander Cochran has completed three operational tours, including 14 aircraft carrier deployments while assigned to F/A-18E and F/A-18C squadrons. During his most recent tour, he had the privilege to command the 'Royal Maces' of VFA-27, attached to CVW-5, homeported in Atsugi, Japan. He has accumulated over 3,000 flight hours in over 30 aircraft, including 760 carrier-arrested landings. He is currently serving as the Maritime Air, Fixed Wing including Carrier Operations SME at the Joint Air Power Competence Centre.



Aerial Tanking in 2035

A Conceptual Look at Passing Gas

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

'In-flight refuelling converts the tactical fighter into a strategic, long-range participant.'
***Anthony Mason, Royal Air Force Air Vice Marshal*[1]**

Predicting the future is a tenuous endeavour at best, as there are simply too many variables to take into account. The best military strategists can hope for is to look to the past to help shape the future, without falling into the same traps, or letting past biases influence the outcome. One thing for sure is that the weapon systems NATO nations employ today are going to be in service for a long time, and this means Air-to-Air Refuelling (AAR) will be required, at least for the next few decades. Commanders must define the battlespace they expect to operate in, and define those threats and the physical environment aircrew will likely face. Operators, planners, and innovators must envision ways to use current systems to counter current and future threats in new, innovative ways, while simultaneously modifying and/or developing systems that enable effectiveness in the future.

The Future Landscape

The main question analysts attempt to answer is what the operating environment will look like. They want to know whether future battles will be fought in the mountains, deserts, jungles, or urban environments. They debate if future actors will still be mainly people, or primarily unmanned or possibly autonomous systems instead. Moreover, analysts want to understand the nature of future threats. Unlike other capabilities, the physical environment does not matter to the same extent for AAR. What matters more to AAR analysts is the level to which airspace within which future warfighters have to operate is contested.

The type and sophistication of threats to today's tanker aircraft will have more to say about how and where AAR operations take place in relation to where the receivers need to operate than the terrain below the tanker. In a permissive environment, i.e. one devoid of threats to the tanker either by airborne or ground-based systems, the tanker can come and go as it pleases. This type of environment places very few constraints on the layout of refuelling orbits and tracks, allowing the tanker to rendezvous with receivers directly over or very near their orbits areas. This extends the receiver's loiter time in its designated orbit area due to reduced transit times from the orbit area to the tanker, and back.

On the other end of the spectrum lies a completely denied environment, i.e. one characterized by a multilayered defence structure consisting of advanced fighter aircraft, long-range strategic Surface-to-Air Missile (SAM) systems, and overlapping medium-range SAM systems covering short-range point defence SAM systems. Assuming these systems force the basing of friendly aircraft a long distance from orbit areas or targets, planners must include AAR in the daily plan in order to extend the range and endurance of fighter, bomber, Intelligence, Surveillance, and Reconnaissance (ISR), Airborne Early Warning (AEW), and even some transport aircraft. This, coupled with the understanding that battles fought in 2035 and beyond will employ a large number of assets that have been in the inventory for several decades, a denied environment presents significant barriers to friendly success without a shift in operational paradigms. Most legacy tanker aircraft lack self-protection suites, and are anything but stealthy, meaning the denied environment almost completely excludes tanker operations close to the orbit areas of their receivers. Unfortunately, orbiting a tanker farther from the receiver's orbit area produces two main issues. First, it means the receiver has a greater distance to travel between the tanker and orbit area, resulting in a greater need for transit fuel. Second, each additional minute spent transiting between the tanker and the orbit area is a minute the receiver is not on-station conducting its primary mission objective. This could lead to coverage gaps resulting in additional risk to mission accomplishment that must be accounted for or additional assets must be used to ensure adequate coverage. The employment of additional assets, depending on type and capabilities, could result in driving the overall tanker offload fuel requirements up. As such, military strategists must find a way to balance the success of receivers with the viability and survivability of the tanker.

Strategists also should consider that adversaries are not the only ones posing challenges to mission success. One main challenge that is not adversary-driven is limited interoperability in terms of equipment on friendly fleets. Generally, there are only two in-flight refuelling systems – boom/receptacle and probe/drogue. These two systems are not interchangeable, meaning receptacle-equipped aircraft can only refuel from a boom, while those equipped with a probe can only refuel from a drogue. Unfortunately, most tankers are equipped with only one of the two systems,

not both. Some boom-equipped aircraft can add an adapter converting the boom into a drogue, but this must be completed on the ground and cannot be changed in flight. This equipment challenge means that commanders must ensure that planners are keeping a close eye not only on the total available fuel aloft, but also on the availability of systems needed to deliver that fuel.

Solutions

As has been done for generations, one can expect strategists, analysts, aircraft manufacturers, and decision-makers to integrate a small number of completely new airframes while modifying legacy airframes with new technology. Simultaneously, personnel will adapt tactics, techniques, and procedures (TTPs) to bridge the gap between old assets and new requirements. Some of these new assets that aircraft manufacturers are producing, currently or in the very new future, include multi-mission tankers and autonomous tankers and receivers, while updates to TTPs include multinational tanker formation operations.

Multi-Mission not Multi-Role. A large tanker aircraft has the capacity to perform more than just the tanker mission. With an understanding of the performance trade-offs inherent in aviation, one must take care when considering what additional capabilities a tanker could accomplish. Airbus has been developing a 'Smart Tanker', which could leverage the refueller's long on-station time for Command and Control (C2) purposes.[2] Other mission sets requiring long on-station times include communication relays and passive electronic information collection. The Airbus 'Smart Tanker' could be the first of several new multi-mission technologies.

Autonomy. Airbus is also very advanced in the development of its automated boom. Currently fitted on the Airbus A-310 aircraft, it is completely contained on the tanker and requires no modification to a receiver aircraft[3]. Utilizing this aircraft, Airbus conducted the first air-to-air refuelling contact with a large aircraft receiver, a Royal Australian Air Force KC-30A[4]. By automating the tanker's ability to recognize a receiver (even in covert conditions) and drive the boom to a receptacle provides several benefits: reduced workload on the tanker crew, system availability to all receptacle receivers requiring no receiver modification, and the potential for reduced stress on both boom and receptacle systems, thereby reducing maintenance requirements on both aircraft.

Automating the boom is good, but a fully autonomous tanker would be even better. By eliminating the space and weight needed for crew components like pressurization, oxygen, windows, or even seats, and trading these for manoeuvrability or even stealth,

© Courtesy of the Italian Army


© Airbus

Airbus Defence and Space AAR boom performing automated contact with Australian KC-30A aircraft.

an autonomous tanker could conceivably accompany a receiver into the vulnerability area. Test programs are already underway with unmanned tanker systems, such as the United States Navy's carrier-based MQ-25 Stingray.[5]

Currently, the US Navy sometimes relies on its F/A-18 E/F Super Hornet as a small 'buddy' tanker asset. If the MQ-25 is realized, Super Hornets would be free to perform their designed mission rather than acting as ad hoc tankers. Current MQ-25 requirements are only to off-load fuel[6] while conceivably accompanying a strike package to a target, but the ability for the drone tanker to receive fuel, in addition to off-loading fuel, could extend loiter time and flexibility.

Northrop Grumman provided proof of this concept – i.e. a drone receiver – during a successful 2015 trial, when its unmanned X-47B Unmanned Combat Air System (UCAS) rendezvoused with an airborne tanker, conducted AAR operations, then departed and landed safely.[7] Combining the requirements of the MQ-25 and the capabilities of the X-47B into a single unmanned aircraft could provide more airborne fuel than a non-refuellable drone, thereby extending a strike package's threat engagement time or extending the endurance of aircraft performing numerous other missions in orbit areas for long periods of time, including AEW, ISR, on-call Close Air Support (CAS), Suppression of Enemy Air Defences (SEAD), etc.

More Gas – Less Space. In order to increase the total number of pounds available for off-load, general understanding is that either the number of tankers aloft or the size of the tankers must increase. However, even if all tankers were dual-equipped – i.e. both boom and drogue – it is unlikely that only one tanker could carry enough fuel for an entire day's requirements. Similarly, when many receivers require fuel simultaneously, more than one tanker is necessary. Current tanker planning assigns a single tanker to an orbit with four fighter-sized receivers. Fuel-flow constraints of smaller receivers limit the amount of fuel that can be passed per minute, resulting in longer times on the boom or drogue, and leading to increased time to fuel all receivers of a formation. This increased time results in some receivers in a formation departing the tanker less than full. One possible solution to this dilemma is the concept of hose-multipliers. Pairing two unmanned tankers with a larger tanker can double the amount of receivers able to refuel at a single time. However, the solution of placing more tankers in the sky becomes problematic as the size of airspace decreases. One possible solution is to shrink the space needed by creating tanker formations. Currently, very few nations use tanker formations, but those that do see their value, and are leading developments in international TTPs for such operations.

The need for more fuel in less airspace, combined with fiscal constraints and the reality that most nations do not operate large tanker fleets, means multinational tanker formations could very well characterize future operations. Furthermore, this concept could have the added benefit of increasing the diversity of airborne equipment, enabling any type of receiver the opportunity to refuel from any tanker formation. Exploiting past lessons identified, operators need to develop, evaluate, and disseminate a set of procedures prior to conflict so aircrews are familiar with them, and they are not attempting to create procedures from scratch under the pressures of combat. One nation with a large tanker fleet that operates formations regularly is the United States (US). In conjunction with the United States Air Forces Europe (USAFE) Tanker Weapons School and the Royal Air Force (RAF) Voyager Squadron, the US Air Force's (USAF) 100th Air Refuelling Wing based at RAF Mildenhall, United Kingdom, is developing international mixed formation procedures using a crawl-walk-run approach. They have already conducted proof of concept flights between USAF KC-135 and RAF Voyager A-330 aircraft. These flights are being conducted to test the TTPs and make incremental changes with aircraft from two nations before widening the scope to include additional tanker types and nations.

Conclusion

The battlespace of 2035 may seem ethereal, but using observations of the past, strategists can make educated guesses about future realties. Due to fiscal constraints, changing threat environments, and the rapidity of changing technology, legacy aircraft will operate simultaneously with newer technologies. This 'new normal' will drive solution sets through multinational efforts to develop new TTPs, drive adaptation of legacy aircraft, and shift paradigms. What is clear today, is that no matter what tomorrow looks like, until engineers develop new propulsion systems that provide airframes with longer endurance and/or range, the need for passing gas from one aircraft to another will remain. ●

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Lieutenant Colonel Edwin Markie, Jr. (USA AF)

is an Air-to-Air Refuelling (AAR) and Air Transport (AT) Subject Matter Expert (SME) assigned to NATO's Joint Air Power Competence Centre in Kalkar, Germany. Prior to arriving at the JAPCC, he was Commander of the 321st Air Mobility Operations Squadron providing theatre-level command and control (C2). Lieutenant Colonel Markie brings more than 20 years of experience in air transport and air-to-air refuelling operations, instruction, and staff operations. Lieutenant Colonel Markie is the Chairman of NATO's Air Refuelling Working Group and member of the Global Air-to-Air Refuelling Strategy (GAS) Team. He has also contributed to air transport studies, initiatives, and training courses. Lieutenant Colonel Markie earned his B.S. in Electrical Engineering from Embry-Riddle Aeronautical University and his M.S. in Aeronautical Science at Embry-Riddle Aeronautical University.


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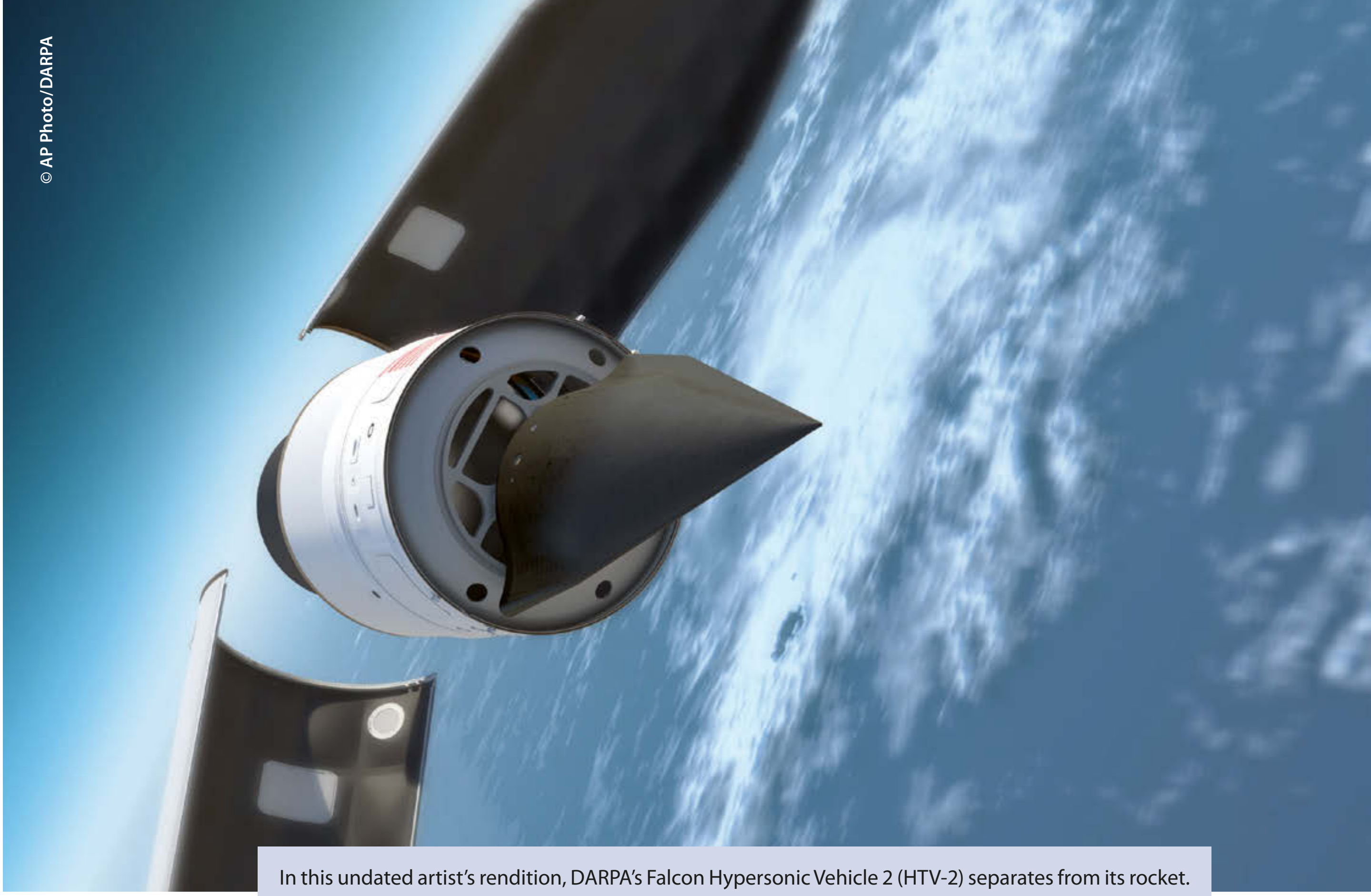

In this undated artist's rendition, DARPA's Falcon Hypersonic Vehicle 2 (HTV-2) separates from its rocket. The HTV-2 can glide through Earth's atmosphere at Mach 20.

Challenges of Future SEAD Operations

An Insight into SEAD in 20 Years

By Colonel Joseph Speed, USA AF, JAPCC

By Lieutenant Colonel Panagiotis Stathopoulos, GRC AF, JAPCC

Fight for Control of the Skies

The advent of balloons in 1783, and their military employment during the American Civil War (1861–1865) and the Franco-Prussian War (1870–1871),[1] highlighted the significance of controlling the skies over a battlefield, and compelled military forces to develop anti-air platform warfare or, in other words, an 'Air Defence' (AD) mission. After more than 200 years, the predominant pursuit of AD remains the same; that is, to detect hostile aircraft and deny their freedom of manoeuvre. In contrast with the past, AD is now an integrated element of joint air power, and it is a key component in certain state actors' overall Anti-Access/Area Denial (A2/AD) strategy.[2, 3]

In order to allow friendly aircraft to conduct missions and support joint air power operations across the spectrum of warfare – from peacekeeping to high-intensity conflicts – NATO has nurtured developments in the Suppression of Enemy Air Defence (SEAD) mission. However, the newest generation of complex and capable enemy air defence assets threatens to overwhelm NATO's current SEAD abilities.

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An F-22 Raptor being refuelled over an undisclosed area before strike operations in Syria. 5th gen. air platforms were employed over Syrian battlefields and operated in, or on the edge of, densely populated cities.

Additionally, unlike the front lines of the past 25 years, increasing odds of urbanized conflicts will likely influence the future battlefield environment. The constant increase in enemy AD capabilities and battlefield complexity begs the question: what are some things NATO can do to prepare for emerging SEAD challenges up to, and beyond, the next twenty years?

Urbanized Conflicts

The effects of globalization, technology advancements, scarcity of resources and climate change, the control and access of the physical global commons,[4] and sovereign territory pursuits on land are some of the catalysts which may shape the future physical environment.[5] In addition, cultural, religious, and nationalistic ideologies are more likely to influence the world than geography.[6] All of these factors could provoke increased global redistribution of populations and migration out of rural areas into cities, particularly in the developing world.

