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Losing the Squidgy Bits



skwidzi – ADJECTIVE, British, informal: soft and wet and changing shape easily when pressed... In the best traditions of form following function, nature abhors not only straight lines but also “squidgy bits”. The latter are, by way of a definition, the soft, squeezey and generally unwanted parts of – often – a living thing, but “squidginess” is a quality found abundantly if not popularly. In humans as in other mammals and in birds, squidgy bits are best avoided, and indeed the fittest are generally the most fleet: a

cheetah at full speed, a hawk descending, or Usain Bolt are distinctly lacking in squidgy bits.

But despite the informality of the phrase, before discarding these thoughts as irrelevant to a professional, technically-minded defence magazine, consider how much squidginess is to be found in the world of defence – and particularly in the world of military aviation...

Before the occult world of advanced aerodynamics kicks in, an aircraft’s dynamic performance depends on its thrust to weight ratio. Setting the context, examples range from an Airbus A-380 at 0.227 to the Space shuttle, throttled back at 3.0: in between are more relevant aircraft such as the BAE Systems HAWK at 0.65, the Dassault RAFALE at 0.988 (fully loaded), the F-35 at 0.87 and the Eurofighter TYPHOON at 1.15. Of course, the devil is in the detail, and not all these figures are directly comparable, but looking at the broader trends it is clear to see a move towards lighter aircraft, lighter engines, and greater thrust for a given engine weight or mass. This is particularly true of spacecraft and rocket engines, but there is one major problem for combat aircraft designers and engineers: the squidgy bit in the middle...

The solution, of course, is to remove it, thus adding hugely to a given airframe in terms of thrust-to-weight, manoeuvrability, payload and survivability: without humans on board our weapon systems become far more efficient. No cockpit, no seats, no onboard oxygen, no life support, no g-force compromises...

There is of course the political / social acceptability discussion about having to have a “man-in-the-loop”, but that is an expedient diversion in order to a) reinforce our own ideal of our own humanity, b) salve our consciences when, inevitably, we lose control of our own technology and c) give our military and its hierarchy a place in future battlefields. The discussion is a double-edged sword, and ultimately a lie, and here’s why:

War is something to be avoided. If it can’t be avoided, then it’s something to be prosecuted with maximum effort and all available resources until the desired outcome is achieved. That means it needs to be done efficiently, and air domination, with uncompromised weapon systems, is quite probably a pre-requisite. Keeping the squidgy bit in the middle is not.

Stephen Barnard

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Generation X: Thoughts on the Future of Combat Aircraft

Ulrich Renn

Air forces and producers of military aircraft on both sides of the Atlantic have started to look at a new generation of combat aircraft. In Europe, France and Germany have recently signed an agreement to develop a common successor for the RAFALE and TYPHOON. Meanwhile, in the United States, the first ideas about aircraft that might follow the F-22 RAPTOR and the F-35 LIGHTENING II are emerging.

Today, F-22 and F-35 are generally regarded to be fifth-generation aircraft, whereas RAFALE and TYPHOON are seen as members of an earlier generation (4+). This signifies that the development of their respective successors will not start at the same point. It is, therefore, not certain that

ture. This is justified by the fact that the specific capabilities of radar sensors (very long range, precise three-dimensional target acquisition and tracking, robust all-weather capability) make them sensors of choice for airspace surveillance as well as for air-to-air and surface-to-air combat.

by several magnitudes smaller than that of previous designs. Even though it was possible to enhance this effect by using radar absorbing material (RAM), Overholser was very clear that an aircraft's form was the most important factor, stating that the four principles of stealth were "form, form,



Photo: Eurofighter GmbH / Armée de l'air

France and Germany are planning a common successor for the TYPHOON and RAFALE.

"X" will stand for the same number and that the next generation of combat aircraft will have the same capabilities on both sides of the Atlantic. Still, it is possible to identify a certain range of technologies and other factors that will have an influence on Generation X.

Low Observability

Together with sensor fusion and multi-platform networks, low observability (or stealth) is generally regarded to be a defining feature of fifth-generation combat aircraft. In a general sense, stealth aims to reduce all tactically relevant signatures. The majority of stealth features that can be found on today's combat aircraft, however, are designed to reduce their radar signa-

Effective protection against detection by radar sensors, therefore, offers significant tactical advantages. Moreover, advocates of radar stealth say that a comparative level of protection against detection of other kinds of aircraft signatures (optical, infrared or acoustic) would – if at all possible – require extensive, complex and costly technical measures which, due to the smaller range and lower precision of related sensors, would have a much smaller tactical significance.

In 1975, Denis Overholser, an engineer with Lockheed's Skunk Works, developed a programme based on the works of a Russian mathematician that made it possible to design a flyable airframe composed of plane surfaces and sharp edges which had a radar cross section that was

form, and material". Further insights into the math and physics of stealth and the emergence of more powerful computers enabled designers to increase the effectiveness of stealthy designs while avoiding extreme aircraft shapes (like that of the F-117 NIGHTHAWK). Still, designing an aircraft with a very small radar cross section will necessitate compromises in other areas of this aircraft's performance.

At the same time, there have been advances in the field of RAM, resulting in more effective paints or coatings with micro structures which better absorb or deflect radar energy. Furthermore, current forms of RAM are more resilient against the wear and tear of daily flying operations, decreasing maintenance costs and increasing aircraft availability. Finally, so-called "meta materi-

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The F-117A NIGHTHAWK, the first operational stealth aircraft

Photo: Northrop Grumman



The B-2 SPIRIT, the best possible shape for a stealth aircraft

Photo: Lockheed Martin



The F-35 LITENING II during a test flight with external stores

als” promise new and extended capabilities for future designs. Active Frequency Selective Surface Materials (AFSS), for example, consist of an extremely thin layer of semiconductors that is flexible enough to be applied to an aircraft’s skin. The AFSS will register and identify incoming radar signals and send a custom-fashioned reply that renders the original signal ineffective. Other forms of active coatings might even enable suppression or “cloaking” of IR and optical signatures.

Currently, a subsonic flying wing is regarded to be the best possible form for a stealth aircraft. This kind of design enables capabilities that obviously fit the role of long-range strategic bombers well. The US Air Force seems to be sufficiently satisfied with the B-2 SPIRIT to select a similar design, the B-21 RAIDER, as its successor. The same cannot be said for fighters or fighter bombers. Therefore, F-22 and F-35 show greater similarity to their predecessors, F-15 and F-16, than the B-2 to the B-52. Despite the fact that the designs of fifth-generation fighters and fighter bombers seem to compromise stealth for the sake of better agility, both the F-22 and the F-35 have been criticised for being unable to dominate fourth-generation rivals in visual-range air-to-air combat. Regardless of the degree to which this may be justified, it still shows that high aerodynamic performance and very low observability are competing design principles. Stealth fighters are at their best when avoiding early radar detection is more important than high agility, namely in beyond-visual-range air-to-air combat or when penetrating sophisticated integrated air defence systems.

The high level of agility required for fighters and fighter bombers also means that their overall dimensions have to be comparatively small. Non-stealthy designs compensate for this by carrying major portions of their fuel and weapons as external stores. External stores and stealth, however, are incompatible. In order to be stealthy, an aircraft must carry fuel and weapons internally, which reduces their range and be ameliorated by as well as the number of targets that can be hit by a single sortie. This can only be ameliorated by changing the overall nature and composition of air operations. Employing “arsenal aircraft” to increase the number of available weapons and tankers to extend range and endurance will provide some solutions, but it also creates new challenges if these aircraft are not as stealthy as the ones they are supporting. Current ideas seem to centre on employing stealth aircraft as a kind of “vanguard” penetrating an opponent’s defences and using their sensors and networking capabilities to find, identify and

New European Fighter Jet: The Clock is Ticking

A dynamic world full of challenging transformations calls for new answers and solutions. The German Federal Ministry of Defence (BMVg) has clearly defined necessary measures for effective air space protection: A family of systems composed of manned and unmanned platforms, dubbed Future Combat Air System (FCAS), should be developed to gear air defence in Germany and Europe. It should live up to tomorrow's requirements as well as replace the weapon systems currently in military service. The Next Generation Weapon System (NGWS), a new fighter jet, will be an essential element of the FCAS. A suitable, all-new high-thrust engine is also needed to power it.

The Project Must be Kicked off Today to Have the NGWS Operational by 2040

"Past experience shows that it takes around 20 years to develop a new fighter jet before it can enter service," says Michael Schreyögg, Chief Program Officer at MTU Aero Engines, Germany's leading engine

The industry expert says this is important, as it would allow direct contact with the customer and ensure their requirements are fully met. More partners could be invited to join in at a later date.

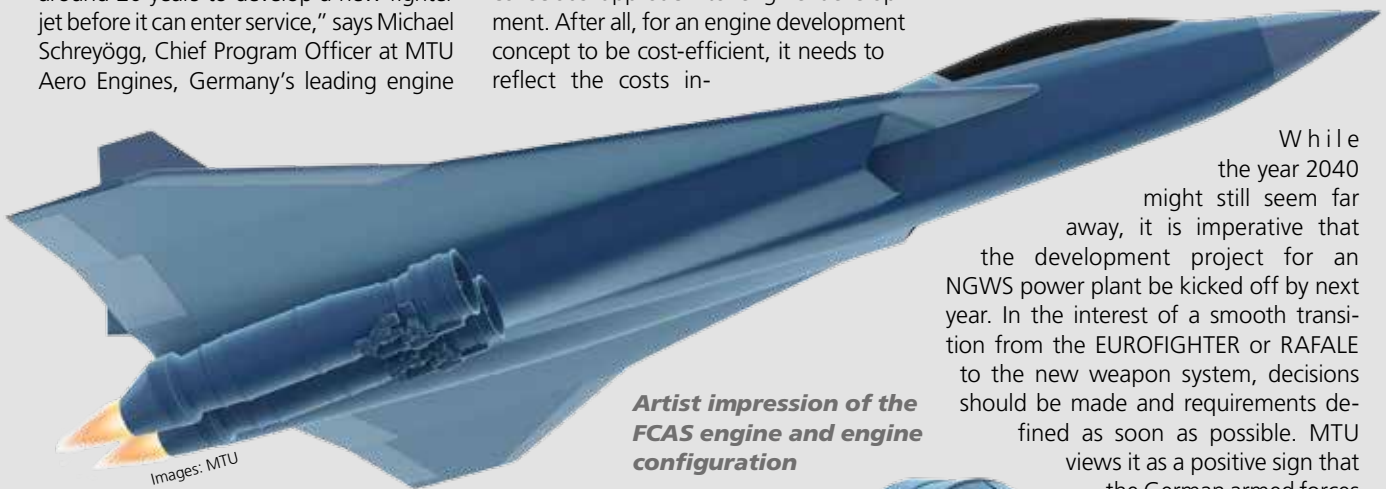
As a manufacturer with full systems integration expertise and comprehensive experience in the field of managing European partnership projects, MTU is ready to go right now. The company is extremely familiar with the technological requirements of next-generation engines and has the organisational structures in place to be able to offer tailor-made service support concepts. Using an engine health monitoring system, the company's experts can evaluate the sensor data transmitted from the engine and detect potential failures so that corrective action can be taken before a problem occurs. This reduces the number of repairs and increases engine availability. In fact, the engine of the future will come with an even higher number of sensors – decisive in perfecting engine analysis.