Indeed, the global population is expected to increase throughout the foreseeable future,[7] with almost all of this growth occurring in the developing world, and largely centred in urban areas. By 2035, urbanization will likely mean that approximately 60 % of the global population will live in cities,[8] usually near oceans. Beyond 2035, distribution among low-income populations and oligarchs may create a polarized society, where the global demand and supply of basic human needs – such as water and food – could drive conflicts in 30 years' time.[9] Meanwhile, the geopolitical power of the world is apparently shifting from a unipolar to a multipolar paradigm, again towards the south and east of the Alliance, increasing the probability of conflicts and world instability.[10]

Consequently, NATO forces may be tasked for joint operations in an urbanized geographical area, where conflicts may encompass a variety of missions, from stabilization or humanitarian operations through high-intensity, open combat. For example, the current environment of the Syrian conflict may be an omen of future conditions of the battlefield. That is, an environment in which military forces combat an array of

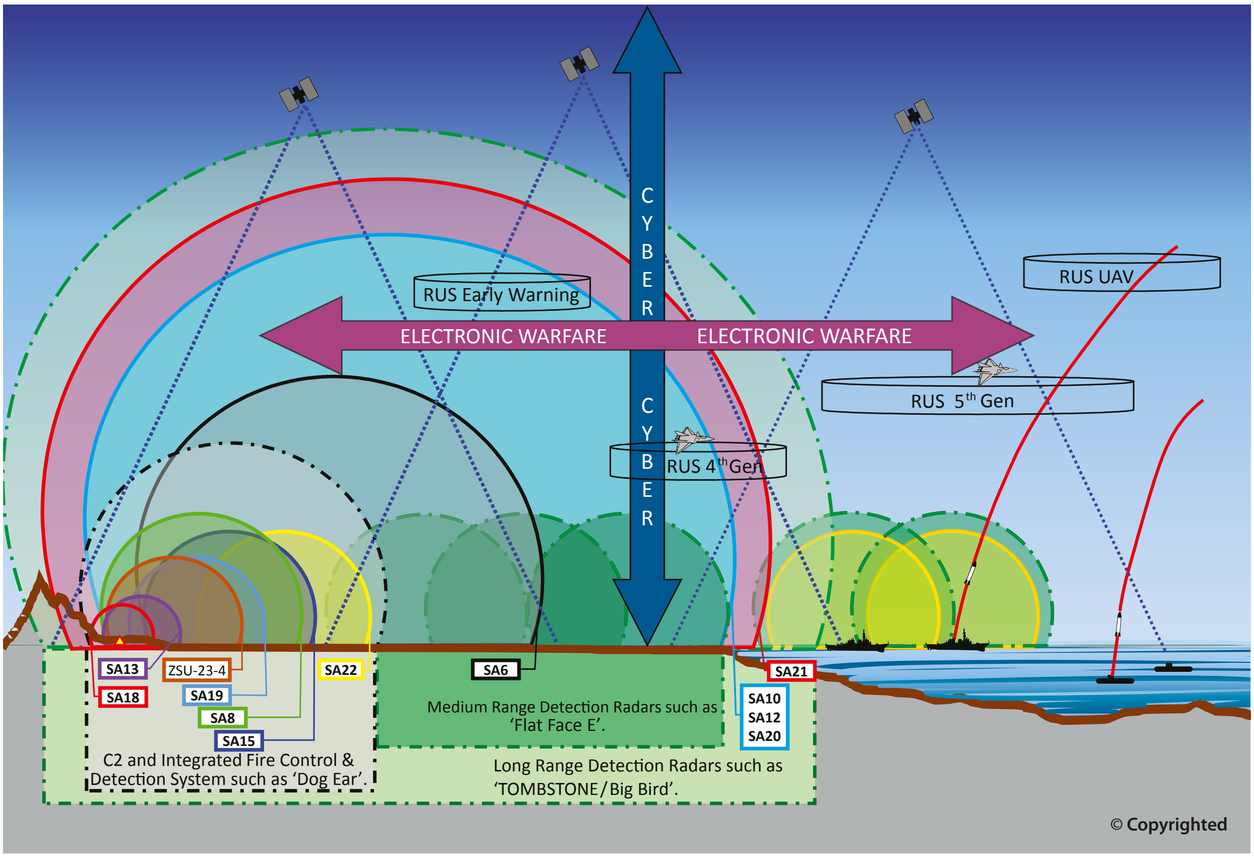

Figure 1: A typical example of detection layers of a Russian Air Defence Area.

violent state and non-state actors, and operate in, or on the edge of, densely populated cities, or even 'megacities'. ('Megacities' are defined as urban areas that blend into one another and have more than 10 million inhabitants.[11]) In fact, Syria's operating environment has exposed some of the difficulties that military forces have conducting various missions, including intelligence, surveillance, target acquisition and reconnaissance (ISTAR), in crowded urban environments.

Because future confrontations will likely take place in an urbanized environment rather than a traditional battlefield, complexity, congestion, degradation, deception, and confusion will likely characterize the future operating environment.

'Threat' Environment is Challenging

Over the last 20 years, potential adversaries of the Alliance have studied western military capabilities and have developed robust A2/AD capabilities in response. Examples are abundant, and include threats such as the Russian SA-20 'Gargoyle' and SA-21 'Growler', the Chinese – built HQ-9, and the Dong-Feng 21. These capabilities are tailored to deny the 'western way of war' by precluding access to what is arguably the west's most potent influencer – air power.

Additionally, many state and non-state actors have been creatively employing military and commercial technologies to develop a range of capabilities for symmetric, asymmetric, and hybrid military activities, including AD. The technological trends include the following: anti-stealth technology, hypersonic weapons, cyber warfare, and access to and/or denial of space capabilities, to name a few. For example, Russian long-range surface to air systems now employ radar with anti-stealth technologies such as the 'NNIIRT 1L119 Nebo SVU/RLM-M Nebo M' mobile VHF active electronically scanned array (AESA) radar. In the realm of hypersonic, the Russians have an air-launched missile, the 'Dagger', which can reach and maintain Mach 10. In addition, China is developing anti-satellite capabilities such as the 'Dong Neng 2 & 3' exo-atmospheric vehicles. Primarily, these are direct-ascent missiles designed to ram and destroy satellites.

Also, advances in computing power and digital signal processing are allowing for more capable AD radars. These systems employ advanced techniques to improve acquisition range and target size detection, and possess increased resistance to electronic attack or deception. In addition, new ideas in electromagnetic spectrum management are allowing radar technology to become more passive than active, which significantly complicates locating and targeting such sites. For instance, Russia is developing passive coherent radar designed for stealthy detection of moving aerial, ground and above-water targets in the protected area of important facilities. While passive radar systems are already being employed in both ground and air platforms, they are normally used to locate platforms vice engage them. That being said, passive radars will likely be able to target and guide weapons against air threats soon, significantly complicating the SEAD mission.

Adversaries' legacy systems of hierarchical data management and links are being replaced with multi-node, high-capacity, efficacy networks, contributing to highly resilient, redundant, and robust Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems. The resiliency of future C4ISR may be augmented by space-based technologies – such as micro-satellite constellations – making an Integrated Air Defence System (IADS) even more effective and agile. In addition, it is quite possible that a nodular system might enable air defence systems to continue to support operations through 'remote' operations, even if some parts of the IADS are damaged or destroyed. A current example of this is Russia's experimentation with multi-node quantum networks. In effect, suppressing or destroying local air defence assets, which are linked into a multi-node network, may not provide effective suppression of the enemy IADS.

'Remoting' operations and unmanned technologies may not only increase the survivability of an IADS, but they will likely extend its detection and targeting capabilities by hundreds of miles. For example, the advancements in space technology may extend the 'remoting' capabilities of an IADS to altitudes extending into space. The combination of the aforementioned activities may increase the passiveness of an IADS, deny its detection and targeting, and make it resilient to most SEAD activities.

Lastly, over the next twenty years very long-range surface-to-air weapons, with advanced seeker guidance, smart warheads, and new propulsion technologies, may be employed in enemy AD missions. In particular, Surface-to-Air Missile (SAM) engagement zones may be extended up to 500 km. One need look no further than the Russian S-500 next-generation SAM system to see the lethality of future AD. Disturbingly, this particular missile system could enter service as early as 2020. These new long-range weapons' technologies may contribute to a highly mobile, flexible IADS when combined with increases in computing power and decreasing size of hardware and processors.

In total, the unfortunate paradigm for the Alliance is that while threat systems are becoming more passive (i.e. harder to find and target) they are simultaneously growing in lethality and range. As a consequence, current Alliance suppression capabilities could be rendered ineffective. At first sight, this doesn't bode well for NATO SEAD of the future. So, what can be done to mitigate this threat?

Suppressing IADS in the Future

During the 2016 NATO-Warsaw Summit, the Heads of State and Government (HOS/G) confirmed the necessity of developing and deploying more effective SEAD capabilities, and acknowledged its increased need due to the evolving A2/AD threat. Even though Alliance leaders traditionally have considered SEAD to be a 'kinetic' air power activity, looking ahead it is quite likely that technological advancements will allow for a greater range of options.

As described, the Alliance expects future IADS to be complex, largely passive, and low observable, yet likely nestled in/throughout urban areas. Therefore, in addition to 'traditional' methods of SEAD, planners should consider new weapons and methods, both lethal and non-lethal, to suppress air defences of the future. NATO SEAD forces should consider integrating solutions that include the following:

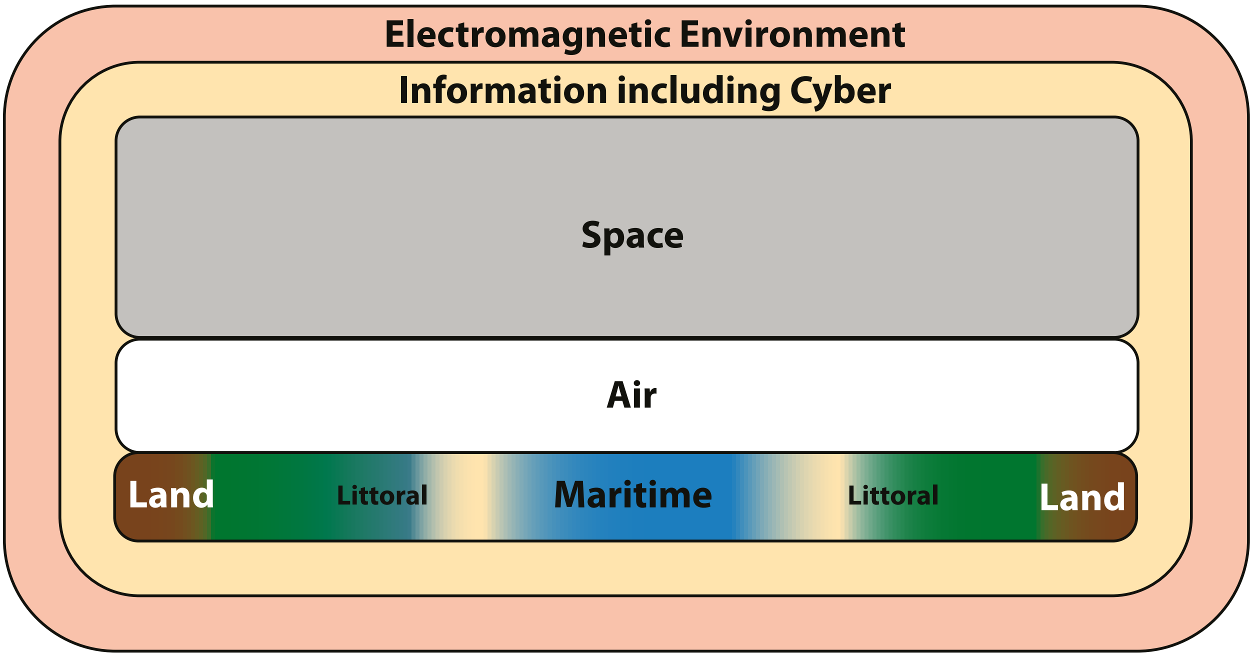

Figure 2: The integration of EMS with every operating domain will ensure increased interoperability and effectiveness of IADS suppression.

High Precision Hypersonic and Hypervelocity Weapons – Due to the high mobility and extreme speeds of modern SAMs, the 'windows' to engage them and their enablers have grown increasingly small over the past years, necessitating an exponential improvement in reaction time from SEAD forces. Therefore, nations and industry should develop weapons used in support of SEAD missions, such as Anti-Radiation Missiles (ARMs), that include specifications for high agility, high energy and high terminal manoeuvrability in order to reach adversary SAM systems before the 'window' closes.

Electromagnetic Spectrum (EMS) Energy Footprint Effects Management – The low observability and passiveness of threat systems will likely increase the volume of targeting uncertainty, so it may become problematic to target specific IADS components. However, it may be possible to control area coverage of an electromagnetic spectrum. Non-lethal weapons, such as a tailored Directed Energy (DE) or Electromagnetic Pulse (EMP) weapon, could effectively suppress low observable and passive air defence systems. For instance, precise control in the effects of an EMP weapon may suppress various IADS components over many square miles, which may deny its collective targeting of friendly forces.

Integration of EMS – Particularly in urban environments, there is a great need to integrate Alliance EMS efforts, especially if employing non-lethal effects in the future battlefield. Thus, electromagnetic spectrum activities should be coordinated and employed from both physical (land, air, maritime/littoral, and space) and non-physical (information, cyber, and electromagnetic) operating domains. To put it simply, if electromagnetic spectrum activities are integrated with every operating domain, it will ensure increased interoperability and effectiveness of IADS suppression.

Resilient & Redundant ISR Operations – In the future, unmanned technologies will increasingly provide passively collected, reliable ISR information in support of IADS suppression. Technology is already allowing linking of unmanned platforms with artificial intelligence and robotics. Biomimetic flocks of 'birds', schools of 'fish', and herds of 'rabbits' – which may behave as natural ISR swarms – consequently increase the probability of detecting low observable and passive enemy IADS elements. Add to this robust – and growing – constellations of satellites (CONoSAT) orbits around the earth in support of surveillance and reconnaissance activities, and the resultant coverage may leave little unable to be detected or targeted on the earth's surface, in the air, and in space.

Summary

The characteristics of the future battle will necessitate SEAD advancements in multiple, non-traditional domains, such as electromagnetic, space, and cyber, rather than just traditional ones. Nevertheless, 'kinetic' SEAD power will still be required, albeit with much improved capabilities, especially in regards to range and speed.

In much the same way that air defence systems have evolved to deny access to one of NATO's greatest strengths, the Alliance's SEAD capabilities must also evolve at the 'speed and flexibility of technology' if we hope to maintain the advantage that NATO air power brings to the fight. In a high-intensity, urbanized conflict, which may well be the worst-case scenario for any SEAD operation, the ability to combine lethal, non-lethal, and/or cognitive effects[12] might be the saving grace that ultimately enables success. ●

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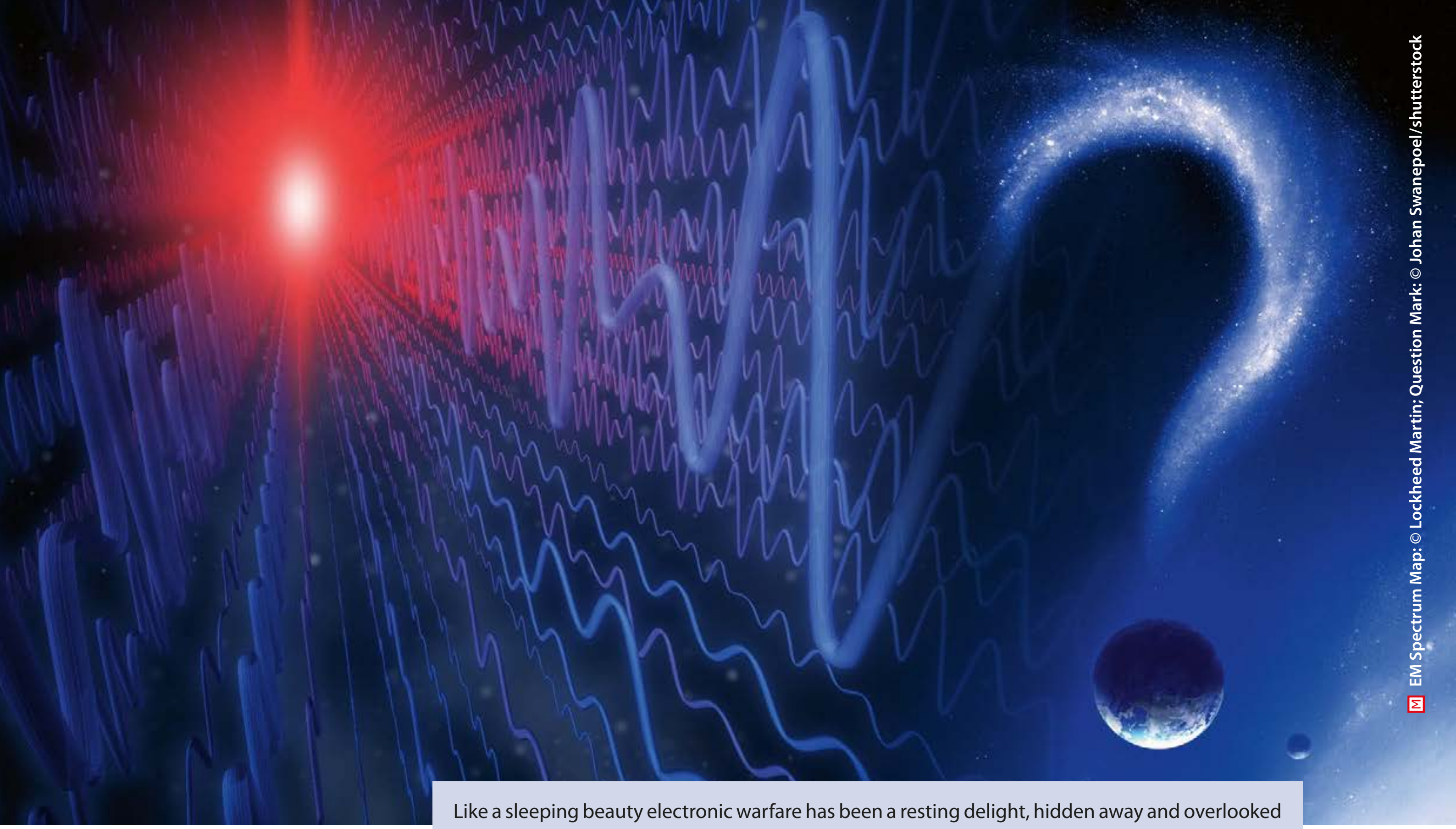
12. The effects of cognitive dimension, which encompasses the minds of those who transmit, receive, and respond to or act on information. It refers to individuals' or groups' information processing, perception, judgment, and decision-making. These elements are influenced by many factors, to include individual and cultural beliefs, norms, vulnerabilities, motivations, emotions, experiences, morals, education, mental health, identities, and ideologies (Source: US Forces, Joint Publication 3-13 'Information Operations', 2014).

Colonel Joseph Speed

graduated from Mississippi State University with a Bachelor of Business Administration Degree in 1992. He has served as an F-16 instructor pilot, flight examiner, flight commander and assistant director of operations. He also has served as a director of operations and squadron commander of flying training and support squadrons. He is a command pilot with more than 2,800 flying hours, including 353 combat hours, and was a SEAD Instructor Pilot in the F-16CJ. He is currently serving as the Combat Air Branch Head at the Joint Air Power Competence Centre.

Lieutenant Colonel Panagiotis Stathopoulos

graduated from the Hellenic Air Force (HAF) Academy with a BSc in Aeronautics in 1995. He holds an MSc in Human Factors and Safety Assessment in Aeronautics from Cranfield University, UK, and is a graduate of the HAF Tactical Weapons Fighter School. He is an F-16 instructor and functional check flight pilot, and he is a command pilot with more than 2,000 flying hours. He has also served as director of operations and subsequently as commander in the 341st Fighter Squadron from 2012–2016. He is currently serving as the Electronic Warfare (EW) including SEAD Operations SME at the Joint Air Power Competence Centre.



EM Spectrum Map: © Lockheed Martin; Question Mark: © Johan Swanepoel/shutterstock

Like a sleeping beauty electronic warfare has been a resting delight, hidden away and overlooked for an age. Now it is grown to a **dragon** ready to be awake again to recreate spectrum superiority.

Electronic Warfare – The Forgotten Discipline

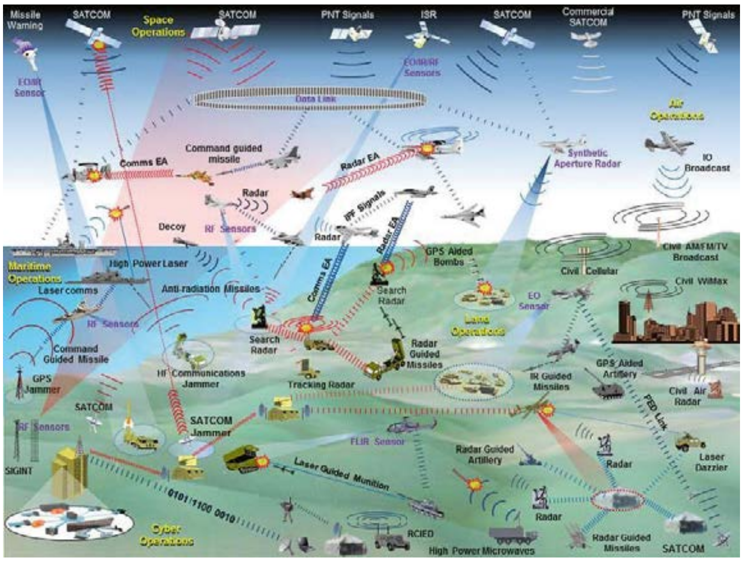
Why is the Refocus on this Traditional Warfare Area Key for Modern Conflict?

By Commander Malte von Spreckelsen, DEU N, NATO Joint Electronic Warfare Core Staff

Introduction

If people talk about a modern conflict, most agree that such a conflict will be fought in all dimensions possible. The North Atlantic Treaty Organization (NATO) has a good view about threats it might encounter on land, on and below the sea, in the air, and in space. Furthermore, cyberspace is increasingly a bright focus area for NATO. Nations continue to develop new weapon systems to operate in these dimensions, but unfortunately, NATO initiatives have, in many cases, not embraced and developed the discipline of Electronic Warfare (EW). A generation of military professionals has grown up without thinking much about the vulnerabilities inherent in operational reliance on the electromagnetic spectrum.

In its EW policy,[1] NATO defines Electronic Warfare as 'a military action that exploits electromagnetic energy, both actively and passively, to provide situational awareness and create offensive and defensive effects'. It is warfare within the Electromagnetic Spectrum (EMS) and (shown in Figure 1) involves the military use of electromagnetic energy to prevent or reduce an enemy's effective use of the EMS while protecting its use for friendly forces.



© NATO Figure 1: Electronic Warfare in today's military environment.

The lack of understanding of the implications of EW can have significant mission impact – even in the simplest possible scenario. For example, having an adversary monitor one's communications or eliminate one's ability to communicate or navigate can be catastrophic. Likewise, having an adversary know the location of friendly forces based on their electronic transmissions is highly undesirable and can put those forces at a substantial disadvantage. The purpose of this article is to highlight that EW is critical to modern operations and needs to be rapidly revived and reinvigorated in order to catch up and keep up with peer adversary advances.

History

Superior weapons and tactics have always conferred advantage in war, and the development of measures and countermeasures is a major thread running through the history of human conflict. Man's use of electricity, electronics, and the electromagnetic spectrum in war has been no exception. In 1888, German Heinrich Hertz demonstrated that 'electrical sparks would propagate signals into the space'.[2] Soon after, militaries were employing this technology to improve their 'conventional' operations through advanced communications, navigation, targeting and battlespace sensing. This revolution in military affairs established the electromagnetic spectrum as a key component of military operations, a component that could be used to enhance a military's capabilities or attacked to diminish their operations.

One of the first recorded applications of EW occurred in 1904 in the Russia-Japanese war, when the Russians successfully jammed Japanese naval communications signals being used to correct naval gunfire at Port Arthur.[3]

During the First World War, though not widespread, each side successfully conducted EW in the form of communications jamming. In addition, the French and British impacted German bombing operations by jamming and spoofing the electromagnetic signals being used by the Zeppelins for navigation. Events such as these merely served as a prelude for the EW activities to follow.

The major breakthrough for EW came with the inventions and development prior to and during World War II. Both the Allied and Axis Powers used EW extensively to attack radar, communications and navigation systems, in what Winston Churchill referred to as the 'Battle of the Beams'.

Further advances in tactics and technology occurred during the Vietnam War as air tactics began to change in order to better benefit and counter EW capabilities. Through the Gulf War in 1991 and every conflict since, military forces have proven that dominance of the EMS is crucial for most military operations.

In the recent conflicts in Iraq or Afghanistan, the EW threat from adversaries was limited. The extent to which coalition forces employed EW was also limited, primarily to actions to defeat the threat of remote-controlled improvised explosive devices, mainly by using jammers.

In the face of such limited opposition, coalition and Alliance forces could use the EMS with few limitations. This enabled the uninterrupted use of the Global Positioning System (GPS) for navigation and heavy reliance on systems like the Blue Force Tracker.[4] Friendly forces enjoyed virtually unhindered communications means for command and control. Old, valuable concepts such as radio discipline, electromagnetic signature control, and frequency hopping were less important in these environments. Therefore, over the years, the focus and devotion towards EW faded within NATO. Policies, plans, and doctrine slowly, but steadily, became outdated. EW training in forces throughout NATO lost focus and EW skills atrophied. Additionally, new, more publicly accessible capabilities like 'Cyberwarfare' emerged and dragged a lot of effort, resources, and attention away from traditional EW, which was to some degree viewed as the purview of high-end militaries and a threat that had faded with the demise of the Soviet Union.

However, recent developments in the security environment have led to a course change concerning EW. NATO has reemphasized the need to be alert and ready again against any emerging threat. Countries like Russia and China have significantly upgraded their capabilities to operate in the EMS. In Eastern Ukraine, Russian-backed forces used sophisticated jamming and interception tactics to undermine communications and surveillance drones. The proliferation of commercial technology in the telecommunications world has accelerated the development of numerous capabilities. With the growth of the commercial wireless market, many other countries now have technology able to operate within the EMS. The EMS environment is becoming more complex, congested, and contested, making it imperative for NATO to continually improve EW capabilities to enable reliable use of the EMS.

The Electromagnetic Spectrum, Electromagnetic Environment and Electromagnetic Operations

Due to both the evolution of how NATO conducts operations and the emerging technologies, the focus for EW has shifted from isolated operations in the EMS to joint Electromagnetic Operations (EMO) in the Electromagnetic Environment (EME). The EMS is defined as the entire distribution of electromagnetic radiation according to frequency or wavelength (Figure 2). Although all electromagnetic waves travel at the speed of light (in a vacuum), they do so across a wide range of wavelengths and corresponding frequencies. Therefore, the EMS comprises the span of all electromagnetic radiation and consists of many subranges, which people commonly refer to as spectral bands, such as visible light or ultraviolet radiation. The EME is the geophysical environment, influenced by such factors as terrain, weather and atmospheric conditions, which supports the radiation, propagation, and reception of electromagnetic energy across the entire EMS.

Within NATO, EMO involves the deliberate transmission and reception of EM energy in the EME for military operations such as communications, navigation, attack, battlespace awareness, and targeting. As shown in Figure 3, EMO not only enables operations in each domain but also provides the thread which links and integrates military forces across the domains and to the cyberspace and information environments.

Within the EME, EMO are conducted by both friendly forces and adversaries. As shown in Figure 4, these EMO often lead to a contested EME. In addition, these operations often overlap with the EM activities executed by neutral actors further leading to a congested EME.

Today, the dependency of military operations upon utilization of the EMS is now a central facet of almost all military activities as military forces around the world have integrated EM capabilities into a vast majority of platforms, systems, and units. Without the freedom to conduct EMO and manoeuvre in the EME, the ability of militaries to achieve superiority in air, land, maritime, space and cyberspace will be placed

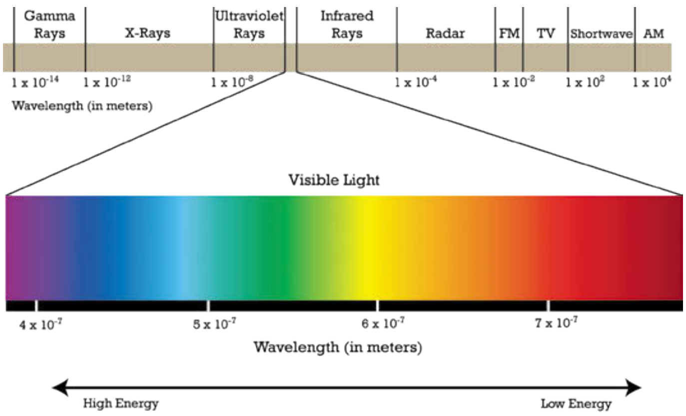


Figure 2: The Electromagnetic Spectrum (EMS). © NATO

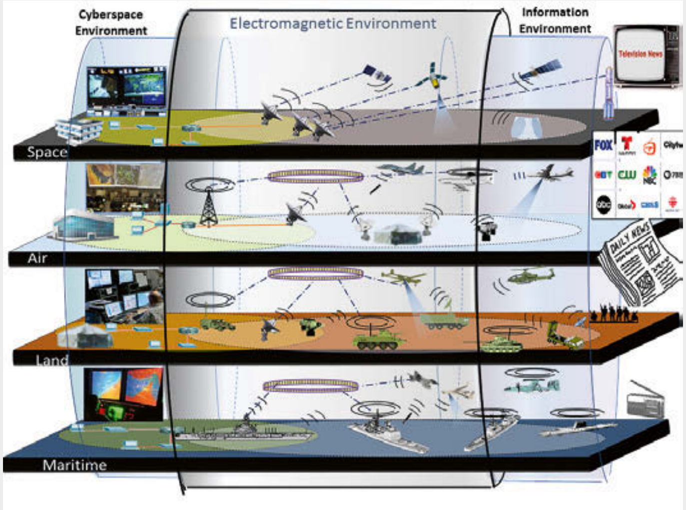


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Figure 3: Electromagnetic Operations in the Electromagnetic Environment.

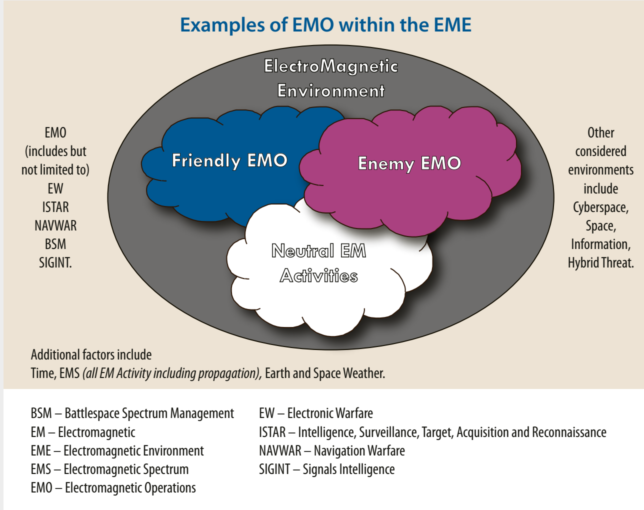

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Figure 4: Electromagnetic Operations (EMO).

at risk. The global increase in affordability and portability of highly sophisticated electromagnetic equipment guarantees that the EME will continue to create even more diverse challenges and modern militaries can be expected to try to deny the use of the EMS by their adversary.

Challenges to NATO Operations

Several factors pose a challenge to NATO operations. First, the high EME usage by the military, civil sector, and adversaries produces congestion, which constrains NATO force manoeuvre. Also, our adversaries have modernized their own EMO by utilizing complex encryption and frequency diversity in communications systems and rejuvenating obsolete, spectrum-dependent systems, such as low-frequency radar, with upgraded hardware. They are also implementing advanced processing algorithms for navigation and battlespace surveillance that make their EM activity more difficult to counter. In addition, adversaries can use sophisticated technologies to attack NATO forces through the EME, denying or degrading a joint force's ability to use the EME to communicate, navigate, and sense. The challenge for NATO commanders is to be able to dominate those elements of the EME they need to support NATO operations, at the time and location required, to achieve mission objectives while denying the same to the adversary.

NATO Strategic View of the EMS

For NATO forces, the EMS is an essential part of military operations, so much so that many Allied leaders now see the EME as an operational environment and a part of the battlespace where friendly forces manoeuvre in time, location, and spectrum to create electromagnetic effects in support of the commander's objectives. In a manner equivalent to operations conducted in the air, space, land, maritime, cyber, and information environments, NATO forces will need to conduct EMO either sequentially or simultaneously. Military leaders will plan, orchestrate, and synchronize their EMO and resources based upon interpretation of the Joint Force Commander's intent, operational priorities, and an intelligence assessment of the EME. Shaping the EME, using all means necessary to allow EMO to support operations across the entire battlespace, will be a critical enabler for mission success.

Evolution of NATO EW

As the combat arm of EMO, EW capabilities for Electronic Attack (EA), Electronic Defence (ED) and Electronic Surveillance (ES) will provide the ability to manoeuvre in the EME and create desired effects that shape the electromagnetic environment, enhance situational awareness, protect friendly forces, and attack an adversary. NATO EW operations will enable military operations in the land, maritime, air, space, and cyberspace. They will support warfighting activities such as Navigation Warfare (NAVWAR), intelligence collection operations, suppression of enemy air defences (SEAD) and information operations (IO). At the joint level, planning for EW in NATO operations will begin in the Operations Planning Process to develop the electromagnetic order of battle and to identify the EW opportunities, capabilities and assets required to accomplish commander's objectives. During operation execution, EW operations will be continually coordinated and integrated across all components to synergize the application of EW capabilities and to assure friendly forces have access to the EMS while denying its use to the adversary. In order to do this, the commander must not only empower an EW battle staff element to plan and execute EMO across the full Joint spectrum of conflict, but must also possess the tools and trained personnel necessary for that execution.

Conclusion

Electronic Warfare has been an afterthought for a quarter of a century, but the exponential growth of space and cyber technologies that rely, above all, on electromagnetic signals, a renewed sense of urgency to rebuild and recapitalize EW capabilities, both offensive and defensive. However, due to the increasing dependencies of modern military systems upon the EMS, commanders must understand the following:

- The EME is an operational environment to be shaped to support NATO EMO while denying its use to the adversary.
- A battle space to be used to conduct EW to attack an adversary while protecting NATO forces.
- A conduit for using EW capabilities to exploit adversary EM signals for military purposes such as situational awareness, indications and warning, and targeting.

The modern challenges of dealing with the high-end capabilities of peer and near-peer adversaries, especially in confrontations requiring operations in Anti-Access/Area Denial (A2/AD) environments, have brought EW back to the forefront. This means that NATO and nations must re-invest in modern EW capabilities, and build enough capacity in these capabilities to compete with peer competitors. NATO is presently rewriting its EW Doctrine and is investigating how to operate in the EMS more effectively. Future articles will examine modern EW capability and doctrine requirements, along with how NATO can best catch up.

'EW has been a sleeping beauty, hidden away and forgotten for a generation. Now it is a dragon about to reawaken, and NATO leaders who continue to ignore its significance do so at the Alliance's peril.'

1. MC 64/11, 4 Jul. 2018.
2. Heinrich Hertz, Electric Waves: Being Researches on Propagation of Electric Actions with Finite Velocity Through Space, Macmillan 1893.
3. Vladimir Semenoff, The Russo – Japanese War at Sea 1904–5: Volume 1 – Port Arthur, the Battles of the Yellow Sea.
4. Blue Force Tracking is a US military term for a GPS-enabled capability, that provides military commanders and forces with location information about friendly (and despite its name, also hostile) military forces.

Commander von Spreckelsen
joined the German Navy in 1993 and holds an MA from Kings College London. He has a background in maritime aviation on 1150 Breguet Atlantic as a Mission Commander. During his career, Commander von Spreckelsen held command of different naval and joint EW units up to battalion size. In between he was posted at the Strategic Reconnaissance Command. In 2015 Commander von Spreckelsen resumed his present position as the Chief of Plans and Policy in the NATO Joint Electronic Warfare Core Staff. On this position in 2017 he was appointed as the Chairman of the NATO Electronic Warfare Working Group. During his career, Commander von Spreckelsen deployed several times on different NATO missions and has 2,500+ flight hours.

Autonomous Weapon Systems in International Humanitarian Law

Errare Robotum Est

By Lieutenant Colonel Andre Haider, DEU A, JAPCC

Introduction

The number of unmanned systems in military inventories has grown rapidly and is still increasing throughout all domains. At the same time, the level of automation built into these unmanned systems has not only increased significantly, but has also reached a level of sophistication at which they are seemingly capable of performing many tasks 'autonomously' and with no necessity for direct human supervision. Highly automated air defence systems are capable of firing at incoming targets automatically, within seconds of detection of a target, assuming this mode of operation has been activated. Basically, everything necessary to build a fully automated weapon system is already developed. The respective technologies merely have to be brought together.