This advanced system is only one example of MTU's comprehensive and cost-conscious approach to engine development. After all, for an engine development concept to be cost-efficient, it needs to reflect the costs in-

Technology Development, a Field in which MTU Excels

The experience gained in these programmes is highly valuable, for instance in the development of a new compressor or control unit. MTU can draw on a wealth of experience in the military sector and on its unique expertise in the field of low-pressure turbines for commercial engines, an area in which the company is the global technology leader. In addition, the company places a strong focus on cutting-edge technologies and new materials, some of which are already in use today. These include ceramic matrix composites (CMCs), additive manufacturing processes (3D printing), virtual design and manufacturing (digital twin) and augmented reality (AR) technologies, to name just a few. These innovative materials and methods help save time – and costs – in production, assembly and maintenance.

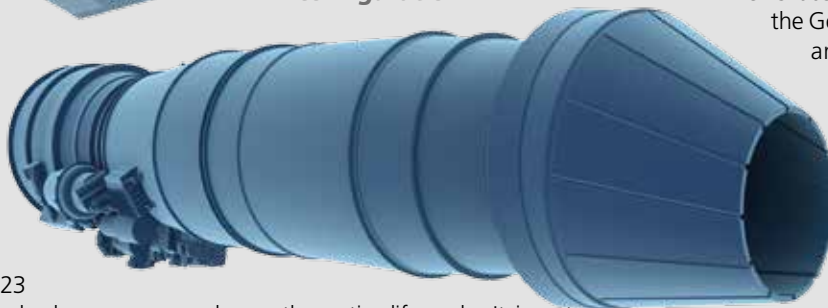
MTU is Ready – Decisions are Needed soon



Artist impression of the FCAS engine and engine configuration

While the year 2040 might still seem far away, it is imperative that the development project for an NGWS power plant be kicked off by next year. In the interest of a smooth transition from the EUROFIGHTER or RAFALE to the new weapon system, decisions should be made and requirements defined as soon as possible. MTU views it as a positive sign that the German armed forces and policy-makers are willing to consider the company's propositions for an exclusive Franco-German partnership as well as separate contracts for the airframe and the engine. Given the tight schedule, the important thing now is to move forward with defence budget decisions and define clear responsibilities for efficient project management. Only then can the development of the new engine pick up speed.

manufacturer. To ensure the operational readiness of the new weapon system from 2040, prototype engines need to be available as early as in 2031, and the type certification process for the engine must start in 2023 or 2024. In turn, the necessary budgets will have to be adopted by the end of 2019, at the latest, to allow participants to develop the requisite technologies without incurring undue risks. Schreyögg favours a Franco-German partnership with clearly defined decision-making structures. He expects that separate contracts will be awarded for the airframe and the engine.



curring over the entire life cycle. It is not least because of this mind-set that MTU has become the industrial lead for practically all engines in the German military's service. The company also has key roles in the most important European engine programmes, for example the EJ200 powering the EUROFIGHTER and the MTR390 for the TIGER helicopter.

track targets and communicate the results so that other assets can engage them from comparatively safe positions.

Using active sensors and communication systems, however, creates more challenges for stealth aircraft, since electromagnetic emissions are also not stealthy. The use of passive sensors to detect aircraft via their emissions is increasing, and the performance of these sensors will keep improving. The counter to this is to equip aircraft with Low Probability of Intercept (LPI) emitters. Typical LPI technologies are agile waveforms, adaptive management of emitter output or random search patterns. Progress in reducing the electronic signature of aircraft can, however, be neutralised by similar progress in electronic reconnaissance.

Similar challenges to stealth arise from advances in radar technology. The flexibility of AESA antennas as well as increased computing power and more effective signal processing algorithms enable low-frequency radars, bi-static radars and passive radars to detect objects with very low radar cross sections at tactically meaningful ranges and track them with enough precision to allow airborne or ground-based weapon systems to engage them. Passive radar is particularly challenging for stealth, since it can use a range of frequencies, is by nature bi- (or even multi-) static and – by virtue of the comparatively low-powered general terrestrial broadcast emitters that it uses – has to use receivers and signal processor algorithms that can detect targets that



Photo: Boeing

Even the “venerable” B-52 is considered an “arsenal aircraft”.

reflect only very small amounts of energy. Even firm advocates of stealth agree, therefore, that the survivability of future combat aircraft in high-threat environments cannot rely exclusively on stealth, but will require other ways and means to “manage aircraft signatures”. Related capabilities include specific tactics and flexible in-flight mission planning based on situational information gathered by on- and off-board sensors to avoid threats as well as advanced Electronic Warfare (EW) to suppress them.

Advanced Electronic Warfare

Since the Second World War, EW has been an important element of air operations. It is characterised by a permanent, increasingly complex and costly competition between Electronic Countermeasures (ECM) and Counter-Countermeasures (ECCM), one striving to prevent the detection of aerial targets and the other to ensure it – neither of them being able to secure lasting dominance. “Cognitive EW” stands for the latest round in this struggle which is just beginning. Its opponent is “cognitive radar” which stands for radar systems that, in simple terms, can employ machine learning processes to detect and track even very-low-energy returns that conventional radars would miss, particularly before a background of ground clutter or interference. Today, the development of ECM starts in a laboratory environment, where the results of electronic reconnaissance are analysed and then used to create or modify the programming of onboard EW systems (“programmed EW”). The flexibility and enhanced capabilities that come with AESA antennas, modern signal processors, increased computing power and smarter algorithms, however, make it possible to change signal characteristics and operating modes of radars ad hoc and in rapid succession. This would require the self-protection of combat aircraft – be it stealth, EW, or (most likely) a combination of both – to provide targeted, effective responses to these changes while they happen. The segment of the electromagnetic spectrum in which stealth will be effective is decided during

the design of an aircraft and can – if at all – only be modified by very costly and time-consuming design changes. Likewise, the current sequence of events necessary to change the properties of EW systems (reconnaissance, analysis, programming, roll-out) is not nearly agile enough to follow rapidly changing electronic threats in “real time”. Hence the desire to move from programmed to cognitive EW.

Cognitive EW is another application of machine learning. It uses elements of the probability theory and statistical modelling to enable EW systems to learn in a similar way to living beings, that is, to gain experience from a continuous stream of stimuli (or data). Consequently, it also begins with reconnaissance. A large network of Signal Intelligence (SIGINT) sensors (ideally all platforms would be equipped to contribute) gathers large amounts of data on possible electronic threats. This stream of data is used to create comprehensive threat emitter libraries and to determine the probable success rates of certain types of countermeasures against certain classes of emitters. This constantly growing stock of knowledge enables a cognitive EW system to compare a newly detected unknown threat to classes of known threats and determine the counter measures which – according to prior experience – promise the highest probability of success. Even if the reaction of a cognitive EW system will not be ideal on first contact with a new threat, it will improve with further iterations – not least due to information sharing within the EW network.

Enhanced Combat Effectiveness

The effectiveness of combat aircraft rests on two pillars. First, the performance of the aircraft itself must be sufficient to prevail against opposing combat aircraft and integrated air defence systems to the extent necessary to reach the target area and return safely to base. Then, it must be equipped with a range of weapons which enable it to neutralise or destroy a wide range of different targets with a high prob-



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ability of success and a level of risk to itself or collateral damage to others that is as low as possible.

Stated requirements for levels of aerodynamic performance of combat aircraft that exceed those achieved by fourth-generation aircraft are rare. Likewise, there are few, if any, new groundbreaking aerodynamic concepts. “Supercruise” may be an exception to this rule. It stands for the ability to fly supersonic without (permanent) use of afterburner. Some aircraft of the newer generations, like the F-35 and Eurofighter TYPHOON, are already able to do this – if with some restrictions and only in certain low-drag configurations. Supercruise is likely to remain a very desirable capability, since it increases an aircraft’s energy level for air-to-air combat, reduces the time available for opposing systems to engage and enhances the kinetic potential of onboard weapons. In addition to a low-drag airframe, it requires first and foremost very powerful engines. Additionally, in order to preserve the aircraft’s performance with respect to range and endurance, these engines should still have low fuel consumption.

There is a new type of engine expected to deliver this – the Adaptive Cycle Engine (ACE). Today’s fixed cycle engines are optimised either for high thrust (turbojet – military) or low fuel consumption (turbofan – commercial). ACE can vary their cycle (the ratio of air flowing through the engine core to air bypassing it), allowing them to work either as turbojets or turbofans depending on the performance required during a certain stage of flight. Furthermore, new materials, like ceramic matrix composites, and techniques to produce complex engine components, like 3D printing, create new options for higher engine temperatures as a prerequisite for further increases in fuel efficiency.