For example, a future unmanned combat aircraft may combine current autopilot, navigation and sensor technology with software modules for air combat and target identification and may carry guided munitions for a kinetic engagement.

The autopilot would enable the aircraft to not only navigate to its pre-planned mission area but also calculate

the route on its own, taking all available data into account (e.g. meteorological information or intelligence about adversary threats). This data could be updated in real time during flight or gathered by on-board sensors, enabling the autopilot to immediately adapt to new conditions. In combat, the aircraft would defend itself or engage adversary targets on its own. Its air combat software module could predict possible adversary actions almost instantaneously and initiate appropriate manoeuvres accordingly, potentially giving it superiority over any manned aircraft and making it capable of surviving even the most hostile environments. The sensor suite would provide the autopilot and the combat software module with comprehensive situational awareness, enabling the weapon system to identify enemy vehicles and their trajectories and compute combat manoeuvres accordingly. Finally, a mission tailored set of lethal payloads would enable the unmanned aircraft to conduct combat operations and engage targets autonomously.

All of the aforementioned technology required to build a fully automated weapon system is already developed and readily available on the market. So the question is no longer if such systems can or should be built. The real question is, when these systems come into service, what missions will be assigned to them and what implications will arise from that development?

The Problem with Autonomy in Weapon Systems

In the civil arena, the use of highly automated robotic systems is already quite common, as seen in the manufacturing sector. But what is commonly accepted in the civilian community may be a significant challenge when applied to military weapon systems. A fully automated or 'autonomous' manufacturing robot, which does not make decisions about the life or death of human beings, will most likely not raise the same legal questions, if any, that a military weapon system would.

Any application of military force in armed conflict is usually governed by International Humanitarian Law (IHL) which itself derives from, and reflects, the ethically acceptable means and customs of war. However, IHL has been altered and amended over time, taking both the development of human ethics and weaponry into account. For example, IHL has been modified to condemn the use of certain types of weapons and methods of warfare.

The proliferation of unmanned systems, and especially the increasing automation in this domain, have already generated a lot of discussion about their use. The deployment of autonomous systems may entail a paradigm shift and a major qualitative change in the conduct of hostilities. It may also raise a range of fundamental legal and ethical issues to be considered before such systems are developed or deployed.

Autonomous Weapon Systems in International Humanitarian Law

International Humanitarian Law, as yet, provides no dedicated principles with respect to autonomous weapons. Because of this, some argue that autonomous weapons are to be considered illegal and should be banned for military applications. However, it is a general principle of law that prohibitions have to be clearly stated or otherwise do not apply. Conclusively, the aforementioned argument for banning these particular weapons is inappropriate. Nevertheless, IHL states that if a specific issue is not covered by a dedicated arrangement then general principles of established customs, such as the principle of humanity and public conscience, apply.

Consequently, there is no loophole in international law regarding the use of autonomous weapons. New technologies have to be judged against established principles before labelling them illegal in principle. Therefore, an autonomous weapon system which meets the requirements of the principles of IHL may be perfectly legal.

The Principles of International Humanitarian Law

During armed conflict the IHL's principles of distinction, proportionality and precaution apply. This also implies the obligation for states to review their weapons to confirm they are in line with these principles. In general, this does not impose a prohibition on any specific weapon. In fact, it accepts any weapon, means or method of warfare unless it violates international law and it puts responsibility on the states to determine if its use is prohibited. Therefore, autonomous systems cannot be classified as unlawful as such. Like any other weapon, means or method of warfare, it has to be reviewed with respect to the rules and principles codified in international law.

© US Navy, Christopher Mobley

The Phalanx Close-In Weapons System during a routine maintenance practice fire.

Prohibited Weapons. First and foremost, any weapon has to meet the requirements of the Geneva Conventions which state: 'It is prohibited to employ weapons, projectiles and material and methods of warfare of a nature to cause superfluous injury or unnecessary suffering … [and] … are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment.' Some examples of internationally agreed prohibitions on weapons include fragmentation projectiles, of which the fragments cannot be traced by X-rays, and incendiary weapons' use in inhabited areas. Autonomous weapons respecting these prohibitions will be well in line with that article.

The Principle of Distinction. Protecting civilians from the effects of war is one of the primary principles of IHL and has been agreed state practice dating back centuries. In 1977, this principle was formally codified as follows: '[…] the Parties to the conflict shall at all times distinguish between the civilian population and combatants and between civilian objects and military objectives and accordingly shall direct their operations only against military objectives.' However, applying this principle turned out to be more and more complex as the methods of warfare have evolved. Today's conflicts are no longer fought between two armies confronting each other on a dedicated battlefield. Participants in a contemporary armed conflict might not wear uniforms or any distinctive emblem at all, making them almost indistinguishable from the civilian population. So, the distinction between civilians and combatants can no longer be exercised only by visual means. The person's behaviour and actions on the battlefield have become a highly important distinctive factor as well. Therefore, an autonomous weapon must be capable of recognizing and analysing a person's behaviour and determining if he or she takes part in the hostilities. However, whether a person is directly participating in hostilities or not is not always that clear. An autonomous weapon will have to undergo extensive testing and will have to prove that it can reliably distinguish combatants from civilians.

However, even humans are not without error and it has to be further assessed how much, if any, probability of error would be acceptable.

The Principle of Proportionality. Use of military force should always be proportionate to the anticipated military advantage. This principle has evolved alongside the technological capabilities of the time. For example, carpet bombing of cities inhabited by civilians was a common military practice in World War II, but would be considered completely disproportionate today. Modern guided ammunition is capable of hitting targets with so called 'surgical' precision, and advanced software, used in preparation of the attack, can calculate the weapon's blast and fragmentation radius and anticipated collateral damage. Especially for the latter, it can be argued that autonomous weapons could potentially apply military force more proportionately than humans. This is because they are capable of calculating highly complex weapon effects in an instant and therefore reducing the probability, type and severity of collateral damage. However, adhering to the principle of proportionality is completely dependent on reliably identifying and distinguishing every person and object in the respective target area. And this, ultimately, refers back to the application of the principle of distinction.

The Principle of Precaution. The obligation of states to take all feasible precautions to avoid, and in any event to minimize, incidental loss of civilian life, injury to civilians and damage to civilian objects inherently requires respect for the aforementioned principles of distinction and proportionality. Additionally, the principle of precaution has to be respected during the initial development of a weapon itself. Any type of weapon has to demonstrate the reliability to stay within the limits of an acceptable failure rate, as no current technology is perfectly free of errors. For example, the United States Congress defined the acceptable failure rate for their cluster munitions as less than one percent. Recent general aviation accident rates in the United States are only a fraction compared to that and even nuclear power plants cannot guarantee 100 percent reliability. It is doubtful that any type of future technology would ever accomplish an error level of zero, which is also true for any autonomous weapon. This again raises the question 'how much probability of error would be acceptable?' and 'how good is good enough?' Weapon development and experimentation must therefore provide sufficient evidence to reasonably predict an autonomous weapon's behaviour and effects on the battlefield.

Responsibilities

The higher the degree of automation, and the lower the level of human interaction, the more the questions arise as to who is actually responsible for actions conducted by an autonomous weapon. This question is most relevant if lethal capabilities cause civilian harm, be it incidentally or intentionally. Who will be held liable for a criminal act if IHL has been violated? Is it the military commander, the system operator, or even the programmer of the software?

Military Commander. Military commanders have the responsibility to prevent and, where necessary, to take disciplinary or judicial action, if they are aware that subordinates or other persons under their control are going to commit or have committed a breach of IHL. Military commanders are, of course, also responsible for unlawful orders given to their subordinates. This responsibility does not change when authorizing the use of an autonomous weapon. If a commander was aware in advance of the potential for unlawful actions by an autonomous weapon, and still wilfully deployed it, he would likely be held liable. In contrast, if weapon experimentation and testing provided sufficient evidence that the autonomous weapon can be trusted to respect IHL, a commander would likely not be accountable.

System Operator. Depending on the level of human interaction, if required, the individual responsibility of the system operator may vary. However, some already fielded autonomous systems such as Phalanx or Sea Horse can operate in a mode where the human operator has only a limited timeframe to stop the system from automatically releasing its weapons if a potential threat has been detected. Attributing liability to the operator is doubtful if the timeframe between alert and weapon release is not sufficient to manually verify if the detected threat is real and if engagement of the computed target would be lawful under IHL.

Programmer. Software has a key role in many of today's automated systems. Hence, the programmer may be predominantly attributed responsibility for an autonomous weapon's behaviour and actions. However, modern software applications show clearly that the more complex the programme the higher the potential of software 'bugs'. Large software undertakings are typically developed and modified by a large team of programmers and each individual has only limited understanding of the software in its entirety. Furthermore, it is doubtful if the individual programmer could predict, in detail, any potential interaction between his portion of the source code and the rest of the software. So, holding an individual person liable for software weaknesses is probably not feasible unless intentionally erroneous programming is in evidenced.

Conclusions

International law does not explicitly address manually operated, automated or even autonomous weapons. Consequently, there is no legal difference between these weapons. Regardless of the presence or absence of direct human control, any weapon and its use in an armed conflict has to comply with the principles and rules of IHL. Therefore, autonomous weapons cannot simply be labelled unlawful or illegal. In fact, they may be perfectly legal if they are capable of adhering to the principles and rules of IHL.

The principles of International Humanitarian Law are predominantly the ones of distinction, proportionality and precaution. None of them can be looked at in isolation as they are all interwoven and require each other to protect civilians and civilian objects during the conduct of hostilities. The technical requirements for an autonomous weapon system to adhere to these principles are extremely high, especially if it is intended to operate in a complex environment. However, considering the current speed of technological advances in computer and sensor technology it appears likely that these requirements may be fulfilled in the not so distant future.

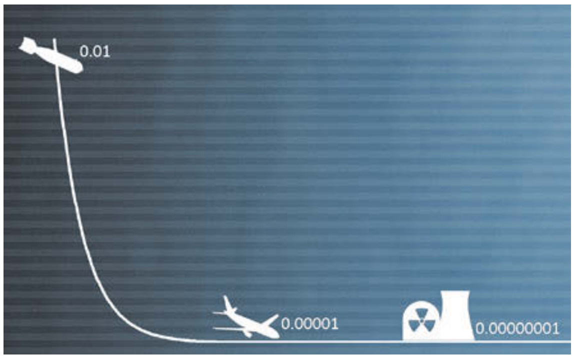

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Figure 1: Failure Rates in Modern Technology.

Nevertheless, not even the most sophisticated computer system can be expected to be perfectly flawless (cf. Figure 1). Consequently, potential erroneous system behaviour has to be an integral part of the review process, and, most importantly, the acceptable probability of error needs to be defined. ●

Lieutenant Colonel André Haider

is the Joint Air Power Competence Centre's (JAPCC) Remotely Piloted Aircraft Systems Subject Matter Expert and the JAPCC's representative in the NATO Joint Capability Group Unmanned Aircraft Systems (JCGUAS). He joined the German Armed Forces in 1992 and is an artillery officer by trade with over fifteen years' experience in command & control and operational planning. He is also a trained United Nations Missions Observer and participated in several EU and NATO missions. His last post was Deputy Commander of the German Army's MLRS Rocket Artillery Battalion.

Aircrafts: © John5199, Background: © KOKTARO/shutterstock

100 Years of the Royal Air Force

And its Influence on Air Power Development

By Lieutenant Colonel Ed Wijninga, NLD AF, JAPCC

Introduction

The Royal Air Force (RAF) was founded on 1 April 1918 during the final year of the First World War. Prior to this, however, a number of British Generals advocated the need for a separate air force able to conduct air operations in concert with the Royal Navy and the British Army, but also capable of carrying out air operations independently. One of the biggest advocates for this was South-African-born general Jan Smuts, who wrote two reports advocating the establishment of an independent air arm. It was Smuts' second report, which spoke of an air service 'as an independent means of war operations' and painted a vision in which aerial operations 'may become the principal operations of war', that led directly to the creation of the Royal Air Force. He stated, 'The necessity for an Air Ministry and Air Staff has become urgent.' Smuts submitted this second report on 17 August 1917, and the War Cabinet considered it on 24 August. Despite some opposition from the Navy and Army representatives, it was approved in principle. The War Cabinet still needed to develop many of the details, but the Air Force Constitution Act was passed on 23 November 1917, and given Royal Assent, it passed into law on 29 November 1917. His Majesty King George V issued a Royal decree at St James' Palace on 7 March 1918, stating he had named the new Service the 'Royal Air Force'. The already existing Royal Flying Corps (RFC) and the Royal Naval Air Service (RNAS) were amalgamated to form the Royal Air Force on 1 April 1918[1].

RAF Westland Wapiti IIa of 30 Squadron in flight over the city of Mosul in Iraq, 11 March 1932.

The RAF's Influence on Air Power Development

The foundation of the Royal Air Force started the era of Air Power development. Many of the World's Air Forces were established and through experience, in both peacetime and war, together with the discussion about how to best employ this new phenomenon; Air Power doctrine was developed. Examining experiences, evaluating new technology, and discussing Tactics, Techniques, and Procedures (TTPs) to develop Air Power doctrine is an evolutionary process that continues to this day. On 26 June 2018, NATO adopted it's first-ever Air Power Strategy. Many concepts, procedures, and doctrine we use today as part of the way NATO employs Air Power have their roots in the history of the Royal Air Force. The RAF we see today is built around the United Kingdom's four core Roles of Air Power; Control of the Air, Intelligence, Surveillance and Reconnaissance (ISTAR), Attack, and Air Mobility. All four of these Roles of Air Power have endured since the earliest days of military aviation. This article will highlight a few of the historical events or inventions that triggered the development of these concepts or professionalized them to the point where we still employ them.

Ubiquity, Agility, Concentration

After the First World War, the British government was in a position where it needed to quickly reduce its defence spending to keep the overall budget under control. Therefore, as with the other components, the government reduced the size of the Air Force drastically. By the end of the war, the RAF had 95 squadrons on the continent together with 55 operational and 199 training squadrons in the United Kingdom, and another 34 squadrons in the Middle East and India. Just five months later, the number of squadrons on the continent was reduced to 44, and half a year later there was only one left. The personnel strength of the RAF had been reduced from 304,000 at the end of 1918, to 29,730 by January 1920.

However, the end of the war had not brought the eagerly awaited peace that Britain was expecting. The post-war period came with numerous questions: the effects of the Russian Civil War, the fall of the Great Ottoman Empire, boundary disputes along the Eastern European boundaries, and the unrest in Afghanistan, Somaliland and Mesopotamia. The British Army was struggling to control these uprisings and conducted several campaigns to maintain order amongst the various populations. Although these campaigns were largely effective, in the case of the Afghan invasion of India on 6 May 1919, the British Forces could not make the Afghans withdraw until 24 May 1919, when the RAF conducted a bombardment of King Amanullah's palace in Kabul. This was done with only one Handley Page V.1500 bomber with four 112-pound bombs on under-wing racks and sixteen 20-pound, hand-thrown bombs. The psychological impact of this attack on the population was unprecedented, causing the Afghans to sue for peace. This was the first time in history that air power had proved to be decisive in ending a conflict. Hugh Trenchard, the Chief of the RAF at that time, would use this event repeatedly as proof of the capability of independent air power. Trenchard also argued that he could solve problems through the use of the Royal Air Force as an independent fighting force. He demonstrated this once more with the conflict in Somaliland. Air power proved to be the crucial factor in defeating the Somaliland Dervishes, a feat that the British Army had been trying to accomplish for years, without being able to strike the decisive blow.

These events in Afghanistan and Somaliland clearly showed that air power could quickly respond to an emerging crisis; aircraft could deploy swiftly over vast distances; and commanders could effectively and decisively employ the RAF at a fraction of the cost of the British Army. The next year, the British government gave the RAF complete control of all British forces in Mesopotamia to control the tribal unrest in the area. Trenchard firmly believed in his concept of 'Air Control', which 'asserted that relatively light air attacks supported by armoured car ground units could achieve the objective with far fewer people than would be needed by the Army, and thus it would be much cheaper' to maintain order in Britain's Colonial Empire. It would shape the RAF's thinking process – and hence its whole organization – for years to come. The RAF demonstrated the combination of the three core characteristics of air power: speed, reach, and height, for the first time during the campaigns in Afghanistan, Somaliland and Mesopotamia, and their synergetic use led to the conceptualization of additional strengths of air power. Ubiquity allows aircraft to counter or pose simultaneous threats across a far wider geographical area than is possible with surface systems. Agility permits air assets to move quickly and decisively between the strategic, operational, and tactical levels of warfare. Concentration, speed, reach, and flexibility let air power assets concentrate military force in time and space, when and where it is required.[2]

Control of the Air

By the mid-1930s the discussion on how to defend Britain in case of war was gaining a foothold. It became widely accepted, due to the emergence of the new modern German Luftwaffe, that any future attack would be primarily through the air. Until then, the RAF had adhered to the policy of standing air patrols to defend against any attacking aircraft. This was very costly in terms of wear and tear on aircraft, fuel, pilots and ground crews. The recently appointed Air Officer Commanding (AOC) Fighter Command, Air Vice Marshal Hugh Dowding, attended a few experiments in 1935 with concrete sound-mirrors, at first, which proved unsuccessful, and later with a system that used electromagnetic radiation. This experiment with Radio Detection And Ranging (RADAR) using electromagnetic radiation was very successful, and Dowding secured funding for further tests and the set-up of a number of experimental stations along the coast. One of the scientists wrote, 'We now have a new and potent means of detecting the approach of hostile aircraft, one which will be independent of mist, cloud, fog or nightfall'. In the years preceding the Second World War, scientists would develop this technology further to the Chain Home and Chain Home Low Radar systems along the British South and East coasts. Dowding, however, wanted to go further. He considered that without a system connecting all

The Operations Room at RAF Fighter Command's No. 10 Group Headquarters.

the information coming from the radars, correlated with inputs from the Observer Corps and coastal air defence batteries, he would still not be able to direct his fighters to any attacker without potentially over-tasking aircraft or wasting fuel. If his radar system worked, there would be no need for standing patrols, wearing out engines, wasting fuel, and tiring crews. Some experiments to use the radar information for 'forward interception' as it was called then, were carried out at RAF Biggin Hill in 1937. The conclusion was as follows: 'Provided that the sector operations room could be supplied with the positions of bombers at one-minute intervals, correct to within two miles, it should be possible to direct fighter aircraft to within three miles of them. This was sufficient to ensure interception in average conditions of visibility' according to an official signals history[3]. The new system was now introduced throughout Fighter Command. Every Sector Operations Room had telephone connections to subordinate airfields, Observer Corps posts, searchlight units, anti-aircraft gun units, and higher headquarters, such as Group Operations Rooms and to Headquarters RAF Fighter Command at Bentley Priory in Northwest London. The integration of all these capabilities through a well-functioning command & control system provided Dowding and his sector commanders with ample early warning and the possibility to position his fighters in the required numbers, at the right time and at the correct location where the enemy was approaching. This system, to a large extent, saved Britain from invasion during the Battle of Britain and served as a blueprint for future air defence operations.

Close Air Support

During the First World War, the British military began to employ Close Air Support, in a rudimentary form. Theorists like Sir Basil Henry (B. H.) Liddell Hart, considered air support to ground troops as a form of mobile artillery, and he also argued, 'For this purpose the close cooperation of low-flying aircraft is essential.'[4] As a result, the RAF began theorizing about air support to ground operations during the interwar years. In August 1940, RAF Group Captain A.H. Wann and British Army Colonel J. D. Woodall issued a report that recommended creating the position of an air liaison officer for Army Divisions and Brigades. These officers were called 'Tentacles'. As a result, the RAF created the RAF Army Cooperation Command, which started to develop the necessary structures. Trained Tentacle teams joined operational

Commanding air officer in the Western Desert, Arthur Coningham (left) discusses tactics with General Bernard Montgomery in 1943.

Pilots of No 19 Squadron, Royal Air Force, scramble from the back of a lorry at Fowlmere, Cambridgeshire.

units for the first time in the Western Desert in 1942, where they were immediately integrated into RAF-Army Air Support Control staffs at corps level and below. They used a system called Forward Air Support Links (FASL), which was a set of vehicle-borne equipment that included radios for immediate control of aircraft and for communication with higher formations. As a result, the response times for close air support, which had been around three hours, were reduced to 30 minutes. Another procedure the RAF developed in the Western Desert was the 'Cab-Rank' system, consisting of three aircraft. One aircraft was in direct support of the ground troops; the second was transiting to the battle area; and the third aircraft conducted refuelling and rearmament. Air Vice-Marshal Arthur Coningham, the commander of the Desert Air Force, perfected this whole system. He created joint RAF-Army Air Support staffs at corps level and at armoured division headquarters. He placed links at subordinate levels down to brigade and sometimes battalion level. The Desert Air Force introduced this system of close coordination, and other RAF units further refined the system, demonstrating tremendous success during the campaigns in Italy, Normandy, and northwestern Europe.

Anti-Submarine Warfare

Starting in earnest early in 1942, the Battle of the Atlantic, in which the German Kriegsmarine sunk an enormous number of merchant ships providing logistic support from the United States to the Allies, was a call by the British and American governments for drastic measures to put a stop to this onslaught. The Royal Navy was not able to counter the U-boat threat and was overwhelmed by the number of German submarines patrolling the Atlantic Ocean, and beyond, in the so-called 'Wolf Packs'. RAF Coastal Command was tasked with supporting the Royal Navy in finding, fixing and destroying U-boats, but this was easier said than done. Early on in the war, RAF aircraft lacked the technical capabilities to detect U-boats, and when detected, it proved quite difficult to destroy them. Technical inventions such as SONAR,[5] Air-to-Surface Vessel (ASV) radar, and the Leigh light followed each other in quick succession and were implemented on aircraft. Moreover, after the Americans joined the war, the RAF was able to obtain American Very-Long-Range (VLR) aircraft, such as the Consolidated B-24 Liberator, which were equipped with the

A Leigh light, fitted to a Coastal Command Liberator.

latest technical capabilities for the specific task of anti-submarine warfare, and were able to close the 'Atlantic Gap'[6] through their very long range. Many of the technologies and accompanying tactics the RAF (with some support from the Americans) developed during this period are still in use today. One of the most important inventions that helped to find U-boats was the ASV radar. This was initially a quite simple system, which the Germans could easily detect through their Metox system, but this was again soon outclassed by the latest ASV Mk III system, which the Germans could not detect by Metox. The ASV MK III system proved to be the technological breakthrough in the Battle of the Atlantic, resulting in a sharp rise in sunken German U-boats, which led to Admiral Dönitz calling-off all U-boat operations in the North-Atlantic in May 1943. After an aircraft detected a U-boat, one of the problems in conditions of reduced visibility or at night was that the submarine still could not be seen sufficiently by the aircrew to allow them to attack. To overcome this, Wing Commander Humphrey de Verd Leigh invented a light with a very high output, and mounted it initially in a turret or nacelle position, but later outboard on one of the aircraft's wings. Once detected, the U-boat had insufficient time to dive, and it provided a clear view for the bombardier to release his depth charges or torpedoes. The Leigh light, as it was soon called, produced a very intense light of up to 90 million candelas. It proved to decrease the chances of survivability for the U-boats, which now preferred to surface when they had greater early warning of incoming aircraft and a chance to fight back.

Conclusion

The Royal Air Force has seen many conflicts and battles in its first century. In these 100 years, the military use of aircraft has matured from simple artillery spotting and balloon busting operations over enemy lines in the First World War to War in the Air leading the most complex military campaigns. The RAF developed many of the ideas, concepts, tactics and procedures that are now firmly embedded in national air power doctrines during times of crisis and conflict. Some of the most significant include close air support and electronic warfare in support of defensive counter-air and anti-submarine warfare. The rapid, decisive, and efficient use of air power we can employ today is largely the result of the work of men and women of the Royal Air Force, who sometimes, against all odds, persevered in their thinking towards creating ways and systems to fight battles with greater success and at less cost. The advent of air power, in which the Royal Air Force played a crucial role, transformed warfare to a point where commanders widely accept that without adequate air power, employed both independently and in support of joint operations, achieving victory in a conflict is far more challenging, and against peer adversaries, almost impossible.

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Lieutenant Colonel Ed Wijninga

is currently employed as Section Head of the Education, Training, Exercises & Lessons Learned section of the Joint Air Power Competence Centre.

Prior to this position he worked as Branch Head Offensive and Support Operations at the Combined Air Operations Centre in Uedem, Germany. Other positions include Staff Officer Close Air Support in the Netherlands Maritime Force at Naval Base Den Helder. He also served two years as Operations Planner at the J5 section in the Directorate of Operations of the Ministry of Defence in The Hague.

In 2004/5 Lieutenant Colonel Wijninga attended the Senior Staff College in The Hague in the first Joint Advanced Staff Officers Course and graduated with an Executive Master degree in Security and Defence (EMSD).

Light-Attack Aircraft

Required Gap Filler or Futile Relic?

By Major Daniel Wagner, DEU AF, JAPCC

Introduction

The projection of Air Power today is clearly focused on the operation and advancement of 5th generation fighter aircraft, such as the F-35 Lightning II Joint Strike Fighter, and on the continuous development of Unmanned Combat Aircraft Systems (UCAS), such as the Predator C Avenger.

It might appear that the complete coverage of Air Power is guaranteed. However, the operation of the best and most powerful fighter aircraft, in combination with more and more autonomous working UCAS, comes with a huge price tag. This price tag includes not only the enormous expenses of buying, maintaining and operating the sophisticated weapon systems, but also the development cost of each system, and that spending seems to increase exponentially with every new technological generation. In addition, the expenses and time to train combat-ready aircrews and qualified mechanics add up quickly.

Immense expenses combined with limited availability might make the priority for 5th generation fighter aircraft employment the countering of adversary high-end capabilities. The numbers illustrate that the new generation of fighter aircraft might become too valuable a resource to be risked on missions supporting ground forces in semi-permissive or low-threat environments. Nowadays, legacy fighters, such as F-16s, F-15s, and F/A-18s, as well as Eurofighters, Rafales and Tornados are delivering a massive impact during missions abroad. For many smaller operations, the employment of UCAS might seem to be a suitable solution. However, legacy fighters will sooner or later be replaced by 5th generation fighters and the UCAS currently lack the necessary flexibility in terms of weapon load-out and mission reallocation while in the air, to support different types of mission.

It seems that, in spite of the great potential these weapon systems offer, there is an existing void between mission value and suitable equipment which could be filled with a less expensive yet adequate weapon system.

The OA-X Programme

This might be the idea behind the Light-Attack Aircraft programme (OA-X) of the United States Air Force (USAF). The programme was formally started by the

An Afghan Air Force A-29 Super Tucano pitch to land at Hamid Karzai International Airport.

USAF with a Request for Information (RFI) in 2009.[1] The focus on a possible Light-Attack Aircraft (LAA), to enter service in 2013, derived from the lessons learned from multiple operations during low-intensity conflicts in Iraq and Afghanistan. The outcome was the purchase of twenty A-29 Super Tucano aircraft for the Afghan Air Force. The re-start of the OA-X programme in 2017 highlights the importance of the requirement for a LAA. Considering the capabilities, cost and availability of fighter-bomber aircraft and UCASs of the present and the future, it may therefore be the case that there is a niche for LAA for the foreseeable future.

Advantages of Light-Attack Aircraft

There are numerous challenges during the development and introduction of any new weapon system, and therein one of the LAAs biggest advantages. An off-the-shelf aircraft can be transformed into a LAA, which offers various options and possibilities to

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A Super Tucano operating from a dirt strip.

conserve resources concerning aircraft development, aircrew and technician training, and sophisticated equipment. Examples include the Air Tractor AT-802L Longsword, a modified variant of the Air Tractor AT-802, an agricultural and fire-fighting aircraft, and the AT-6 Wolverine, a light attack variant of the trainer aircraft T-6 Texan II, which is currently the primary basic trainer of the USAF, the United States Navy (USN) and Hellenic Air Force. Additionally there are existing LAA, such as the A-29 Super Tucano, also known as EMB 314 Super Tucano. The two-seat, single turbo-prop-powered aircraft includes state-of-the-art radios, data link and multiple sensors (electro-optical, infrared and Laser designation/illumination/range-finding). The military aviation equipment on board was originally developed for modern fighter aircraft, including the 5th generation fighter, and has been successfully integrated into the airframes. The aircraft's cockpit and engine are armour-protected. Multiple weapon stations, including a wide spectrum of weapons and ammunition, as well as a capable self-defence system complete the LAA. The unit cost is expected to be approximately USD 12 million to USD 13 million, with operating costs of USD 1,200 to USD 1,600 per flight hour.[2] Compared to the legacy fighters and 5th generation fighters, and even the A-10 Thunderbolt II, these operational costs are significantly less. By reducing the number of missions which have to be flown by expensive jet fighter aircraft, including a noticeable contingent of the A-10, the purchase of LAA would not only pay dividends by prolonging the lifetime of the jet aircraft, but also by saving resources during actual operations.

In addition to the actual costs of buying and operating a new aircraft, there are more features to be considered. Clearly a LAA, just like any legacy fighter, will not be able to substitute for a 5th generation fighter, which is able to penetrate hostile airspace with a significantly reduced chance of detection, due to its cutting-edge stealth technology. However, it seems that the LAA could play a major role in Small Joint Operations (SJO), where the need for stealth technology and superior fighters might not be a top priority, but supporting the troops on the ground is. And this is exactly what the LAA was 'purpose-built' for. It can employ precision-guided munitions (GBU-12, GBU-59, GBU-48 and GBU-58) as well as general-purpose bombs (Mk-81 and Mk-82). In addition, it can be equipped with laser-guided rockets and missiles and, most importantly, .50 calibre guns. For defensive air-to-air, anti-helicopter and/or anti-UCAS purposes, AIM-9M/X Sidewinder missiles could be fitted. The flight time, depending on the configuration, ranges between three and five hours. The modern cockpit is

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Successful release of a 500-pound GBU-12 laser-guided weapon from an AT-6 Wolverine.

a digital glass cockpit including Head-Up-Display (HUD), Hands-On-Throttle-And-Stick (HOTAS) and weapons management system. The secure UHF and VHF radios, as well as the data link via link-16, ensure successful integration and interoperability into the modern warfare environment.

Successful integration and interoperability is definitely a priority for any new weapon system that is being introduced in any military domain. *NATO defines interoperability as 'the ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives.'*[3] *Interoperability 'allows forces, units or systems to operate together. It requires them to share common doctrine and procedures, each other's infrastructure and bases, and to be able to communicate with each other.'*[4] Successful integration into the modern warfare environment can only be achieved via a multi-domain approach, to cover all mission-critical areas during the full spectrum operations.

Areas of Operation

The well-equipped LAA might be a valuable complementary capability with unexpected synergies in future multi-domain operations. These include Close Air Support (CAS), Intelligence, Surveillance and Reconnaissance (ISR) missions, Counter-Insurgency (COIN), armed over-watch and, due to the excellent communications and sensor equipment, Forward Air Controller (Airborne) (FAC[A])missions. Based on these capabilities, the LAA could even exert allocated Command and Control (C2) of the ground battle in an assigned area. To achieve this, the ground commander or a liaison officer could utilize the rear seat in a LAA. For such a scenario it should be clarified that LAAs would have to operate at least in a formation of two aircraft for mutual support and to accomplish the high task load. Because of the wide range of missions in multi-domain operations, the integration of LAA even into a Major Joint Operation (MJO) can be a valuable addition and critical resource. The LAA could provide the 'eyes and weapons' in the sky for the ground troops. This direct support would not just be a kinetic strike capability and airborne protection against opposing forces on the ground, but also a moral boost for own troops.

To improve the support efficiency of the ground troops by LAA, different load-out options within a formation could be considered. For example, one option could be a ground-attack variant, characterized by a heavy weapon load-out, maximizing the

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An A-29 Super Tucano releasing a GBU-12 during a combat mission scenario as part of the OA-X programme in 2017 at Holloman Air Force, New Mexico.

kinetic strike potential. Another option could be a self-defence load-out, to defend primarily against opposing UCAS, helicopters and attacking aircraft. Excellent support and security, especially for the ground troops, could be provided by a sensor and jamming load-out, to identify possible Improvised Explosive Devices (IEDs) or interrupt the opponents' lines of communication.

Drawbacks and Challenges

A huge drawback compared to the jet aircraft is the distinctively slower response time, due to the significant difference in speed. This impact can be reduced by the use of Forward Operating Bases (FOBs), but it cannot be eliminated. Airfield requirements for LAA are less demanding compared to any jet aircraft. The required runway length and consistency (grass or gravel), in combination with easier maintainability of the aircraft and minimal logistic effort, could turn even a small airstrip into a high-value FOB. This would offer completely new levels of integration for fixed-wing aircraft into the support of ground troops. Aircrews would have the valuable opportunity to plan and brief future operations face-to-face with the troops on the ground. The ground commander could be integrated in an airborne C2 function as mentioned above. In addition, the coordination with helicopter aircrews, who are using FOBs more regularly, could be instantly improved to ensure the joint cooperation. Regular transport missions, MEDical EVACuation (MEDEVAC) missions or Personnel Recovery (PR) missions could be planned more precisely and therefore executed more efficiently. The benefits of this level of integration could be vital for the overall success of any future operation.

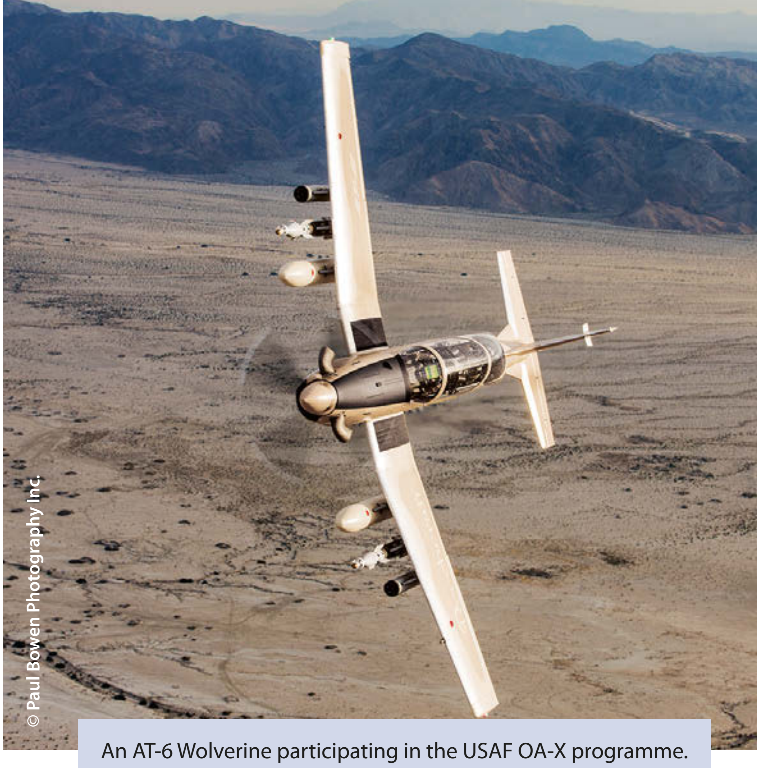
Building Partner Capacity

Another rarely recognized and widely underestimated advantage which the LAA offers, is in Building Partner Capacity (BPC).[5] Providing resources for developing nations, and assisting their training to evolve their own Air Power capability, is an important soft power tool, especially in irregular conflicts like Afghanistan and Iraq. The combination of an affordable aircraft, reasonable priced training for aircrews, straightforward maintenance and logistic requirements make it a great platform for economically unstable states. The long-term goal would be to deploy LAA for Irregular Warfare (IW) operations in the aforementioned states by their own aircrews, without direct support of Alliance aircraft.

Conclusion

The existing assets of 5th generation fighters, legacy fighters and UCASs are sufficient and adequately equipped to operate in the joint arena of battlespaces around the globe. However, there is a huge price tag attached to their capabilities, which quite often exceeds the perceived value of 'low-end' ground attack and support missions.