Practically all major engine producers are researching the possibilities of ACE. Since 2006, General Electric has been involved in two DOD-financed research programmes resulting in an engine that is expected to deliver 20% more thrust while saving 25% of fuel. For a typical tactical fighter, this would translate into a 35% longer range or 50% longer endurance. This kind of performance increase without the need to carry more fuel on the aircraft would mean a significant boost to the effectiveness of all smaller combat aircraft – in particular smaller stealth designs like the F-35.

Beyond ACE, one finds development programmes for engines for extreme applications like hypersonic flight or flights transiting between the higher reaches of the atmosphere and low orbit space



The sensors of the EOTS (Electro-Optical Targeting System) on the F-35

Photo: Lockheed Martin



An example of an advanced workstation for RPA operators

Photo: General Atomics

(such as the ESA-sponsored Synergistic Air-Breathing Rocket Engine, SABRE). The numerous technical challenges still to be mastered make it unlikely that these projects will have a direct influence on the next generation of combat aircraft. For the next decades, hypersonic flight in particular is going to be found in missiles rather than aircraft, even if occasional references to a “Hypersonic Global Strike Force” can be found in US sources.

During the last two to three decades, western combat aircraft have been employed predominantly in asymmetric conflicts. These conflicts generated specific requirements for aircraft weapons, albeit not to the extent that they would not apply to other forms of conflict in a similar way. High precision and scalable weapon effects, both instrumental to avoiding collateral damage, will continue to be essential properties of air-to-ground weapons. The revival of NA-

TO’s attention to the demands of Collective Defence and an increased possibility of air operations in contested airspace will, however, also move stand-off capabilities (back) into focus. Long-range stand-off weapons allow non-stealthy aircraft to engage heavily defended targets with acceptable risk levels, and they can also be used to extend the relatively short range of some stealth fighters. Lasers are about to become a truly new element in aircraft weaponry. Several US manufacturers are working on high-energy lasers that could be employed by aerial platforms against air and ground targets. The intended installed power ranges from 60 kW to more than 100 kW and fieldable solutions could become available as early as 2022. Due to the fact that lasers place high demands on scarce aircraft resources such as space inside the airframe, power supply, or cooling means that smaller combat aircraft will probably see lasers first as external

stores. This does not apply to larger aircraft. An AC-130 equipped with a variant of General Atomics' High Energy Liquid Laser Air Defence System (HELLADS) may become the first tactical aircraft to field an internal laser weapon.

Lasers offer the advantages of invisibility and silence, making it harder to spot the aircraft firing them. Most importantly, they offer a "store of ammunition" that is limited only by an aircraft's ability to generate the necessary power. In the extreme, this could make a long-held dream of air operations planners come true: in-flight rearming – maybe by using a process similar to today's air-to-air refuelling. In any case, lasers offer advantages when it comes to engaging a large number of (smaller) targets in a short time and at low cost. This could be an option to give stealth fighters a "deeper arsenal" or to overcome the often-lamented mismatch between the high price of sophisticated guided weapons and the comparatively low value of certain types of targets.

The power output of current lasers is still so low that they need to be focussed for a longer period of time (several seconds) on precisely the same spot on the target in order to destroy a more resilient structure. If a fast-maneuvring fighter aircraft fires a laser at a similar target, that places very high demands on all technical components involved in tracking the target and pointing the laser. Even if all technical challenges involved in this process are mastered, this could still require the firing aircraft to adopt a tactically disadvantageous behaviour that would not be necessary when firing a fire-and-forget missile. Therefore, the tactical viability of laser weapons as main armament for combat aircraft will depend to a large extent on the ability of future lasers to discharge an amount of energy that will destroy larger or more resilient structures faster than today.

Sensor Fusion and Netcentric Operations

The F-35 is generally regarded as the new benchmark when it comes to the number of onboard sensors and the degree to which data from these sensors is fused. At the same time, the F-35 can transmit its sensor data to other members of a network as well as receive data from off-board sources and fuse them into a comprehensive and seamless onboard situational picture.

The final aim of netcentric command and control is to create tactical- and operational-level networks that will include all assets in a theatre of operations regardless of the type of system, domain, or level of command. Such a network would allow the creation of a theatre-wide common

situational picture as a basis for a significantly accelerated command and control cycle. But a network of this size would likely include hundreds of nodes which would generate enormous amounts of data that could only be handled in a meaningful way with the help of algorithms that can send each node the right kind of data with a degree of detail appropriate for its function and level of command. A combat aircraft operating in such an environment needs robust on-board computing power as well as access to large bandwidths and high data transfer rates, which would also result in the further complication of already very complex system software.

If the effectiveness of a combat aircraft depends significantly on its ability to remain in more or less permanent contact with an overarching network, this again raises the question of its electronic signatures. Stealth aircraft need LPI communication in order to

struggle, adequate protection of networks may not be possible and that means that future combat should not lose the ability to operate successfully in an autonomous mode.

Optimal Man–Machine Interfaces

Using data from its own sensors as well as feeds from other members of its network, the F-35 can collect large amounts of situational information about a wide area around the aircraft. Displaying such a complex three-dimensional situation to the crew with the aid of predominantly two-dimensional displays remains a major technical challenge. It still requires a major breakthrough if using the wide range of situational information available on the aircraft is to become as intuitive as "looking out of the cockpit".



Photo: DARPA

DARPA uses its "Gremlin" project to explore manned–unmanned teaming.

retain their tactical advantage. The F-35 is equipped with a Multifunction Advanced Data Link (MADL) which is said to have LPI characteristics; due to its low power output, however, it can only be used within a tactical formation and not to communicate with the extended operational environment. For the latter purposes, the F-35 still uses Link 16, which is certainly not optimised for LPI. Concepts for LPI long-range communication equipment are still hard to find (at least in open sources), although some solutions seem to arise from the use of new waveforms enabled by Software Defined Radios (SDR).

Regardless of the kind of solution that can be found for the communication in long-range networks, it has to be resilient against EW and cyber-attacks. Realistically, it cannot be expected that there will be a single solution which could solve this problem for a longer time period. Rather, this will be another field in which measures and countermeasures follow one another in an endless struggle. At any given point in this

In any case, future crews will be forced to invest much more of their work into managing and assessing information. This would be aggravated by having to facilitate control of "unmanned wingmen". To avoid an overload (particularly on single seaters), aircraft manufacturers have started to introduce numerous automated assistants that will relieve the crew of some (routine) flying tasks.

Under the term Aircrew Labour In-Cockpit Automation System (ALIAS) the US Defence Advanced Projects Research Agency (DARPA) is developing a modular system of automated assistants that can be adapted to a specific type of aircraft (even legacy aircraft) and mission which can take over aircrew tasks from take-off to landing, including the handling of emergencies. The final stage of this development could be a fully-fledged "digital co-pilot" that could be assigned tasks by the aircraft commander and handle them autonomously.

If future combat aircraft will be flown to a large extent by automatons, this begs the



Photo: Luftwaffe

Schematic of a tactical-operational-level network

question if they need to be manned at all or if they should be Remotely Piloted Aircraft (RPA). This will not free developers from the need to design a man-machine interface that would allow remote operators to acquire a degree of situational awareness that would let them cope with complex situations. But any technical solution would not have to satisfy the stringent requirements set for airworthy equipment, fit into a tight fighter airframe, work with limited energy supply and cooling or withstand the stresses of the airspace environment.

Physically separating aircraft and aircrews on a large number of platforms will, however, increase the volume of data to be handled by tactical and operational networks significantly. Everything that an “on-scene” crew experiences or does would need to be transformed into data streams and transmitted from and to the unmanned platform. The higher the number of unmanned platforms in the fleet, the higher the demand on bandwidth and data transfer rates – unless better algorithms for data compression and a higher degree of autonomy for the unmanned platforms provide some relief.

The dependency of unmanned platforms on wireless networks intensifies the question of network resilience against EW and cyber attack. The current generation of RPA has yet to be operated in complex hostile electronic environments. So, there are no practical impressions of the limitations this would entail. But it can be expected that a certain level of autonomy would be required as a last resort to ensure a degree of effectiveness or at least the recovery of the platform.

Ideas of what constitutes an autonomous unmanned weapons system are still rather diverse. A position paper from the British MOD chooses a very demanding definition, according to which autonomous weapon systems should be able to understand the

intention of a higher echelon and transform it into corresponding actions on their own. It is obvious that such complex demands can only be satisfied by systems with a high degree of Artificial Intelligence (AI). They call for learning systems that can develop solutions for the challenges posed by their missions autonomously.

There are already some developments in the field of unmanned flying platforms that rely on a degree of (AI-based) autonomy that goes considerably beyond that of today’s RPA. Unmanned combat aircraft, like the nEUROn by Dassault, the TARANIS by BAE or the X-47B by Northrop Grumman, are meant to fly missions in highly contested airspace where a permanent controlling influence from an external source may be impossible or undesirable. On top of this, they are expected to show more adroit and complex tactical behaviour than long-range cruise missiles, since their mission requires them not only to engage distant targets, but also to return safely to base.

Manned-Unmanned Teaming (MUM-T) will hardly be possible if all unmanned wingmen would have to be controlled (all the time) like RPA. Rather, it can be assumed that the effectiveness of MUM-T will depend on how well a large number of unmanned wingmen can support a rather small number of human teammates by intelligent autonomous action. An even stronger pull towards more autonomy originates from swarming technology. Here, a large number of very small (micro) unmanned platforms work as a swarm that – like swarms of insects, birds or fish – organises itself, including the assignment of tasks to its members – nations, the machine to machine.

In the western nations, the prevailing opinion stipulates that for legal and ethical reasons humans must play a decisive role in the planning, execution and control of operations of unmanned platforms – in particular, when they involve the use of deadly

force. The exact limits of the relevant legal and ethical norms are, however, hard to define. The distinction between whether an automated system is just supporting a human decision maker or whether it decides a life-and-death matter on its own is hard to make. In view of an increasing number of automated assistance systems, this will apply similarly to manned aircraft. Another difficulty arises from the fact that the development of AI is still in its infancy, which makes it hard to determine the level of performance that will be typical for AI systems in their maturity. Currently, many people consider AI to be (at least potentially) dangerous and even some influential members of the science and technology community, like Stephen Hawking, Elon Musk or Steve Wozniak, have called for a ban or at least stringent limits on the development and use of AI in weapon systems.

Complexity and Availability

The majority of fourth- and fifth-generation combat aircraft are multirole aircraft. This has been caused by a continuous development which saw ever-increasing – if operationally justified – requirements leading to increasingly complex and costly components, subsystems and entire aircraft. The resulting higher prices, in conjunction with limited defence budgets, have led to decreasing volumes of aircraft buys, loading a constant or even increasing number of tasks on a smaller number of airframes. This, in turn, again causes rising requirements which lead to higher prices and even smaller buys for the next generation.

Today, this effect is most pronounced in the area of weapons system software. In modern combat aircraft, operation of the aircraft itself (flight-related software) as well as all of its major subsystems (mission-related software) are controlled by software. The enormous volume of lines of code required as well as the high degree of integration, caused by the need to interconnect practically all aspects of aircraft operation, has made software issues the most prominent cause for time and cost overruns in aircraft development, despite conscious efforts of governments and industry to increase the reliability and efficiency of procurement processes.

Due to the complexity of combat aircraft and the high demands of modern sophisticated components and materials (such as RAM), maintenance and repair has become another area that consumes more money and time than before. Therefore, some fourth-generation and practically all fifth-generation aircraft show availability rates that stay stubbornly below the levels typical

for earlier generations and will not allow a comparable intensity of flying operations. In peacetime, low availability endangers aircrew training and proficiency levels: on operations, it reduces fleet performance and endangers mission success.

Consequently, there are many demands to break the upward spiral of complexity and cost and make future combat aircraft simpler and more affordable in order to bring the fleet sizes and availability of Generation X back to acceptable levels. Most ideas centre on reducing complexity by distributing tasks onto a larger number of specialised platforms – many of which should be unmanned. Unmanned platforms designed to handle a narrowly limited number of tasks can be expected to be relatively cheap. If they can be teamed with manned platforms that do not replicate their specific functions, thus becoming less complex and cheaper themselves, this should lead to overall reduced procurement and operating costs for the entire fleet. Seeing that Generation X is anyhow foreseen to operate as part of a tactical/operational network, a solution of this kind would not go against current developmental trends and promises to deliver unimpaired performance – provided the network's completeness, integrity and resilience against EW and cyber attack can be ensured.

Conclusions

In spite of the undisputed fact that a low radar signature will always be a significant tactical advantage in beyond-visual-range combat, it appears that even in the US, stealth is no longer generally regarded as a condition sine qua non, worth even painful compromises in other areas of aircraft performance. If evolving threats mean that the survivability of future combat aircraft hinges on forms of self-protection that are highly adaptable and responsive, then stealth – as we know it – can only make a basic contribution, and other ways of “managing signatures” become more important. Regardless of the effort put into stealth, air forces will also have to invest heavily into staying up front in EW (such as by exploiting cognitive approaches) and into keeping their tactics and their training in line with the changing characteristics of aerial combat. The designers of Generation X will, therefore, have to answer the question concerning what kind of investment in stealth – in the form of cost and compromise – will offer the right return to ensure optimal performance of their fighter force as a system.

Cognitive EW is one of several areas where the future will be decided to a large extent

by the technical as well as the legal and ethical limitations that will govern the use of AI. Basically, self-protection systems are non-lethal subsystems, thus they should fall into a field where AI is given a rather free rein. The same could be said for assistance systems like the digital co-pilot or software to ease the control of large numbers of unmanned platforms. But the discussion about where the assistance ends and unwanted autonomous decision making begins is going to persist – at least in countries that tend not to take a question like this lightly. Nor should it be taken lightly. If technical progress keeps advancing unregulated at current speeds, this has the potential to become a life-and-death question for human beings sooner rather than later.



Photo: Luftwaffe

Notional elements of the German variant of the Future Combat Air System

Speed and high agility are the foundation of defensive and offensive airborne combat power. Since compromising these capabilities will lead to tactical inferiority, their demands should retain a greater influence of combat aircraft designs than more peripheral qualities (like stealth). This must not mean that Generation X will replace supercruise with hypersonic flight. It will remain a challenge to fit an engine capable of developing the required thrust plus the fuel required to sustain it for an operationally meaningful length of time into a typical fighter airframe.

Similar obstacles confront the use of lasers as primary aircraft weapons. Only when it becomes feasible to generate a significantly higher amount of laser energy within the confines of a fighter airframe (or its external weapon stations) will the laser start to replace the automatic cannon and the guided missile. Until then, the laser is going to remain an add-on for purposes merely supporting main combat roles.

The fusion of sensor data is already a very important capability and will certainly stay that way. However, an ideal way to display the resulting flood of situational informa-

tion so that its interpretation becomes easy or even intuitive, has yet to be found. It is possible that, even for Generation X, the supply of information may still exceed the possibility to display them in a way that prevents overloading the capacities of human crews. Better displays alone will probably not suffice, but the development of intelligent assistants may provide a way.

Future air weapons systems are frequently seen not as single platforms but as systems of systems (such as the Future Combat Air Systems, FCAS, being considered in France, Germany and the United Kingdom). Concepts like this are basically well suited to support plans to distribute the multirole capabilities of current complex manned combat aircraft onto a system of more spe-

cialised, less complex and – to a large extent – unmanned, promising lower cost for procurement as well as operation of a fleet as a whole. To deliver all functions necessary to complete a given task, a complete system (all necessary functions covered) of these platforms would have to cooperate via comprehensive tactical and operational level networks with an assured resilience against EW and cyber attack.

Thus, the security and dependability of networks becomes a critical path. Without it, some if not all elements of the FCAS would need a residual capability for autonomous operation. A viable autonomous combat aircraft that could prevail in demanding future environments, however, would most likely not be less complex and, therefore, incur greater – not smaller – lifecycle costs than current fighters. If Generation X cannot break through the lamentable spiral of rising requirements, increased single platform complexity, increasing lifecycle cost and decreasing fleet sizes, it will be very hard – if not impossible – to come back to aircraft availability rates that will allow an intensity of flying operations that satisfies all demands of training and operations. ■

Modern Aircraft Integration into NATO Air Operations

Werner Hartwig

Force multipliers like the F-35 require a realignment of tactics, techniques and procedures for the Allied Air Command. NATO needs to rethink how it uses its air resources.

Aircraft such as the F-35, or F-35B, assembled outside the United States rolled out of the Final Assembly and Check Out facility at Cameri, Italy, on 5 May 2017. In the same year, on 3 November 2017, Norway welcomed its first three F-35 JOINT STRIKE FIGHTERS to Orland Air Base. These are highly newsworthy events in the world of combat aviation, because 5th-generation aircraft, herein called Modern Aircraft, take multi-role aircraft versatility, performance and survivability to the next level. As the F35s unfold their mission roles, they offer an unparalleled step change in NATO's ability to dominate the air domain in support of its collective defence mission and deterrence posture.

As NATO's only air-domain headquarters, Allied Air Command's primary operational role is the force employment of NATO forces assigned to it in peacetime. With the introduction of Modern Aircraft into NATO nations and the pending offer of Modern Aircraft for force employment, it is incumbent upon Allied Air Command to assess the impact of the developing tactics, techniques and procedures as they relate to the integration of Modern Aircraft into, for example, European civil airspace. Allied Air Command must also assess the implication of Modern Aircraft on NATO training and exercises, as well as on concepts of operations for peacetime, crisis and conflict.

Author

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Photo: U.S. Air Force



The first F-35 LIGHTNING delivered to the US Air Force on 10 March 2014 at Luke Air Force Base

In addition to the training requirements, Allied Air Command has analysed the following key areas of its responsibilities and tasks that will be impacted by Modern Aircraft integration.

Air Policing

Supercruise capability and/or higher maximum speeds than currently observed will influence Air Policing procedures and techniques. Greater areas can be covered by fewer assets. Endurance and range are expected to increase, possibly reducing the number of assets required to cover a certain area of responsibility. The time from scramble to on-station will be reduced, which will likely impact the Readiness States, or reaction times, and could offer the ability to reduce the number of required Quick Reaction Alert locations. The faster cruising and maximum speeds of Modern Aircraft, complementary to increased range, could lead to a reassessment of optimal Quick Reaction Alert locations based on tactical and economic considerations. Fewer locations, while maintaining equal strength and coverage, may result in reduced overall expenses for individual nations. With their enhanced Identification capabilities, Modern Aircraft used in an Air Policing role might lead to a review of Identification definitions and criteria, given that advanced sensors are able to identify objects with a higher fidelity and at much longer ranges than the human eye, and regardless of environmental constraints. The definition and implementation of Visual

Identification might be adapted accordingly, so the entire Identification process within the air domain's Command and Control chain stands to benefit from these enhanced capabilities. Scrambles are part of the training requirements of NATO's Integrated Air and Missile Defence System with a focus on the Air Policing Command and Control system. Currently, nations typically use the same assets for both Quick Reaction Alert duties and as target aircraft to train Quick Reaction Alert aircrews. The use of Modern Aircraft assets in anything but the most advanced target-emulation role is an inefficient use of such high-capability resources and is of limited training value for experienced Modern Aircraft aircrews. As such, it is anticipated that those nations with Modern Aircraft on Quick Reaction Alert will turn to alternative, cheaper target-emulation solutions, such as legacy or contracted aircraft.

Command and Control Connectivity

A challenging area for all military operations is to keep up with developments in the field of modern Command and Control connectivity and interoperability. Modern Aircraft will be able to contribute to and provide unprecedented battlespace awareness. In order to take maximum advantage of the Modern Aircraft contribution to modern battlespace management capabilities, Allied Air Command needs to ensure the technical capabilities exist to communicate and exchange information with all integrated plat-

forms. These will include, but are not limited to, both technical and procedural developments within Tactical Data Link networks. Systems are being developed that allow Modern Aircraft to connect digitally to, and exchange data with, 4th-generation aircraft and other platforms when operating in highly contested threat areas. These systems will operate through the existing Tactical Data Link platforms and will be able to connect with Modern Aircraft. This new "communications gateway" will have to be equipped with multi-level security features. Improved battlespace awareness through data sharing will provide a real-time Common Tactical Picture and Common Operational Picture. As the overall air-domain Command and Control entity, Allied Air Command will require the capability to initiate, manage, update, and have real-time access to modern Tactical Data Link networks. This will provide the real-time ability to update Air Task Orders, communications frequencies, and airspace, as well as providing the capability for real-time prosecution of Time Sensitive Targets and conduct of the Dynamic Targeting process.