Comparing the cost and effort to operate LAA in a permissive low-threat environment, such as Afghanistan or Iraq, with the 5th generation fighter and even the legacy fighters, including the A-10 Thunderbolt II, shows that this alternative could pay off quickly. Not only in monetary terms, but also with efficiencies in personnel and equipment. The LAA will not be a substitute for 5th or even 4th generation aircraft, but could be an expedient and economical short-to-mid-term solution to support the right kinds of operations for a prolonged time frame.



An AT-6 Wolverine participating in the USAF OA-X programme.

The LAA concept offers great value for money. There are several fully developed, battle-tested and readily available airframes already serving as LAA. They support a variety of missions in operating areas which cannot be met by many other aircraft. This puts them in a top spot of the most efficient aircraft, tactically and economically. To benefit from the positive side effects ascribed to the fleet of legacy and 5th generation fighters, an expeditious procurement of LAA seems to be a solid solution. It would be an investment into saving on the defence budget of any military armed force. The aforementioned OA-X programme in the US characterizes the urgency of the matter. The programme is down to two aircraft, the A-29 Super Tucano and AT-6 Wolverine. More testing was done during the second phase of OA-X experimentation, from May to July 2018, to expedite the procurement process and purchase the first aircraft in 2019. The LAA is a cost-effective solution for an enduring niche need, and it seems to be a wise approach to explore this capability as a way to get more combat capability out of limited budgets. ●

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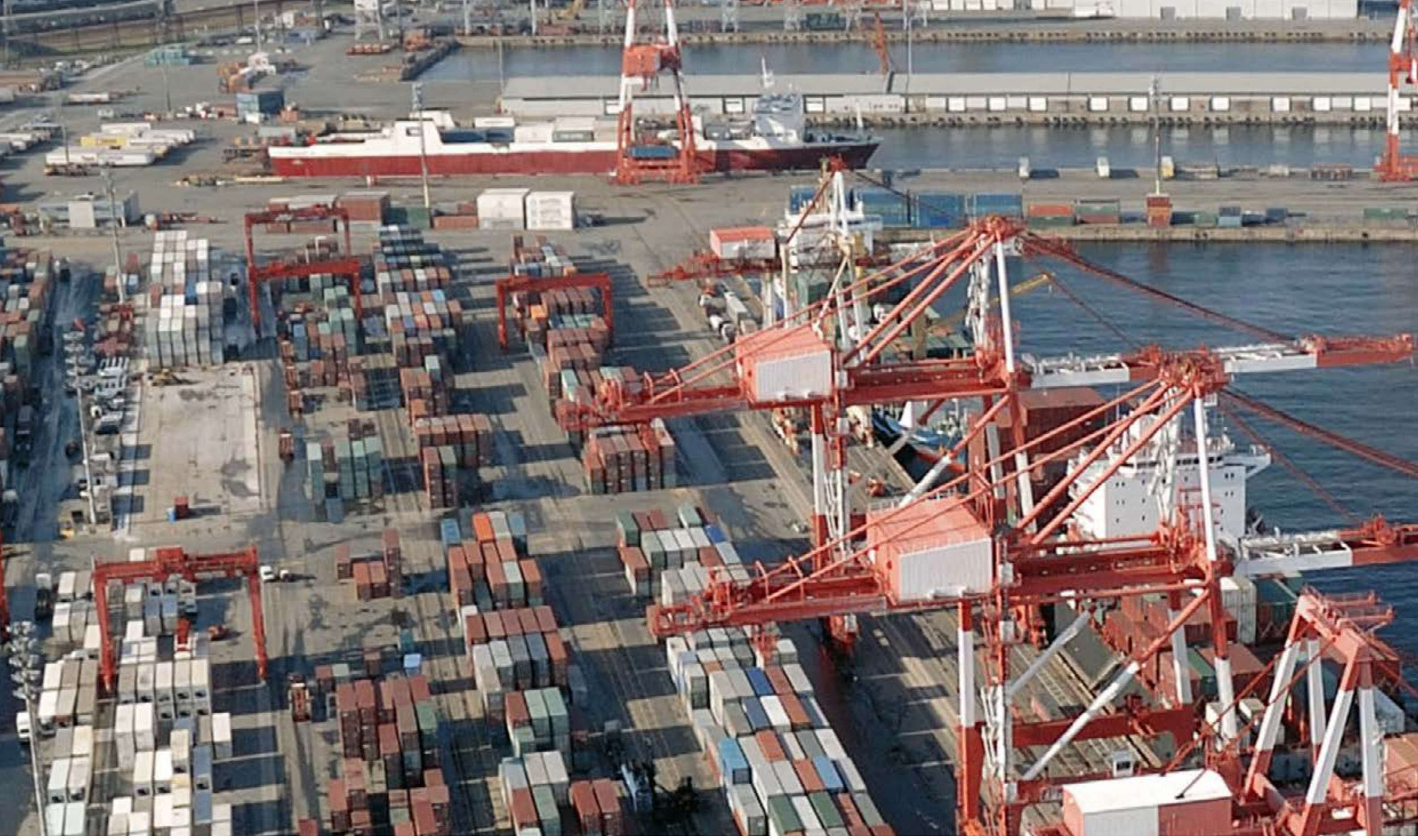
Major Daniel Wagner

joined the German armed forces in 1999. He completed his aviation training at Pensacola Naval Air Station in 2003 to become a Weapon Systems Officer on the TORNADO. During his time in the squadron he became a Flight Safety Officer, a Tornado Instructor, participated in several Flag exercises as well as the TLP flying course and deployed to AFG. In October 2017 he joined the Assessment, Coordination & Engagement branch at the JAPCC in Kalkar.



Rotary Wing Unmanned Aerial Systems

Market Snapshot and Support for Maritime Operations

By Lorenzo Fiori, Strategy and New Initiatives, Leonardo Company Helicopter Division

Introduction

Unmanned Aerial Systems (UASs) are proliferating across the spectrum of military and civilian fields. NATO has recognized the importance of these systems, and is transforming to take advantage of them. Various NATO and non-NATO organizations are working the complex issues associated with UAS operations within the Alliance[1]. As the current levels of global market adoption show[2], UASs can meet many of the most challenging requirements of both civilian and military operators. However, factors such as public acceptance, technological progress, cost, and operational requirements will probably impact the way the UAS market will evolve, and potentially lead to commanders employing UAS in missions that only manned platforms executed in the past. Leonardo Helicopter Division (LHD), part of Leonardo S.p.A, is a designer and manufacturer of helicopters (branded 'Agusta Westland') and Rotary Wing Unmanned Aerial Systems (RUASs). As the following paragraphs of this article will cover, LHD, which has been investing in Unmanned Aerial Systems since 2010, firmly believes that RUASs will play a fundamental role in a variety of maritime missions in the future.

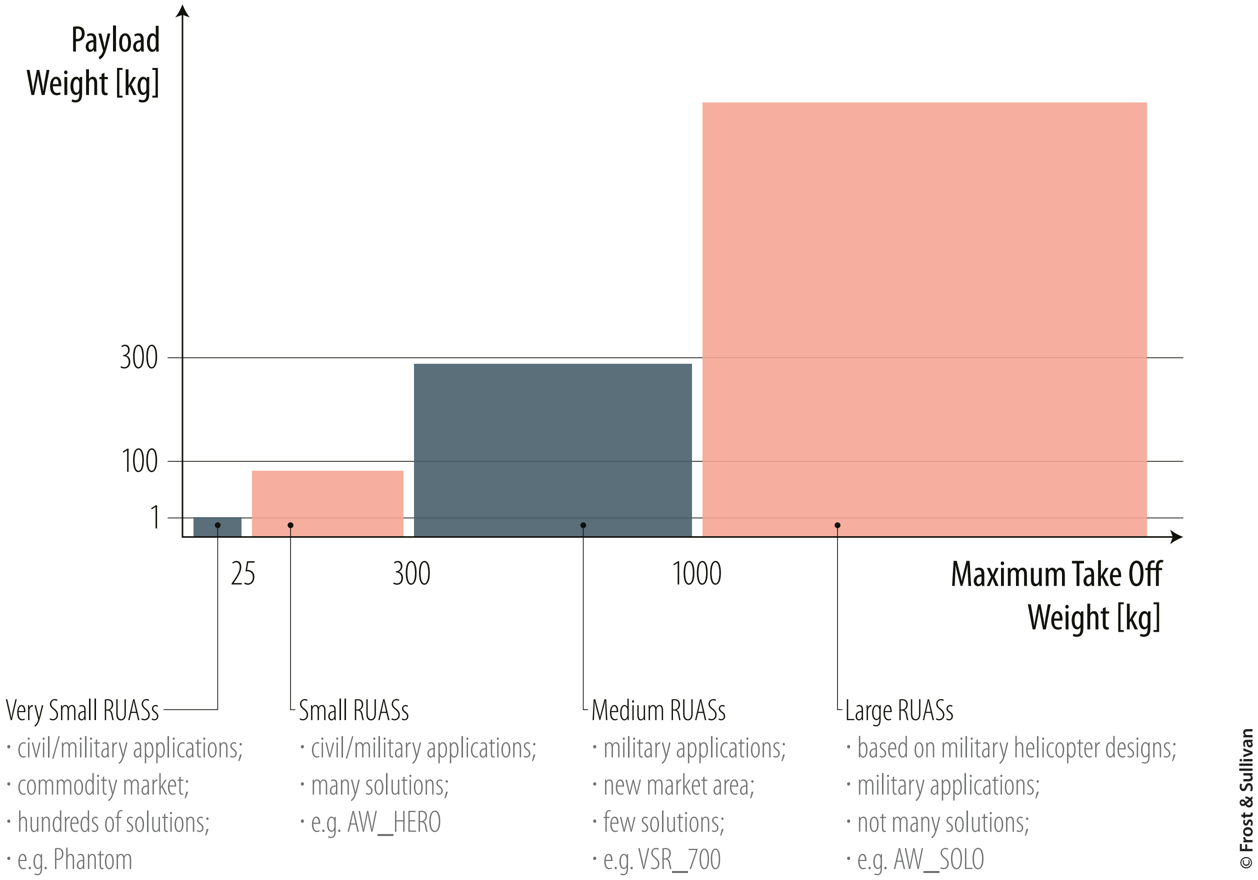


Figure 1: RUAS market segmentation in terms of Payload Weight and Maximum Take Off Weight.

A Brief Introduction to the RUAS Market

The 'Maximum Take-Off Weight' (MTOW) and the 'User Type' are two useful indicators for analysing the RUAS market with a good level of granularity. In terms of weight, four MTOW classes embrace the whole RUAS market spectrum adequately as depicted in Figure 1 on page 65.

On the other hand, from a 'User Type' perspective, one can divide the RUAS market into three segments: military, dual-use operations, and civilian.

'User type' and 'weight class' combinations are synonyms of operations which can be rather different one from each other. While the operation peculiarity may not support RUAS design commonality across MTOW classes and segments, one concept appears to have general validity: regardless of the mission, future RUAS users will task engineers to find technical solutions capable of minimizing costs while guaranteeing interoperability and adequate performance compared to manned helicopters.

In terms of prospective trends in market demand, military, governmental, and civilian customers adopt 'very small' RUASs mostly for land requirements, while 'medium' and 'large' RUASs currently find limited requests. Comparatively, requests for 'small' RUASs to deploy for military and governmental naval applications, such as Intelligence, Surveillance, and Reconnaissance (ISR) missions and border control roles, are growing. In LHD's view, while the use of 'small' RUASs might expand to the civilian segment as well, military and governmental customers could, in the medium term, evolve and deploy bigger RUASs on a wider scale for land and naval resupply missions, or for high-end naval warfare missions, e.g. Anti-Submarine Warfare (ASW)[3].

Focusing on military and governmental customers, and analysing concepts of operation in terms of scenario intensity and mission complexity, LHD anticipates that manned helicopter operations will decrease in the long term. In particular, by 2035, the simpler the mission and the lower the scenario intensity – e.g. persistent ISR mission in law enforcement scenario – the higher the chances of UASs replacing manned assets completely. On the other hand, manned helicopters will increasingly work alongside RUASs exploiting Manned-Unmanned Teaming (MUM-T)[4] capabilities the more complex the mission and the higher the warfare intensity level. MUM-T is indeed a growing capability area, and thanks to advances in autonomous technologies, one expects MUM-T to deliver important operational and cost advantages in all operational domains.

RUAS Deployment in Naval Applications

Shifting the focus to the maritime domain, the interest in Vertical Take-off and Landing (VTOL) UAS design is gaining momentum in shipborne applications. While fixed-wing UASs still find their way into naval operations, but normally operate from ashore in support of the Maritime Command, VTOL RUAS designs can easily embark on a ship and operate directly from there with minimal, logistical impact. The introduction of various RUAS types into service over the last years, and the recent EU tenders related to maritime security (e.g. OCEAN 2020 programme), reinforce the emerging trend of resorting to RUASs for ISR and similar missions among military and governmental entities. In this perspective, and according to industry forecasts, while 'large' RUASs are already in service but have limited market, the demand for 'small' RUASs is experiencing a sharp rise due to balanced compromises among costs, performance, interoperability, and simplicity of operation.

In military and governmental maritime applications, 'small' RUASs need to meet a specific set of high-level requirements, such as minimization of the logistical footprint on ships, 5+ hours flight endurance, heavy-fuel compatibility, integration of modular payloads featuring a variety of sensors (e.g. radar, thermal and optical cameras, lasers, sniffers), and capability to perform automatic ship take-offs and landings under severe sea state conditions. In addition, requirements also can include integration with the ship's Combat Management System (CMS)[5], safe data dissemination towards any asset, and cybersecurity.

Engineers should design state-of-the-art 'small' RUASs in accordance with the strictest requirements that modern missions – environmental monitoring, ISR, and combat support (CS), for instance – demand today. Employing a RUAS for such missions would increase capability and minimize crew risks without demanding additional resources. For instance, while a single shipborne helicopter can only provide time-limited mothership ISR persistence, due to recurring maintenance needs, the combination of the same helicopter with a RUAS can lead to 24/7 ISR persistence at the same or even reduced overall cost – which means a net gain in operational capability while respecting the operational financial budget allocation. In other roles, like CS, a RUAS can operate and achieve a commander's desired effect without exposing operators and more costly assets to the potential consequences of an adversary's reaction.

In the future, 'small' RUASs could further evolve to integrate new payloads, expanding their operational reach to missions like Communication Relays, Mine Countermeasure Operations or ASW[6]. In this context, 'small' RUASs could insert and monitor sonobuoys in ASW missions, or support minesweeping sorties by means of an Airborne Laser Mine Detecting System (ALMDS)[7]. While integrating new payloads is strategically important, MUM-T will likely be crucial to further 'small' RUAS developments as well. In particular, MUM-T will permit mission execution in a collaborative way, thus increasing the time which operators of manned helicopters can devote to other high-value activities crucial to mission success. In addition, thanks to better situational awareness, MUM-T also will create a reduction in risk for manned assets and operators. It is worth mentioning that LHD's 'small' RUAS (AWHERO)[8] already can operate at a Level of Integration 3 (LOI 3) when teamed with manned platforms. This level of integration, out of the 5 LOI foreseen by STANAG 4586 as reported in the next table, means that a helicopter can receive data from the RUAS's payload and control the payload itself.

As previously mentioned, 'large' RUASs already are in use in naval military applications. Current rates of adoption are still limited though, and further acquisitions for complex warfare missions (e.g. ASW) or for ship-shore resupply roles likely will happen at a later stage. 'Large' RUASs surely would reduce the workload on manned helicopters, but this benefit comes at higher costs, complexity, and larger logistical footprints compared to 'small' RUASs. Notwithstanding these barriers, OCEAN 2020 demos, in which LHD will operate both 'small' (AWHERO) and 'large' (SW-4 Solo)[9] RUASs in various maritime missions, suggest that military and governmental users look at 'large' RUASs with

Level 1	Indirect receipt and/or transmission of sensor product and associated metadata, for example KLV Metadata Elements from the UAV.
Level 2	Direct receipt of sensor product data and associated metadata from the UAV.
Level 3	Control and monitoring of the UAV payload unless specified as monitor only.
Level 4	Control and monitoring of the UAV, unless specified as monitor only, less launch and recovery.
Level 5	Control and monitoring of UAV launch and recovery unless specified as monitor only.

Table 1: UAV Level Of Integration table as per STANAG 4586.

a certain degree of interest. As prospective customers understand the benefits of shipborne UAS, it is reasonable that engineers will conceive modern ship designs tailored for RUAS operations. RUASs also could be deployed aboard ships already in service. While UAS integration is reasonably straightforward in retrofit, small ship hangars, possible lack of space for new antennas or control stations, and potential impacts to the ship's Radar Cross Section (RCS) might pose the biggest barriers to RUAS adoption on older ships already in service.