Airspace

Increased Modern Aircraft sensor and weapon ranges will require larger training airspace. Given peacetime airspace assignment is a national responsibility, within the heavily congested European airspace (by both civil and military users), it will be a challenge to make available large, dedicated military training areas that are required to adequately train the very long Beyond Visual Range-capable air assets. The Single European Sky concept and development provides an option to become part of the solution. Early Allied Air Command involvement to anticipate Modern Aircraft airspace requirements is important, providing a strong supporting function to national efforts to secure adequate airspace for NATO training. Within the context of assigning airspace as military training areas, special attention will be required with respect to restrictions, such as supersonic flight, chaff/flare expenditure and threat emitters. Furthermore, airspace management within a joint network environment will necessitate a dynamic approach involving all joint stakeholders.

Exercises

Modern Aircraft participation in NATO exercises is forthcoming. National participation with Modern Aircraft in NATO exercises offers excellent mutual training with an opportunity to gain experience and capture lessons identified on Modern Aircraft integration



Photo: U.S. Air Force

F-22 RAPTORS and F-35A LIGHTNING aircraft fly in formation after completing a training mission over the Eglin Training Range, Florida, on 5 November 2014. The purpose of the training was to improve integrated employment of fifth-generation assets and tactics.

across the NATO air enterprise. Defining exercise scenarios to benefit Modern Aircraft aircrew training requirements will be based on offered capabilities and concepts of operations. Allied Air Command is already exploring options to adapt its exercises to accommodate Modern Aircraft training requirements from an Air Command and Control perspective. In its primary force employment role as the NATO Command Structure's Joint Force Air Component, Allied Air Command will be responsible for training assigned personnel in efficiently planning and tasking Modern Aircraft assets to permit their effective Air Command and Control. It is expected that, at least initially, Modern Aircraft coordination will be enabled by experienced Modern Aircraft liaison personnel providing expert guidance to ensure smooth integration into NATO's training environment.

Force Employment

Improved and new capabilities will lead to a reassessment of how NATO plans to employ its air assets. Depending on the threat and the environment, stealth characteristics and shared-sensor capabilities could mean that different numbers may be required to achieve the same effects, as 4th-generation aircraft and Modern Aircraft, working in mutual support, will be regarded as force multipliers. One force employment consideration is that the high cost and limited numbers of Modern Aircraft may cause them to be considered by nations as High-Value Assets. Therefore, the Risk Level determination process will likely be scrutinised by nations as closely as ever. The good news regarding risk, however, is that fewer assets may be required to achieve the same effects, and the improved capabilities of Modern Aircraft in a high-threat environment will increase asset and aircrew survivability.

Red Air Resources

The replacement of older fighter aircraft by 4th/5th-generation aircraft Aircraft will create a challenge with regard to so-called Red Air resources. The term refers to air-

craft flown in simulated opponent roles for training under combat conditions. With less tactical training value for aircrew flying as Red Air, nations will be more reluctant to offer their Modern Aircraft for this kind of support during international exercises. A dedicated Red Air flying unit, multinational, NATO or commercial, could be the most efficient and affordable solution to close this gap of Red Air resources. Even though the decision on standing up such a unit is a national and/or commercial decision, Allied Air Command involvement in the concept of operations, contracting, planning, tasking and execution will likely be essential for NATO. Multinational concepts like the C-17s on Pápa Air Base, a NATO unit like the Airborne Early Warning and Control Force in Geilenkirchen or the contracting of Electronic Warfare support services for NATO all provide existing, positive examples of similar arrangements.

Conclusion

With Modern Aircraft transitioning from concept to reality, these highly capable air-combat platforms are on the very verge of being operationally capable within a NATO context. It is doubtful that the next NATO operation involving air-combat assets will not include Modern Aircraft. As the most likely entity for NATO to be tasked to provide the Air Command and Control of these assets, Allied Air Command is leaning forward and dealing with the Modern Aircraft integration challenge in a highly proactive manner. Within the constraints of the complexities and challenges normally associated with the introduction of new technologies and capabilities, Allied Air Command's lead role is being supported greatly by a host of other outstanding, interested agencies, such as the European Air Group or the Joint Air Power Competence Centre. As these new, highly capable air assets become operational within NATO nations, Allied Air Command is committed to leading the integration of Modern Aircraft into the NATO air domain in preparation for the force employment in whatever role or mission they may be assigned. ■

Recognition of Military Aviation Authorities

Strengthening Cooperation, Developing Synergies, Saving Resources

Luftfahrtamt der Bundeswehr

In order to increase the efficiency of European cooperation with respect to military capabilities and armaments, the current coalition agreement between the Christian Democratic Union of Germany, Christian Social Union in Bavaria, and Social Democratic Party of Germany supports the planning, development, procurement and operation of military capabilities.

In this context, the application of common standards for armament and harmonised regulations for operation can help to improve the economic use of scarce resources. This article provides an insight into how international cooperation of the German military aviation authority and the concept of recognition of foreign military aviation authorities effectively contribute to a strengthened cooperation.

Multinational Cooperation with Extended Approach

To make the Bundeswehr fit for the future, the current coalition agreement and the 2016 White Paper emphasise particular areas of engagement in Europe, including multinational armaments cooperation. Common designs need to be developed on the basis of common capability requirements. Development, procurement and operation of joint armament projects are to be co-

ordinated more directly with the partner nations. For military aviation, this includes the establishment of multinationally harmonised basic principles and sets of rules for the certification and operation of aircraft fleets. Joint regulations will not only improve interoperability in fleet operation but also form the basis for targeted cooperation in the certification and the initial and continued/continuing airworthiness of military aircraft. This is fully in line with the policy of the European Union Global Strategy passed in June 2017. It calls for an increased application of joint standards as a key element of effective cooperation and better use of scarce resources.

A vivid example of this extended approach to multinational cooperation is Germany's involvement in the European Tanker Transport Fleet. Plans are to procure and jointly operate up to eight Airbus A330 MRTT (Multi-Role Transport Tanker) aircraft in a multinational Tanker Transport Fleet together

with the partner countries of The Netherlands, Belgium, Norway and Luxembourg. Another example is the future air transport squadron of the German and French air forces in Evreux in France which will be equipped with HERCULES C-130J transport aircraft. In 2017, German Federal Minister of Defence Dr. Ursula von der Leyen and her French counterpart Jean-Yves Le Drian signed the corresponding agreement during the meeting of NATO defence ministers.

Uniform Set of Rules for Military Aviation

In order to improve cooperation in military aviation, a set of rules called "European Military Airworthiness Requirements (EMARs)" was created under the umbrella of the European Defence Agency (EDA). These rules, which are based on the EU regulations for civil aviation, provide standards for the cer-

Photo: www.nato.int/photos



Signing of the A330 MRTT Declaration of Intent

tification and the initial and continued/continuing airworthiness of military aircraft. EMAR regulations have no direct legally binding effect within the participating member states. They must be anchored in the national legislative/directive framework.

For the Bundeswehr, the Federal Office of the Bundeswehr for Military Aviation (FOMABw), in its function as supervisory and regulatory authority, has translated the EMAR into a national regulatory framework and put into force the German Military Airworthiness Requirements (DEMAR) in January 2017. The European partner countries will also successively transfer the EMAR set of rules into their national regulatory frameworks.

Recognition – Network of Trust of Military Aviation Authorities

As mentioned above, military aviation is a national responsibility. Figuratively speaking, the mutual recognition of military aviation authorities will thus build a bridge across the “borders” of national legislative/directive frameworks. Recognition is based on the idea of saving own resources, tapping capacities or reduc-

excellently reflect the objective and content of the instrument of recognition of military aviation authorities.

Recognition artefacts include both aspects of regulatory and supervisory function, as well as project-related decisions, services and products of partner authorities. Examples include the approval of design and production organisations, maintenance and technical management of military aircraft as well as military aircraft maintenance licences and technical training.

The more similarities exist between two aviation authorities in terms of standards, regulatory frameworks and working methods in the field of airworthiness, the easier it will be to take advantage of the aforementioned services and products and the greater will be the potential to save own resources.

European Recognition Guideline

Taking advantage of recognised services and products requires knowledge and an assessment of the working method and standards of the military aviation authority of the partner nation. Similarities and differences need to be identified systematically.

Hence, recognition requires that qualified auditors perform a quality assessment of standards and processes of a foreign aviation authority and a conformity assessment of regulatory frameworks and documents in the field of airworthiness.

To this end, the possibilities and limits of the usability of services and products of a partner nation will be assessed in the form of a standardised recognition process between the military aviation authorities. Similarities and differences in the supervisory and regulatory function of an aviation authority will be analysed in audits. Furthermore, it will be assessed whether the services and products to be recognised comply with the own

This will be followed by an on-desk review where auditors will analyse the Military Authorities’ Recognition Question Set (MARQ) of the partner nation. This question set is based on the ICAO safety goals. It provides answers as to how the respective aviation authority performs its function as a supervisory and regulatory authority in the field of airworthiness. It serves as a source of information for assessing the eligibility for recognition.

In addition, auditors will conduct an on-site visit to the foreign aviation authority. In the end, this is intended to increase confidence in the working method of the aviation authority through personal contact.

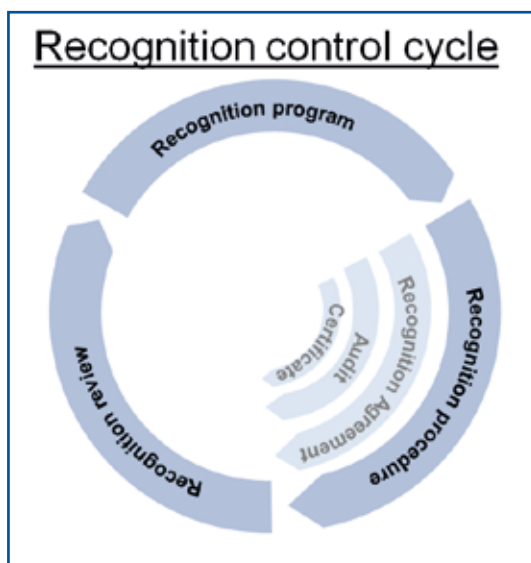
After evaluation of the MARQ and the on-site visit, the similarities and differences between the FOMABw and the partner authority concerning performance of the regulatory and supervisory function will be identified and documented in a recognition report. If the auditors determine sufficient validity of the authority’s supervisory and regulatory function and the usability of services and products in the national regulatory framework due to sufficient regulatory conformity, they will recommend recognition of the partner authority.

Finally, the recognition certificate will be signed by the directors of the aviation authorities. For the Bundeswehr, this will be done by the Director-General of the FOMABw. After signing, the services and products listed in the recognition certificate can be used in the national regulatory framework. The use of aforementioned services and products has to be in accordance with the applicable regulations for the certification and operation of Bundeswehr aircraft and aeronautical equipment.

In assessing the validity of an authority, the auditors will regularly check whether the validity prerequisites for the recognition certificate continue to be fulfilled sufficiently. For this purpose, they analyse current information on the work of the authorities and on potential changes in the performance of the regulatory and supervisory functions in coordination with the military aviation authority of the partner nation.

Annual Recognition Programme

It is expected that, in the future, the certification and the initial and continued/continuing airworthiness of military aircraft will increasingly be effected in accordance with the EMAR set of rules (A400M, C-130J, A330 MRTT, and so on). The number of recognition procedures and the importance of cooperation of the aviation authorities will equally increase.



ing own inspection efforts by using the services and products of another recognised aviation authority for the certification and the initial and continued/continuing airworthiness of military aircraft. Recognition draws on the competence of the aviation authority of the partner nation.

In the end, recognition is based on two elements, namely, the basic appreciation of the competence of the partner authority with regard to its regulatory and supervisory function and the “equality” of foreign and own services and products. Both aspects

national standards of the regulatory frameworks in the Bundeswehr.

With the “European Military Airworthiness Document – Recognition (EMAD R)”, the European Defence Agency has issued a standardised guideline for the process-oriented conduct of the recognition procedure.

According to EMAD R, the partner nations will initially define the framework and objectives, that is to say, the concrete service and product requirements, for the recognition procedure in an agreement (Recognition Agreement).

To plan the recognition activities, the FOMABw will prepare an annual recognition programme in coordination with the project officers at the Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support. This programme will form the basis for the coordination of recognition activities with the partner nations and for the targeted planning of the resources required to conduct the recognition. The figure shows the programme for 2018 (extract).

A400M and EUROFIGHTER – Examples of Synergies through Recognition

Recognition certificates are already being used successfully in several international programmes. For technician training as part of the A400M programme, for instance, France relies on the recognition of the FOMABw as supervisory authority. Based on this recognition, France uses the DEMAR 147 approved Air Force Engineering Training Center as the training facility for A400M-type training. Thus, the French aircraft technicians undergo training on the A400M type in the English language side by side with comrades of the German Air Force. After successful completion of the training, the French soldiers can submit the training course certificates to their aviation authority for application for a Military Aircraft Maintenance Licence. The joint technician training saves resources on both sides and creates the basis for a possible later cooperation in the operation of the A400M.

In the EUROFIGHTER programme, too, a recognition certificate is being used successfully. The aviation authorities of Germany, Great Britain, Italy and Spain mutually recognise the privilege granted to their respective national industry of classifying and approving minor technical changes and repairs concerning the EUROFIGHTER. By granting privileges, the performance of authority functions will be delegated. The supervisory function of the aviation authority will remain unaffected. In this case, mutual recognition contributes to better efficiency of the certification rules for the EUROFIGHTER programme, as a renewed full examination by the national aviation authority will not be necessary. This saves own resources.

Bottom Line

The instrument of recognition of military aviation authorities is still young. Nevertheless, the importance of recognition is steadily increasing in the light of the European will to implement intensified cooperation and the efficient use of scarce resources. It is a



A400M training station



EUROFIGHTER recognition signing ceremony in 2016

key element in the international cooperation of the aviation authorities. In Germany, the Federal Office of the Bundeswehr for Military Aviation is responsible for recognition. True to the principle of “Strengthening Cooperation, Developing Synergies, Saving Resources”, the instrument of recognition in military aviation will enable the more efficient use of scarce resources. Especially in multinational programmes, resources can be saved by using recognised services and products of the partner countries.

By now, a network of trust extending beyond the use of the recognition results has been established among the military aviation authorities. In the course of the recognition procedures, the audit teams gain insights into best practices of military aviation in Europe and beyond. The further development of the Bundeswehr also benefits from these findings.

Way Ahead

The increasing importance and number of recognition activities were the main reason for the Director-General of the FOMABw to specify “Recognition” as the central subject for the current chairmanship of the European Military Airworthiness Authority Conference (EUMAAC).

The specification of this subject fell on extremely fertile ground, considering that all nations are interested in close and resource-saving cooperation in the field of airworthiness. In a Recognition Workshop conducted in November 2017 under the technical control of the FOMABw, representatives of the EUMAAC member states developed proposals for the further development of the recognition instrument.

The workshop focused on strengthening the common understanding of how better to exploit advantages of recognition and to conduct recognition procedures – in accordance with quality assurance requirements and more efficiently through improved standardisation – and to meet the expected increase in recognition activities between the nations through improved synchronisation.

The invitation extended by Major General Christian Badia, Director-General of the FOMABw, to his counterparts of the EUMAAC member states to participate in an on-site visit to the FOMABw from 20 to 23 March 2018 provided an opportunity to practically apply the new standards and thus to further strengthen the sustained cooperation of the military aviation authorities in Europe. ■

“Kicking Down the Door...”

Recent Platform-Related Developments and Statistics in Air-To-Ground Weaponry

Georg Mader

In comparing the monetary value of reported combat aircraft contracts around the world, the observer is often misled or confused because – sometimes considerable – quantities of air-launched weapons may have been requested but might or might not be included in the reported figures. If the customer already has appropriate ordnance in his inventory, or if he switches to a totally new supplier, this can significantly alter the costs by more than 30%. And recent conflicts, all with air power participation, underline the increasing use of and demand for precision-guided munitions.

While users are constantly ‘using’ their platforms, so many new developments and/or modernisation packages accompany or are offered on current and future aircraft, that even focussing purely on Western systems requires encyclopaedic space. A closer look at the scale of operational use of precision air-launched weapons, and how several current and future key weapons are related to their corresponding platforms, may thus be enlightening. Aircraft ordnance was and is the true enabler behind air power. This is perfectly illustrated by the ongoing US-led multinational effort to destroy IS in Syria and Iraq as well as the Saudi-led mission against allegedly Iranian-backed Houthi fighters in Yemen. Almost 11,000 guided bombs and missiles were launched in only three months of 2017 – a 62% increase compared with some 6,700 in the same period in 2016. Middle Eastern nations and US forces in the region are constantly replenishing their stocks, as shown in several US Congressional notifications up to 2017.

Iraq and Syria

According to AFCENT (USAF Central Command), the increased pace of air support operations reflected the intensity of the fighting around the IS-held cities of Mosul in Iraq and Raqqa in Syria. Both strongholds were battered by coalition forces on the ground, led by the Iraqi Army and sup-

Photo: AIRBUS



Kuwaiti TYPHOON with BRIMSTONE

ported by the USAF and allied air forces. Each month has seen more air-to-ground weapons released than any single month over the first 2½ years of Operation INHERENT RESOLVE (OIR), which began August 2014. And in one month of 2017 alone, some 3,800 powered and gliding air-launched weapons of all kinds were deployed against IS. As explained to the author and underlined by a former US CAOC Commander, more often than the public is aware, weapon release is not authorized. Nevertheless, the number of sorties with at least one weapon dropped has also increased to around 3,200 for the first quarter of 2017, compared with some 2,700 in the same period in 2016. AFCENT’s statistics however, do not take into account all the coalition weapons fired, meaning

the true number of weapons released is of course higher. The numbers provided on 31 March 2017 – no figures for 2018 yet – include weapons released by aircraft under command of a Combined Forces Air Component Commander, which are all aircraft from all US military branches plus coalition aircraft. Strikes conducted by the newly delivered Iraqi L-159 and Su-25K aircraft or Mi-28 attack helicopters or armed UAVs are, for example, not included in AFCENT statistics.

Another interesting detail is that since 2015, more than 50% of air-to-ground weapons delivered over Afghanistan were delivered by UAVs; a dramatic increase, given that in 2011 that share was 5%. In 2017, US-controlled UAVs used 530 guided missiles and ‘smart’ bombs, mainly 127 or 227 kg

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GPS- or laser-guided. During the Manbij Offensive in 2016 and confirmed by the USAF, (meanwhile retired) MQ-1B PREDATORS and MQ-9 REAPERS launched over 300 Lockheed Martin AGM-114 HELLFIRE air-to-surface missiles, which accounted for approximately 40% of all kinetic strikes conducted by coalition aircraft during the two-month battle. UAVs are also increasingly laser-designating guided weapons released by other coalition platforms. The French pioneered that technique in Mali in 2013, when HARFANG UAVs lasered Islamist targets for LGBs dropped from distant, high-altitude ATLANTIQUE II aircraft.

Yemen

A 50% increase in employment of smart ordnance is also reported by the Saudi AF and the KSA press, but without giv-

ing the UAE-AF. Taking into account that with the UAE-AF another formidable (mainly US-) equipped air arm is taking part not only in Yemen but also in support of General Haftar’s Libyan National Army (LNA), or that Sudan has apparently changed sides and brought its Su-24s to bear against the Houthis – one can understand the scale of precision weapon usage.