Conclusions

Rotary Wing Unmanned Aerial Systems will play an increasing role in the naval domain, especially for military and governmental users. This could mean that RUASs will drive a more limited use of manned helicopters, with missions dictating if a manned helicopter is more practical or effective in that particular time or space than a RUAS. In 20 years' time, the end user will likely operate mixed manned-unmanned helicopter fleets for the most critical missions in medium-high intensity warfare scenarios, while for routine missions in more stable environments operators will more and more resort to RUASs only. Expected technological developments in the MUM-T domain, for areas such as sensor capabilities and artificial intelligence, almost certainly will induce cost reductions without being detrimental to operational capabilities. In addition, RUASs will mitigate both the risks and the workload of those who operate manned helicopters. 'Large' RUASs are already in service, but their use is currently limited only to major NATO navies. Conversely, the concept of 'small' RUASs for naval operations is gaining wider acceptance among the military and governmental communities. International demonstrations in the field of maritime security, such as the EU's OCEAN 2020 initiative, will help solidify RUAS acceptance through live testing of ISR, ship interdiction, and data dissemination profiles. The limited logistical footprint combined with capable sensors will allow 'small' RUASs to increase ship capabilities even on platforms with a small flight deck. In the near future, larger RUASs might gain wider market acceptance for complex missions such as Anti-Surface Warfare (ASUW) and resupply, but they will always operate from larger ships. ●

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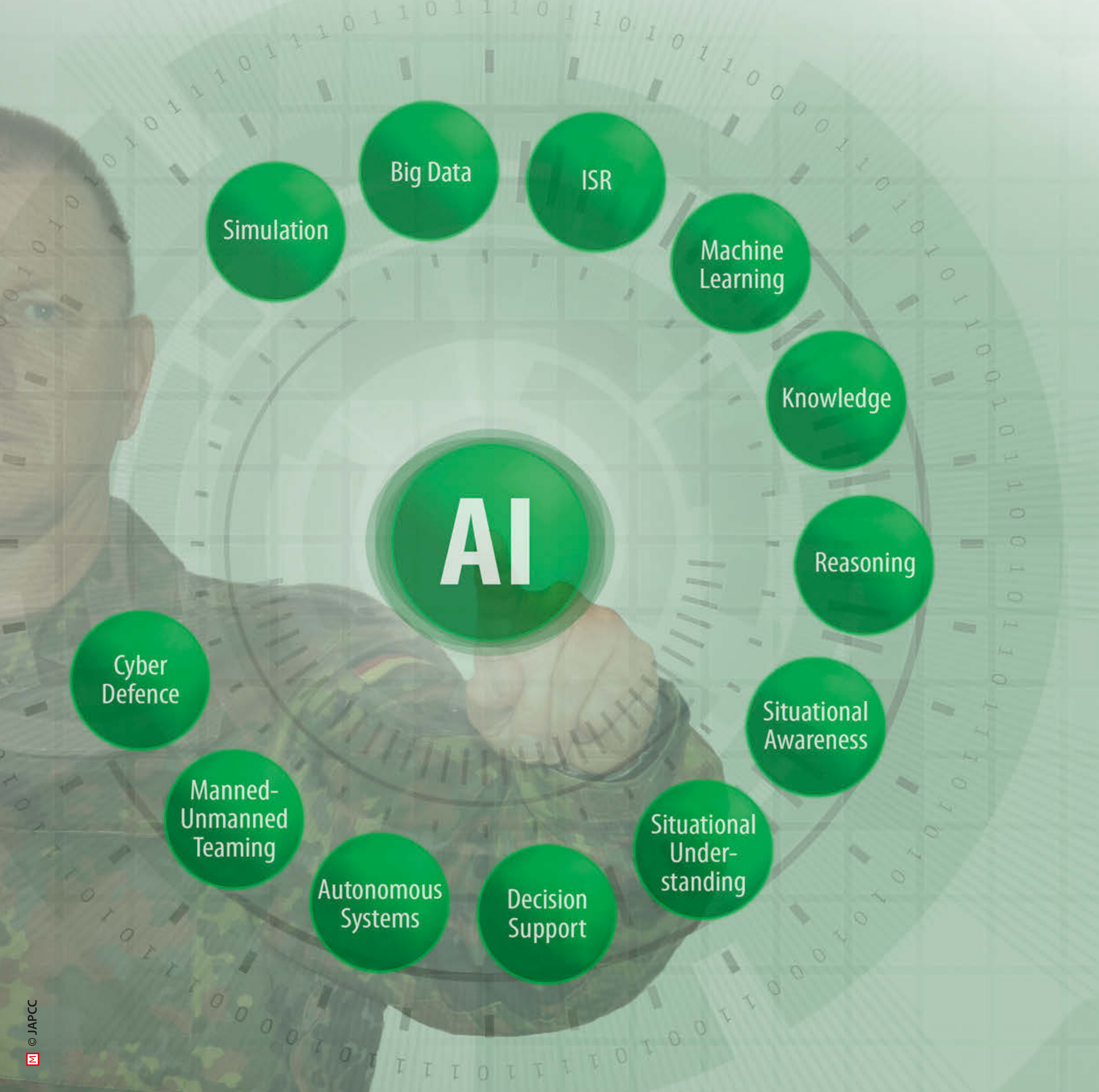
Lorenzo Fiori

is a mechanical and electronics engineer. He has worked in aerospace for more than 30 years for several companies, covering operational posts ranging from Engineering, QA, Marketing & Sales, Programme Management, and Operations. In 2007 he joined Finmeccanica (now Leonardo) with several appointments, starting as Chief of the Technical Office and later as Senior Vice President of Strategy. He also participated as a board member to some of the subsidiaries. Since July 2016 he is responsible for Strategy and New Initiatives within Leonardo's Helicopter Division.

The Future Role of Artificial Intelligence

Military Opportunities and Challenges

By Andy J. Fawkes, Consultant Thinke Company Ltd
By Lieutenant Colonel Martin Menzel, DEU A, JAPCC



Introduction

Artificial Intelligence (AI) today is one of the hottest buzzwords in business and industry, and it has military applications, too. In fact, industry has developed AI as a technology over the last 60 years, and periodically it becomes mainstream news. Progress has not always been smooth, particularly in the 20th century when funding for AI research was principally public sector, primarily aimed at academic research and the military. Enthusiasm waxed and waned, as AI did not consistently deliver the desired level of capability.

However, in the 21st century we have seen industries outside the defence sector, such as large Internet providers and companies in the automotive field, make significant contributions to AI development. These developments are of significant interest as they may provide answers how to further improve unmanned systems' autonomy, and improve our ability to process vast amounts of information and data better within military command and control (C2) systems.

The purpose of this article is to provide a basic understanding of AI, its current development, and the realistic progress that can be expected for military applications, with examples related to air power, cyber, C2, training, and human-machine teaming. While legal and ethical concerns about the use of AI cannot be ignored, their details cannot be discussed here because this essay is focused on technological achievements and future concepts. However, the authors will address the question of reliability and trust that responsible commanders need to ask about such AI applications.

Artificial Intelligence – What it is and What it is Not

The concept of what defines AI has changed over time. In essence, there has always been the view that AI is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. In common language, the term AI is applied when a machine mimics cognitive functions attributed to human minds, such as learning and problem-solving. There are many different AI methods used by researchers, companies, and governments, with machine learning and neural networks currently at the forefront.

As computers and advanced algorithms become increasingly capable, tasks originally considered as requiring AI are often removed from the list since the involved computer programs are not showing intelligence, but working off a predetermined and limited set of responses to a predetermined and finite set of inputs. They are not 'learning'. As of 2018, capabilities generally classified as AI include successfully understanding human speech, competing at the highest level in strategic game systems (such as Chess and Go), autonomous systems, intelligent routing in content delivery networks, and military simulations. Furthermore, industry and academia generally acknowledge significant advances in image recognition as cutting-edge technology in AI.

While such known and 'applied AI' systems are often quite powerful, it should be noted they are usually highly specialized and rigid. They use software tools limited to learning, reasoning, and problem-solving within a specific context, and are not able to adapt dynamically to novel situations. This leads to the term 'weak AI' or 'narrow AI'. Weak AI, in contrast to 'strong AI', does not attempt to perform the full range of human cognitive abilities. By contrast, strong AI or 'general AI' is the intelligence of a machine that could successfully perform any intellectual task that a human being can. In the philosophy of strong AI, there is no essential difference between the piece of software, which is the AI exactly emulating the actions of the human brain, and actions of a human being, including its power of understanding and even its consciousness.[1] In scholarly circles, however, the majority believes we are still decades away from successfully developing such a 'general AI' capability.

Military Simulation for Training and Exercise

A number of 'narrow AI' applications began to appear in the late 1970s/80s, including some for military simulation systems. For example, the US Defense

Advanced Research Projects Agency (DARPA) funded a prototype research program named Simulator Networking (SIMNET) to investigate the feasibility of creating a cost-efficient, real-time, and distributed combat simulator for armoured vehicles operators.[2] By 1988, a Semi-Automated Forces (SAF) or Computer-Generated Forces (CGF) capability was available to support more complex and realistic exercise scenarios with simulated flanking and supporting units that could be managed with little human resource requirement.

Meanwhile, various nations and companies developed their own SAF/CGF or constructive simulations[3], the majority of which are broadly interoperable and can be connected to other Live, Virtual, and Constructive (LVC) simulation environments. NATO air power, for example, is capitalizing on such capabilities with Mission Training through Distributed Simulation (MTDS), which has demonstrated reliable connectivity and beneficial training opportunities between multiple types of aircrew simulators and training centres.[4] In addition, since 2001, the Command & Control – Simulation Interoperation (C2SIM) data exchange standard offers existing command & control, communication, computers and intelligence (C4I) systems the potential to switch between interacting with real units and systems, including robotics and autonomous systems, and simulated forces and systems.[5]

From Remote-Controlled to Autonomous Physical Systems

Unmanned vehicle research has allowed state-of-the-art remote operations to progress significantly during recent decades, for both civil and military applications. The advance of AI, however, is now offering unprecedented opportunities to go beyond remote control and build autonomous systems demanding far less direct control by human operators. Examples of autonomous systems development include self-driving cars, trains, and delivery systems in the civil traffic and transport sector.

In the same way, the military is developing systems to conduct routine vehicle operations autonomously. For example, by 2014, the US Navy X-47B program developed an Unmanned Combat Air Vehicle (UCAV) that had completed a significant number of aircraft carrier catapult launches, arrestments, and touch-and-go landings, with only human supervision. In April 2015, the X-47B successfully conducted the world's first fully autonomous aerial refuelling.

The conduct of combat operations by autonomous systems, though, is greatly complicated by diverse legal and ethical issues that are far too complex to discuss in detail within this essay. Moreover, military commanders need to ask themselves how much trust they want to place in what the AI-enabled autonomous system promises to be able to do. How much better is it with regard to persistence, precision, safety, and reliability, as compared to the remote human operator? When it comes to kinetic targeting on the ground, the 'human-in-the-loop' being able to intervene at any time probably should remain a requirement.

Conversely, in the field of air-to-air combat, where millisecond long timeframes for critical decisions inhibit remote UCAV operations, there has been a recent and promising leap forward. In 2016, an alternate approach funded by the US Air Force Research Laboratory (AFRL) led to the creation of 'ALPHA', an AI agent built on high-performing and efficient 'Genetic Fuzzy Trees'.[6] During in-flight simulator tests it has constantly beaten an experienced combat pilot in a variety of air-to-air combat scenarios, which is something that previous AI-supported combat simulators never achieved.[7] While currently a simulation tool, further development of ALPHA is aimed towards increasing physical autonomous capabilities. For example, this may allow mixed combat teams of manned and unmanned fighter airframes to operate in highly contested environments[8], as further described below.

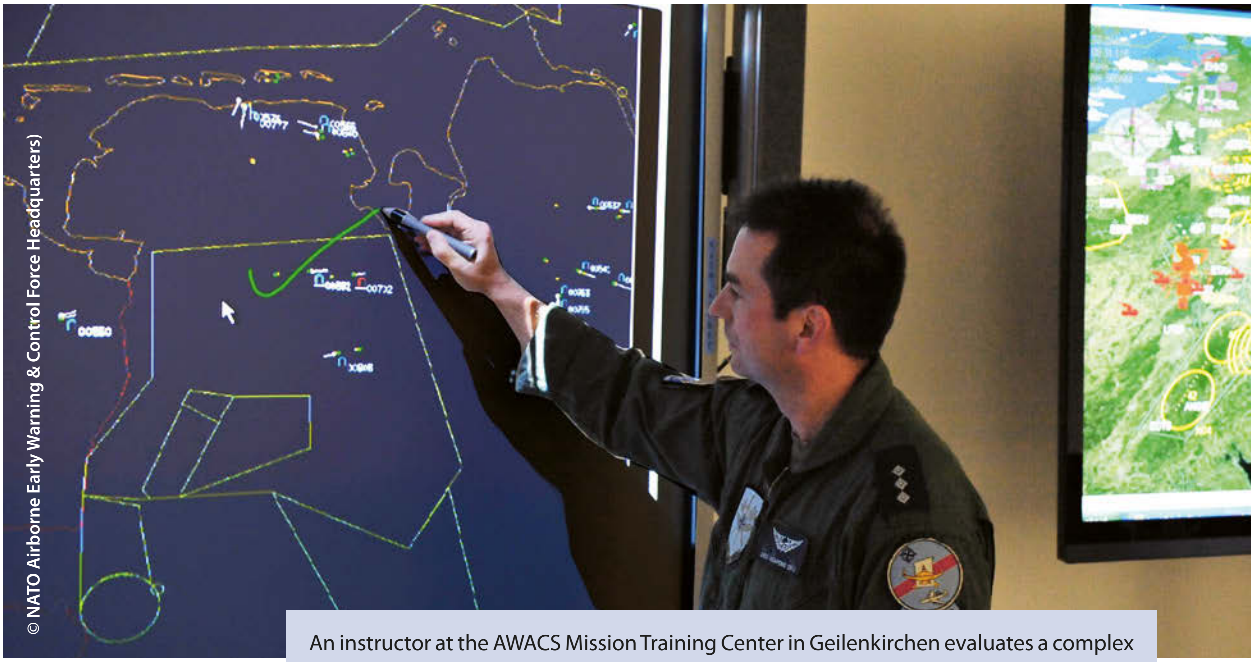
Human-Machine Teaming

A variation on the autonomous physical system and military operations with human-controlled vehicles is the manned-unmanned teaming (MUM-T) concept, which leaders deem to be a critical capability for future military operations in all domains. Some nations are currently testing and implementing diverse configurations to improve the following: pilots' safety, situational awareness, decision-making, and mission effectiveness in military aviation. The US Army has been conducting MUM-T for some time – most notably involving Apache helicopter pilots controlling unmanned MQ-1C Grey Eagles – and the Army will assign a broader role to MUM-T in the further development of its multi-domain battle concept.[9]

The US AFRL has been working on the *'Loyal Wingman'* model, where a manned command aircraft pairs with an unmanned off-board aircraft serving as a wingman or scout. In a 2015 live demonstration, a modified unmanned F-16 was paired with a manned F-16 in formation flight. In a 2017 experiment, the pilotless F-16 broke off from the formation, attacked simulated targets on the ground, modified its flight pattern in response to mock threats and other changing environmental conditions, and re-entered formation with the manned aircraft.[10] USAF planning foresees future applications pairing a manned F-35 Joint Strike Fighter with such an unmanned wingman.

In the above test scenario, however, the unmanned F-16 conducted only semi-autonomous operations based on a set of predetermined parameters, rather than doing much thinking for itself. The next technology waypoint with a more demanding AI requirement would be *'Flocking'.* This is distinct from the 'Loyal Wingman' concept in that a discernible number of unmanned aircraft in a flock (typically consisting of a half-dozen to two dozen aircraft) execute more abstract commander's intent, while the command aircraft no longer exercises direct control over single aircraft in the flock. However, the command aircraft can still identify discrete elements of the formation and command discrete effects from the individual asset. A futuristic video published by AFRL in March 2018 shows an F-35A working together with six stealth UCAVs. The AFRL has also released an artist's concept of the XQ-58A 'Valkyrie' (formerly known as the XQ-222), a multi-purpose unmanned aircraft that team members are currently developing for a project called Low Cost Attritable Aircraft Technology (LCAAT).[11]

The third waypoint, *'Swarming',* exceeds the complexity of flocking, so that an operator cannot know the position or individual actions of any discrete swarm element, and must command the swarm in the aggregate. In turn, the swarm elements will complete the bulk of the combat work. For example, in October 2016, the US Department of Defense demonstrated a swarm of 103 'Perdix' autonomous micro-drones ejected from a fighter aircraft.[12] The swarm successfully showed



An instructor at the AWACS Mission Training Center in Geilenkirchen evaluates a complex scenario provided within Mission Training through Distributed Simulation (MTDS).

A US Navy X-47B stealth autonomous aircraft exercises touch and go landings on the aircraft carrier George H. W. Bush.

collective decision-making, adaptive formation flying, and self-healing abilities. While not primarily an offensive tool, there are a multitude of uses for such drone swarms, including reconnaissance and surveillance, locating and pursuing targets, or conducting electronic warfare measures. Furthermore the swarm could act as expendable decoys to spoof enemy air defences by pretending to be much larger targets.[13]

Evolution in Cyber and Information Operations

The application of AI and automation to cyber systems is the most immediate arena for evolution and advantage. The cyber domain's intrinsically codified nature, the volume of data, and the ability to connect the most powerful hardware and algorithms with few constraints creates an environment where AI can rapidly evolve, and AI agents could quickly optimize to their assigned tasks. With the growing capabilities in machine learning and AI, 'hunting for weaknesses' will be automated, and critically, it will occur faster than human-controlled defences can respond.

However, AI approaches alone have thus far failed to deliver significant improvements in cybersecurity. While the industry successfully applies deep neural networks and automated anomaly detection to find malware or suspicious behaviour, core security operator jobs such as monitoring, triage, scoping, and remediation, remain highly manual. Humans have the intuition to find a new attack technique and the creativity to investigate it, while machines are better at gathering and presenting information.

AI Support to C2 and Decision-Making

Military headquarters have largely moved from paper-based to electronic-based workflows. This, in-turn, adds information awareness but also data volume which the staff must manage. Future intelligence, surveillance, target acquisition and reconnaissance systems will generate even larger amounts of (near) real-time data that will be virtually impossible to process without automated support. At the same time, increasingly advanced, network-enabled, joint, and multi-domain capabilities will emerge, and a nation or coalition of nations will have these tools available for use in their own operations. For commanders to effectively orchestrate actions in such environments, they need situational understanding and decision-support on possible courses of action (COAs), their effects, and consequences. Improved data management and interoperability, data fusion, automated analysis support, and visualization

Artist rendering of some XQ-58A 'Valkyrie' autonomous systems, which are low-cost attritable aircraft designed to function as flock wingmen to manned aircraft in contested airspace.

technologies will all be essential to achieving manageable cognitive loads and enhanced decision-making. These critical capabilities are not only for commanders and headquarters staffs, but also for platform operators, dismounted combatants and support staff.[14]

Aside from traditional algorithms, simulation and AI are envisaged as tools that can enhance decision-making. However, related research and development are still in their infancy. Only recently, in 2017, the NATO Science and Technology Organization made *'Military Decision Making using the tools of Big Data and AI'* one of its principal themes. Following a call for papers, the organization collected many academic and expert views. To better define the task, some of these inputs started by breaking down John Boyd's well-known Observe-Orient-Decide-Act (OODA) loop – an abstract model generically embracing different types of military decision-making processes – and then assigned future required AI roles and functions to each of the OODA steps.[15]

Observe (sensing). Harvest data from a broad array of sensors, including social media analysis and other forms of structured and unstructured data collection, then verify the data and fuse it into a unified view. This requires a robust, interoperable, IT infrastructure capable of rapidly handling large amounts of data and multiple security levels.