It must be mentioned that a number of these weapons are true legacy systems, supplied some time (often decades) ago, and are no longer manufactured or sold. This includes the most controversial category that may have been used in Yemen, in the shape of the – meanwhile obsolete – HUNTING BL-755 cluster bomb. This has not been exported since 1989, though both Saudi Arabia and the UAE are known to hold stocks. But while the UK is a signatory to the UN’s 2010 Cluster Munitions

Convention and is committed to dispose of its own cluster containers and their submunitions, while working to prevent their use by anyone else, Saudi Arabia is not a signatory. Absent also are the US, Russia, China, India, Brazil and Israel – just about all the really potent air power owners out there. And the Russians – as shown over Aleppo/Syria – have their very own approach to such “ethically-motivated” considerations.

US Developments

The most notable recent event involving air-to-ground ordnance was of course in 2017 when US forces in Afghanistan dropped the first 21,000 lb GBU-43/B Massive Ordnance Air Blast (MOAB) in combat. The popularly translated “Mother of

all Bombs”, perhaps inaccurately reported to be the largest air-launched weapon, combines a KMU-593/B guidance section and BLU-120/B warhead with an 18,633 lb Tritonal explosive fill. At 9.45m long it is too large to be dropped from a conventional bomber and so had to be deployed from Lockheed Martin MC-130H special mission aircraft. Credited with a blast yield of 11 tonnes (TNT), MOAB destroyed an IS tunnel complex in Achin district in Nangarhar province, reportedly leaving over 90 IS fighters dead. However, it is important not to draw too many ‘hard-fact’ conclusions from aspects of the wars in Syria and Iraq: Lessons from that theatre are widely incorporated, but especially in the US dominant focus is still to provide own or coalition forces with powerful future tools to “kick down the door” – or several smaller doors, as explained to the author at a RED FLAG



UK-TYPHOON armament package

ing detailed numbers. However, regarding Yemen, here a much more European input is verified. In response to a Parliamentary written question, former British Defence Secretary Michael Fallon, confirmed that a number of British-supplied weapons have been used in Yemen, including the MBDA STORM SHADOW long-range cruise missile, the MBDA dual-mode BRIMSTONE (whose integration on RSAF Tornados has so far not been officially confirmed), BAE ALARM anti-radiation missiles (withdrawn from service in the UK in 2013), and UK supplied PAVEWAY-II laser-guided bombs (LGBs), as well as the Raytheon/UK PAVEWAY IV dual-mode (IN/GPS) LGB. Secretary Fallon also listed the PGM500 (known as the AL HAKIM in the UAE), a modular powered/glide-bomb used exclusively by

Moving Targets Still Pose a Challenge

The key (manned) tool to kick down the doors will be the 2,400-plus F-35 JSFs that the three US services remain determined to field. Last year at Naval Air Weapons Station China Lake a carrier-variant F-35 successfully destroyed a remotely controlled pick-up truck with a 500 lb GBU-12. While this weapon has now been dropped from every F-35 variant within the currently fitted (initial full capability) software-standard Block 3i, the GBU-12 provides limited moving target capability. Block 3i does not – unlike most legacy aircraft that currently fly

close air support (CAS) missions – have an automated targeting function with lead-laser guidance, which means automatically computing and positioning the laser spot to lead a moving target in order to increase the likelihood of a hit. Interestingly, an earlier DOT&E report said that this deficiency is also not planned to

be addressed in the coming Block 3F, due to be rolled since May 2018. In February 2017, the USAF issued a “sources sought” notice for an “interim” 500lb-class weapon with a moving target capability for the F-35. The notification called for information from the US industry only on a non-developmental precision-guided munition, capable of being integrated onto the F-35A ahead of an expected RFP. Possible contenders include the Boeing GBU-54/B Laser JDAM based on the MK 82 or BLU-111 500 lb bombs, as well as the Lockheed Martin PARAGON LGB kit fitted to the MK 82 or BLU-111. The USAF is also ordering 400 of the Raytheon GBU-49 ENHANCED PAVEWAY II, a fielded weapon that has similar size, weight, and interfaces to the GBU-12, or a similar weapon that does not require lead-laser guidance. According to USAF ACC, the GBU-49 could be quickly integrated into Block 3F to provide a robust moving target capability much earlier for the F-35. The alternative is sobering, as considerations to field lead-laser guidance initially with Block 4.2 might be delivered in 2022 – at the earliest. Due to this “interim” shortfall and ahead of the next FY budget, lawmakers on Capitol Hill have not been pleased with the DoD’s F-35 JPO office assigned to work with Lockheed Martin (LM) because of “providing insufficient justification and incomplete information also on weapons integration in an untimely manner”. The Pentagon seems to continue to ignore most criticism, and keeps the money flowing. In June 2018 LM reported the delivery of the 300th F-35, while in the incoming Block 3F standard the GBU-31/32 1,000lb/2,000lb JDAMs, the “popular” GBU-39 Small Diameter Bomb (SDB) and the Navy Joint Stand-Off Weapon (JSOW)-C1 are intended to be employed.

Beyond Block 3F – from some distant day around the end of the century to the mid-2030s – the F-35-family is planned or expected to carry in Block 4:

- AGM-158 Joint Air-to-Surface Standoff Missile (JASSM) cruise missile;
- the GBU-38 500lb JDAM;
- AGM-154A/C Joint Stand-Off Weapon (JSOW) glide bomb;
- JDAMs GBU-31 (2,000 lb) and GBU-32 (1,000 lb);



Graphic: Raytheon

GBU-12 PAVEWAY II

- PAVEWAY II GBU-10 (2,000 lb), GBU-16 (1,000 lb) and PAVEWAY III GBU-24A/B (2,000 lb);
- MK 83 BLU-110 (1,000 lb) Low-Drag General Purpose (LDGP) bomb;
- MK 83 BSU-85 High-Drag General Purpose (HDGP) bomb;
- Mk 84 (2,000 lb) LD/HDGP bomb;
- MK 84 BSU-50 BALLUTE (2,000lb) HDGP bomb;
- MK 82 (500 lb) LD & HD bomb;
- CBU-99/100 ROCKEYE II cluster munitions CBU-103/105 Wind Corrected Munitions Dispenser (WCMD);
- STORM SHADOW Joint Air-to-Surface Stand Missile (JASSM) cruise missile (UK);
- BRIMSTONE air-to-surface missiles (UK);
- Selected Precision Effects at Range capability (SPEAR)-3 (UK).

released further from the target than other dual-mode or GPS-guided weapons,

while having the same dimensions, mass properties and outer mould line of in-service LGBs, which allows easy integration onto US or coalition aircraft.

Marines Want to ‘Harvest’

At least 10 of the USMC’s planned fleet of 79 KC-130Js have already been modernised with an innovative package that includes a roll-on/roll-off dual-screen fire-control console mounted in a removable platform in the aircraft’s cargo compartment, a LM AN/AAQ-30 target sight sensor mounted under the portside wing fuel tank and a Common Data Link. This permits using the HARVEST HAWK (HERCULES Airborne Weapons Kit) with its four AGM-114P HELLFIRE II laser-guided air-to-surface missiles, mounted on the port-side refuelling pylon as well as MBDA GBU-44/E VIPER STRIKE, and Raytheon GRIFFIN-A air-to-surface munitions launched from a ramp-mounted 10-round rack and a pressurised dispenser dubbed the “Derringer Door”. According to Lt Gen John M. Davis, the iteration of the corps’

Photo: Georg Mader



Diehl missiles at IDEX-2017

The PARAGON-PAVEWAY mentioned above was tested by LM on an F/A-18, and according to the company will be tested on F-15 and F-16 aircraft. The weapon – previously named “Dual Mode Plus-LGB” – integrates an inertial navigation system and GPS all-weather moving-target capability. According to Joe Serra, precision-guided systems director at LM Missiles and Fire Control, PARAGON can be

aviation plan calls for providing HARVEST HAWK systems for all its KC-130J platforms, and subsequently enhancing the service’s Bell-Boeing MV-22B OSPREY tilt-rotor aircraft with a similar weapons package. “We are looking to equip the C-130J and MV-22B with these enhanced capabilities in order to make all our aircraft true multi-mission platforms”, said Davis to the author in November 2016.

Photo: Georg Mader



JDAMs aboard CVN-73 USS GEORGE WASHINGTON

Different Hammers for Different Allies

The best or latest example of modern US precision weapons being transferred also to “young” allies is Poland. Spearheading NATO’s encounter of a real eastern threat, Poland received its first batch of AGM-158A JASSMs in January 2017, as confirmed by Polish deputy defence minister Bartosz Kownacki. JASSM is a 2,000 lb air-to-ground precision standoff weapon designed to destroy high-value, well-defended targets. These (stealthy) air-launched cruise-missiles (ALCMs) were ordered by Warsaw back in December 2014, in a package worth US\$250M and including 40 AGM-158As as well as the parallel modernisation of the Polish Air Force’s F-16C/D Block 52+ aircraft from M4.3 to the M6.5 standard. Upgrade of the first F-16 (tail number 4040) began at the end of 2016, and initial operational capability with the JASSM was declared by the Polish Air Force in early 2017. Meanwhile all the JASSMs are due to be delivered, with the contract fully completed at the end of 2019. To date LM has produced more than 1,700 JASSM ALCMs for use on the F-16C/D – interestingly the oldest and still most regularly used USAF combat aircraft.

A different example of how modern air-launched weaponry is not just exported but ‘embedded’ into an industrial footprint, infancy and growth-potential of a programme, is the Joint Strike Missile (JSM), created in Norway by KONGSBERG Defence Systems. Initially funded by the

Royal Norwegian Air Force (RNoAF), it is a daughter of KONGSBERG’s earlier Naval Strike Missile (NSM). JSM is a 416 kg high-subsonic, air-launched weapon, around four metres in length, 48 cm in width (internally stowed) and 52 cm in height. Featuring a 125 kg combined blast (primary effect) and fragmentation (secondary effect) high-explosive warhead encased in titanium alloy, it can destroy sea- or land-targets from a range of 200 nautical miles. Custom-designed fuse programmes are downloaded prior to launch and two-way Link-16 provides for target update, re-targeting, mission abort, and bomb hit indication communication. In negotiating to acquire LM’s F-35 the Norwegians established the condition that JSM is not only integrated for them, but also marketed to other F-35-customers interested in such a capability. This was agreed upon and has already borne fruit. In early April 2017 Australia signed an NOK150M (US\$17.4M) contract with for the integration of the Norwegian “additional terminal guidance capability” weapon for her own 72 F-35s on order, with about 100 missiles reportedly contracted.