Orient (situational understanding). Apply big data analytics and algorithms for data processing, then data presentation for timely abstraction and reasoning based on a condensed, unified view digestible by humans, but rich enough to provide the required level of detail. This should include graphical displays of the situation, resources (timelines, capabilities, and relations and dependencies of activities), and context (point of action and effects).

Decide (plan generation). Present a timely, condensed view of the situation, with probable adversary COAs and recommended own COAs including advice on potential consequences to support decision-making. To this end, it must be made possible to assess and validate the reliability of the AI to ensure predictable and explainable outcomes allowing the human to properly trust the system.

Act. As AI gets more advanced and/or time pressure increases, the human may only be requested to approve a pre-programmed action, or systems will take fully autonomous decisions. Requirements for such AI must be stringent, not only because unwanted, erroneous decisions should be prevented, but also because the human will generally be legally and ethically responsible for the actions the system takes.

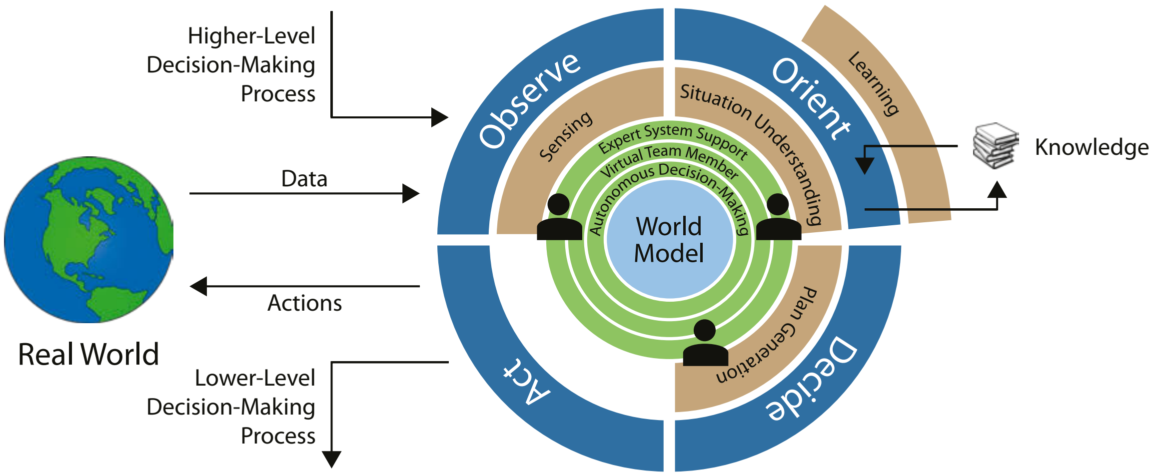


Figure 1: A system view of the OODA decision-making cycle supported by AI.
(Source: NATO Science & Technology Organization STO-MP-IST-160, graphic rebuilt at JAPCC.)

Summary and Conclusion

New AI technologies not only have potential benefits, but also shortcomings and risks that need to be assessed and mitigated as necessary. The very nature of AI – a machine that determines the best action to take and then pursues it – could make it hard to predict its behaviour. Specific character traits of narrow AI systems mean they are trained for particular tasks, whether this is playing chess or interpreting images. In warfare, however, the environment shifts rapidly due to the 'fog and friction of war'. AI systems have to work in a context that is highly unstructured and unpredictable, and with opponents that deliberately try to disrupt or deceive them. If the setting for the application of a given AI system changes, then the AI system may be unable to adapt, thus the risk of non-reliance is increased. In context, militaries need to operate on the basis of reliability and trust. So, if human operators, whether in a static headquarters or battlefield command post, are not aware what AI will do in a given situation, it could complicate planning as well as make operations more difficult, and accidents more likely.[16]

The increasing array of capabilities of AI systems will not be limited by what can be done, but by what actors trust their machines to do. The more capable our AI systems are, the greater their ability to conduct local processing and respond to more abstract, higher level commands. The more we trust the AI, the lower the level of digital connectivity demanded to maintain system control. Within this context it will be critical to develop the appropriate standards, robust assurance, certification regimes, and the effective mechanisms to demonstrate meaningful human accountability.[17]

That being said, there are important requirements for military AI applications that may render civilian technologies unsuitable or demand changes in implementation. In addition, further ethical and legal issues will often play an important role. Hence, defence organizations will have to make difficult choices. On the one hand, they must benefit from the rapid civil developments, while on the other hand, choose wisely where to invest to make sure that applications will be fit for military use.[18]

AI technology has become a crucial linchpin of the digital transformation taking place as organizations position themselves to capitalize on the ever-growing amount of data that is being generated and collected. Technology for big data and AI is currently developing at a tremendous pace, and it has major potential impacts for strategic, operational and tactical military decision-making processes. As such, operational benefits may be vast and diverse for both the Alliance and its adversaries. However, the full potential of AI-enhanced technology cannot yet be foreseen, and time is required for capabilities to mature. ●

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Andy J. Fawkes MSc MBA

began his career in 1979 in the UK Royal Corps of Naval Constructors, and after his training he worked on number of submarine projects and taught nuclear systems at the Royal Naval College Greenwich. Following several central MoD policy posts including HR and in the central MoD science staff he moved into the field of training and simulation in 2000. Since then he has held a number of positions including the MoD simulation policy lead, joint training systems sponsor, and the UK representative on the NATO Modelling and Simulation Group (NMSG) for 12 years, including 2 years as the Group Chair. On leaving MoD in 2012 he has been an independent consultant and regular public speaker on simulation and technology. He also provides consultancy support to Bohemia Interactive Simulations, a global provider of training simulation software and Ocean Software, which provides military air training and operations management software.

Lieutenant Colonel MBA Martin Menzel

began his military carrier in 1985, spending several years in the German Army Engineer branch, including positions as Company Commander and as Chief Instructor at the German Army NCO School. In 1999, he stepped over into the Military Intelligence branch. With a broad range of intelligence positions and functions held at Headquarters 1st German/Netherlands Corps, Joint Force Command Brunssum, SFOR, and ISAF, he became a highly experienced staff officer with regard to the conduct of military intelligence at the operational level in NATO or multinational staff environments. From May 2014 to September 2018, Lieutenant Colonel Menzel served as the JAPCC's Subject Matter Expert for Research, Analysis and Intelligence Support, and he also was the Assistant Editor of this journal.

The JAPCC Annual Conference 2018

The Fog of Day Zero – Joint Air and Space in the Vanguard

The JAPCC's 2018 Joint Air and Space Conference was held between 9th and 11th October in Essen, Germany. Attendees from across the NATO Joint Air Power community addressed the need for greater awareness of current threats and readiness to protect our assets from subtle, consistent, and often anonymous attacks going on below the threshold of Article 5.

This year's event was made possible through the generous support of 8 industry sponsors. It drew more than 280 attendees from NATO and partner nations as far away as Australia, Chilé and Peru, and included 55 General and Flag officers and senior civilians. Both days of the event were opened with keynote speeches by senior officers to set the stage for the subsequent panel presentations and discussions.

Underscoring the appropriateness of the conference theme, many panelists referred to the concept of *'Fog'* as the situation when it is not clear whether a nation is under attack, or from whom, due to the lack of conventional indications and warnings, and opinions varied about whether 'Day Zero' is the day the shooting starts, the day non-kinetic attacks are identified as such, or an ambiguous and perhaps lengthy period where destabilizing preparatory attacks may be taking place covertly. Legal concerns were discussed about adversaries' use of soft power and non-state actors as proxy organizations, the use of hybrid warfare and cyberspace to conduct attacks, and the thresholds that could trigger declaration of Article 5. There were many interesting discussions concerning reliance on the Space domain, in which the importance of developing a clear NATO policy was stressed.

Key questions debated during the event included not only how can Allied air and space power be utilized to deter or respond to new forms of 'attack', and how and when can new, non-kinetic forms of hostile activity be declared an 'armed attack', but also how can we protect our air and space operational and C2 capabilities in the face of 360-degree multi-domain threats from actors ranging from peer competitors to VEOs in a world where we no longer have a clearly defined front line and a secure 'rear' area?

A summation of the Conference discussions and suggested answers to some of these questions will be forthcoming in the soon-to-be-published *Conference Proceedings*. Next year's event will be held from 8–10 October 2019, again in Essen, Germany. We invite you to visit us and to watch for more information online at: www.japcc.org.

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Close Air Support Project

During the International Security Assistance Force and Operation Enduring Freedom missions in Afghanistan, many of the Tactics, Techniques, and Procedures, as well as Lessons Learned/Lessons Identified, were developed in a permissive air environment. In fact, over the past 20 years, the vast majority of NATO operations involving Air Power have enjoyed Air Superiority or, in some cases, even Supremacy. Because of this, NATO's Close Air Support (CAS) and Joint Terminal Attack Controller capabilities have matured along these lines.

However, over the last few years the strategic geopolitical environment has rapidly and dramatically evolved. Along with this shift came certain changes including a 'new' hybrid-warfare paradigm and the introduction of so-called Anti-Access/Area Denial (A2/AD) environments. This abrupt change of environment and perceived threats has provoked soul-searching in many mission sets, including CAS.

Energized by the burgeoning security changes in Eastern Europe, the NATO Wales 2014 and Warsaw 2016 Summits highlighted various capability shortfalls within NATO, including CAS. Specifically, a resurgent peer competitor (Russia) cast doubt on the Alliance's ability to conduct CAS in a challenged environment.

Therefore, based on a request from AIRCOM the JAPCC has undertaken a study which intends to address the future of CAS within the Alliance. Specifically, the project analyses CAS from historical and contemporary viewpoints and considers resources, both present and future, which may affect the effective execution of CAS. Lastly, the study makes specific recommendations to ensure the Alliance is prepared for CAS of the future.

The release of this project is planned for the first half of 2019.

The 2018 JAPCC Steering Committee and Senior Resource Committee

The JAPCC's Memorandum of Understanding requires regular meetings of the 16 Sponsoring Nations (SN) to provide strategic direction to the Director in order to optimize the effectiveness of the Centre and to approve budget and manpower matters. To this end, the JAPCC Steering Committee (SC) and Senior Resource Committee (SRC) meet annually at the Centre, where the SN Air Chiefs or their representatives review the previous year's work with the Directorate and set the course for the future of NATO's sole Joint Air and Space Power Centre of Excellence.

In June of this year, the SC was chaired by JAPCC Director, General Tod Wolters and the SRC was chaired by Brigadier General Burkhard Kollmann. Convened at the Centre's home base in Kalkar, Germany, the committees reviewed the 2017–2018 Program of Work, and directed future lines of effort considering myriad current and emerging challenges to NATO security. The SC also celebrated the fact that all signatures necessary to welcome Denmark into the JAPCC family were submitted to Allied Command Transformation. The occasion was marked with a small ceremony at the iconic JAPCC Tail Fin which now reflects Denmark as a full Sponsor Nation. Delegates were impressed by recently published JAPCC studies, including the newly approved NATO Joint Air Power Strategy and the follow-on Air Level of Effort (Air LoE) study. The Air LoE project has been endorsed by Allied Command Transformation and the Military Committee, and is currently informing the development of NATO Political Guidance for 2019. Delegates directed the JAPCC to continue taking on projects consistent with strategic guidance from the NATO Summits but also to inform future projects with the impact of emerging technologies like 3-D printing and artificial intelligence.

During his welcoming comments, General Wolters remarked, 'If we don't have bright minds and smart people who are thinking at 2030 and beyond we will never get out in front of potential adversaries.' As a strategic think tank, the JAPCC regularly produces forward-thinking documents that inform the choices of senior civilian and military policymakers in NATO and the Nations. The JAPCC currently has 33 Subject Matter Experts (SME) dedicated to increasing Allied readiness and effectiveness by working with national and international organizations at the tactical, operational and strategic levels. Good news was received when Greece declared its intent to send an additional SME to Kalkar in 2019, and Italy announced it would shift an overhead position to a SME position, bringing the total number of active SMEs at the JAPCC to 35. However, JAPCC still has 13 additional positions unbid, and 10 that are bid by SNs but are currently unfilled. Some of these vacancies are in areas that a recent SACT report identified as areas needing more attention, including ISR, Electronic Warfare, and Integrated Air and Missile Defence/Ballistic Missile Defence.

Both SC and SRC delegates expressed gratitude and praise for the year's hard work on the part of JAPCC SMEs. The SRC noted another year of cost savings which will be credited to the nations. The Committee also approved the 2019 budget.

In his closing remarks to the Steering Committee, General Wolters remarked 'We are far and away the most powerful Alliance in the history of humanity.' He further encouraged the delegates, 'As misaligned as we think we are, our alignment is tremendous and I think we all recognize that as a strength.' ●

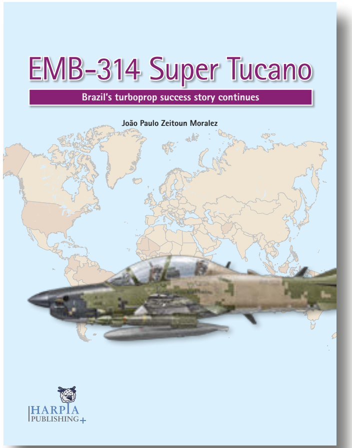
JAPCC Staff Ride – Battle of Arnhem

The yearly JAPCC Staff Ride is an integral part of the JAPCC Education and Training (JET) programme. The purpose of the JET is not only to introduce the JAPCC newcomers to the organization and equip them with the necessary skills to operate as effective staff members, but also to provide regular and continuous training for the established JAPCC staff members.

This year's Staff Ride took place on 19 September 2018 and was hosted by a senior member of the JAPCC, who prepared a remarkable battlefield tour in the area of Arnhem. His great historical background knowledge of the Battle of Arnhem and the area laid ground for a great educational experience for all other JAPCC members. The battlefield tour took place in the same week in September as allied operation 'Market Garden' in 1944, which underlines the accurate planning and guidance by the 'Tour Guide'. The ride commenced at one of the landing and drop zones, where the 1st British Airborne Division and the 1st British Airlanding Brigade landed on Sunday 17 September 1944. Next stop was the bridge of Arnhem, where the British Forces, under the command of Lieutenant Colonel John Frost, fought a fierce battle with the German Forces. Following the trails of the battle westward, the tour stopped at the house where Major General Urquhart had to hide in an attic from the German Forces on his way back to his Headquarters at Hotel Hartenstein, which was also the final stop of the battlefield tour. There, in the village of Oosterbeek, the airborne troops established a perimeter around their HQ, but finally had to retreat across the Rhine River after the battle was lost. Paying respects to the fallen soldiers and the laying of a wreath the military cemetery of Oosterbeek completed the informative tour.

The JAPCC members found the Arnhem staff ride extremely informative as many were not aware of the details of the severe battle that was fought here and the subsequent impact it had on Allied operations in the autumn of 1944. Many lessons were identified with regards to planning, intelligence, airborne operations, air-land integration and sustainment operations. These lessons were considered quite valuable by all participants in the Staff Ride.

'EMB-314 Super Tucano – Brazil's Turboprop Success Story Continues'



By João Paulo Zeitoun Moralez, Harpia Publishing L.L.C., 2018

Reviewed by:
Maj Daniel Wagner, DEU AF, JAPCC

'EMB-314 Super Tucano – Brazil's Turboprop Success Story Continues' describes the successful transformation of the Brazilian Air Force from the EMB-312 Tucano to the EMB-314 Super Tucano, and its worldwide success story. The author divided the book into four chapters, in which he provided great insights into the challenges faced during the development and introduction of the Super Tucano. The vital necessity in the Brazilian Air Force to improve its existing air fleet generated an aircraft of great versatility combined with low cost per flying hour. This combination made the Super Tucano a prominent choice for the air forces of smaller countries, which the book describes in further detail.

The great reliability of the EMB-314 Super Tucano, combined with its latest achievements in several crisis areas, proved its worthiness, and provided the foundation for further flight testing in the US Air Force.

The reviewer highly recommends this compact – but very informative – book for all military aviation fans. The detailed technical information and the artwork described in the appendices of the book, particularly, make it a 'must-read' for light-attack aircraft enthusiasts. ●

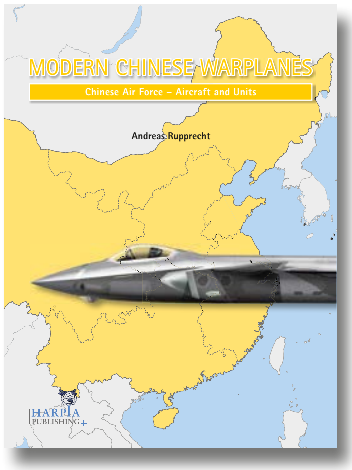
'Modern Chinese Warplanes: Chinese Air Force – Aircraft and Units'

This comprehensive and compact directory entitled 'Modern Chinese Warplanes – Chinese Air Force, Aircraft and Units' by Harpia Publishing offers a magnitude of detailed facts alongside numerous illustrations and covers a new era of Chinese air power. This recently released publication expands upon the previously published version (2012) and provides more depth and insight into Modern Chinese Air Power to a degree of detail that was previously unavailable.

In this volume, new updates reveal recent reforms and modernizations of the People's Liberation Army Air Force (PLAAF) which provide the most significant changes since its foundation 69 years ago. This thoroughly revised edition is organized in three parts: the most important military aircraft and their weapons found in service today; aircraft markings and serial number systems; and orders of battle for the PLAAF.

Practical and well-structured. The level of accuracy is impressive in an all-encompassing manual cataloguing military aircraft and the weapons found in Chinese service today.

A good reference, and a good read for analysts, and Subject Matter Experts alike! ●



By Andreas Rupprecht, Harpia Publishing L.L.C., 2018

Reviewed by: Mr S. J. Ingram, Chief Publications, Promotions & Communications, JAPCC

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