Israel’s Legacy of Hard Strike Continues

Because of its ‘special’ security situation the Jewish state and its highly professional industry have a long history of providing their air-force (IAF) with a variety of indigenously developed air-launched ordnance, best illustrated, for example, by ELBIT’s LIZ-

ARD-3 LGB and LIZARD 4 GPS/INS-PGM; Rafael’s POPEYE missile or SPICE system; ELOP’s PGM; or IMI’s DELILAH long-range stand-off missile. All of them have been used against Hamas or Hezbollah threats and targets, from neighboring Syria to as far as Sudan. A recent Israeli brainchild is the SKYSNIPER, presented by IAI (Israel Aircraft Industries) a year ago. With a weight of around 900 kg, a warhead of about 400 kg and a rocket motor delivering Mach 3.5 over a 250km range in just four minutes, it would be quite a significant weapon, and one beyond the reach of most of the serious two-digit GBAD systems. IAI describes it also as an anti-radar missile, using GPS/INS guidance to achieve pinpoint accuracy under all weather conditions. The IAF has not yet announced any order, but that has often been the case for ordnance seen much later to be in use. IAI claims SKYSNIPER would fit the frame, with up to four carried by F-15, F-16 and F-18 – and the F-35 already was off Beirut...

EUROFIGHTER – slowly – grows bigger claws...

In 2019 the TORNADO will be phased out from service with the RAF, after decades of fulfilling the strike role. The air forces of Germany, Italy and Saudi Arabia aim for 2025 for their variants. But the Luftwaffe is already looking beyond that timeframe, calculating if the EUROFIGHTER TYPHOON would be a credible precision weapons platform for the years to come, or by when would have a wide integrated

strike capability. To correct this however, the RAF is leading efforts to “upload” the TYPHOON with more air-to-ground weaponry. While Tranche-1 in the UK will remain a pure air-defence tool (until 2035), all Tranche-2s since June 2014 are to P1Eb (Phase 1 Enhancements) standard, the evaluation of “P1Eb Further Work” (P1Eb FW) is concluded, as the first part of the UK’s “Project Centurion” and delivered to the Spanish AF in early 2018. This package of enhancements aims to deliver a seamless transition of capability from TORNADO to TYPHOON by the end of 2018. In April 2017 the concentrated workload on the Phase 2 Enhancement (P2E) and P3E packages, that underpin “Project Centurion”, were also revealed.

According to Eurofighter GmbH CEO Volker Paltz, P1Eb, conferring full swing-role capability, was delivered to the nations from June 2014 on and entered service in 2016. P2Ea is delivering the heavy STORM SHADOW ALCM from MBDA. Testing of P3E is expected around this May and should be completed by December 2018. P3Ea will focus on the delivery of the low-collateral precision-strike close-air-support air-to-surface weapon BRIMSTONE 2, declared IOC on the TORNADO GR.4 in July

2016, some 43 months (!) beyond the originally projected October 2012 in-service date (ISD). The requirements of the Omani and Kuwaiti customers will reportedly be addressed in a further P3Eb package. P4E still is a subject of discussions with the four core nations and is expected to deliver a range of enhancements in three phases. Delivery of P4E is expected between 2019 and 2022, again dependent on customer requirements. “BRIMSTONE 2” is the RAF designator for what MBDA, the manufacturer simply refers to as “BRIMSTONE”, essentially to distinguish it from the earlier, single-mode millimetric wave (mmW – operating at the near optical wavelength of 94 GHz) BRIMSTONE and the Dual Mode (DMB) variants. BRIMSTONE 2 adds significant capability over the in-service DMB, which it is intended to replace in the RAF TORNADO GR4’s precision strike inventory. Housed in a new, more robust modular airframe, the mmW BRIMSTONE/DMB tandem penetrator warhead has been replaced with an insensitive-munition (IM)-compliant warhead, manufactured by TDW in Germany. It retains the same capability against armor as the original warhead, but delivers enhanced capability against non-armored targets. An IM-compliant ROXEL

VULCAN rocket motor replaces the ATK motor from the earlier mmW BRIMSTONE and DMB.

In 2017, RAF pilots began flying 40 trials with two launchers, each containing three such missiles (together with PAVEWAY IV LGBs). These tests included aero-data gathering flights to test how the addition of the BRIMSTONE and other assets interacts with the aircraft’s flight control system software. According to BAE Systems chief test pilot Steve Formoso, “The results have been excellent, with the pilot maintaining manoeuvrability whilst carrying a heavy weapons load. The BRIMSTONE will help pilots engage fast-moving targets, at longer ranges.” The German Luftwaffe is also benefitting from UK pioneering, as it plans to introduce the dual-mode BRIMSTONE with a domestic-built TDW warhead into its fleet from next year on. Another MBDA weapon destined for the UK – but not for the TYPHOON – is the highprecision, network-enabled, 60 mile standoff air-to-surface SPEAR (Selective Precision Effects At Range). In 2016 a GBP 411M (US\$548M) contract to develop the SPEAR solution for the UK MoD requirement realistically heralded development of this capability for the future F-35B LIGHTNING II fleet. But



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TYPHOON with STORM SHADOW and BRIMSTONE

development takes another four years, and the weapon, with pop-out wings and an innovative turbojet powerplant, will not enter service until the mid-2020s, according to the UK MoD. SPEAR has a multi-mode seeker and a multi-effects warhead. It can be used as a fire-and-forget weapon, in a semi-active mode via laser designation, or in a fully networked mode thanks to a two-way datalink. An improved SPEAR is also currently a candidate for the F-35 Block 4B software release, with the expectation of an in-service date from 2022. While being developed specifically for the UK F-35B, it will also be a candidate for integration on F-35A and F-35C variants in the wider F-35 community.

Germany: Tailored Impact on Target

Politicians and soldiers from the author's fatherland – Austria – as well as from its language-related big neighbor, Germany – presumably with obedience still rooted in historical genes and “no go's” – often hesitate to call a bomb a bomb, or a missile a missile. Thus, when we look at the Luftwaffe (not the only air-policing Austrian one) is approaching its air-to-ground work, we have to deal with wordings like “powered short-range effector”, “powered mid-range effector” or “system against hardened targets with reduced collateral-damage potential”. In illustrating this reluctance to a clear(er) language, the first category means, for example, Diehl's brilliant idea of a laser-guided air-to-ground version of the legendary AIM-9 SIDEWINDER air-to-air missile. This is used against small ground targets like “technicals”, or boats for the German TORNADOS, which according to today's plans will be around until 2025 to 2030. The second term means the already-mentioned Dual-Mode BRIMSTONE or

the modular 500 km standoff weapon, KEPD-350 TAURUS (Kinetic Energy Penetration Destroyer) for parts of the current 125-strong EUROFIGHTER fleet. The third term is the wording for the TIP (“Trojan” Improved Penetrator) on the Mk.83, launched in 2014 with a value of some €13.6M, with 150 due to be delivered to the Squadrons in 2019. TIP is a lower-explosive, “minimum-collateral-optimised” modification of the standard dual-mode guided Raytheon GBU-48. This 454 kg weapon is undergoing Luftwaffe introduction since 2016 and was verified in ambitious tests by the end of 2017. In fact, the ENHANCED PAVEWAY II EGBU-16, also based on the Mk.83 dumb bomb, launches the long-advertised multi-role capability of the EUROFIGHTER. For the TORNADO, the GBU-54 GPS-guided JDAM (Joint Direct Attack Munition) was acquired, and has been in service since 2016. The JDAM was tested by the Tactical Air Force Wing 33 on ASSTA 3.0-equipped aircraft from Buechel at the South African Overberg range in March 2017. For that premiere, a local team developed full-scale remote-controlled vehicles which were used as targets. Alongside GBU-24 LGBs, improved KEPD-350s, following an upgrade with new hard- and software, were trialled as well. Four such weapons were launched with reportedly very good results. Each live missile carried a 500 kg (1,100 lb)

warhead – something not possible in cautious Germany. What is remarkable is that KEPD-350 is currently integrated also in the RoKAF's F-15K SLAM EAGLE fleet, with the missiles under delivery to South Korea since October 2016. The 2013 contract names a 170 of the 350 -500 km very low (30 m) flying weapons, designed for use against hardened and buried targets. The RoKAF model slightly differs because it is equipped with a new Rockwell Collins GPS receiver that comes with a Selective Availability Anti-Spoofing Module (SAASM) to prevent (North Korean) jamming. If their presence influenced recent summits and some ease remains a speculation...

France

At the last LIMA exhibition in Malaysia, the author witnessed how self-confident Dassault is advertising the air-to-surface part in the “Omnirole” concept of the RA-



Rafael's SPICE EIOp-PGM

FALE as being much more “out-from-one-hand” and complete, compared with the Typhoon. Finally boosted by RAFALE export contracts for Egypt, Qatar and India, progress in associated ordnance development is being made in quick time. In 2017, the French defence procurement agency (DGA) awarded Safrane Electronics & Defense (ex-SAGEM) an order for new AASM Block-4 modular air-to-ground weapons. Next to doubling the production capacity, the requirement means a new standard of the well-respected weapon, used in anger in Libya and Mali with extreme precision and well-regarded throughout the fight-erworld. AASM or “HAMMER” consists

of guidance- and range-extension kits mounted on NATO-standard bombs and is available in inertial/GPS, inertial/GPS + IR-imaging and inertial/GPS + laser guidance. To date, more than 1,700 AASM have been delivered to the French armed forces. Initial deliveries of Block-4 will take place in 2019.

Not at all a “Third World” Impetus...

Aside from the big players, interesting developments and joint developments are constantly diversifying the sector and are creating niche- or sub-markets. Probably to be named at the forefront of this process is South African munitions maker DENEL Dynamics. Denel's RAPTOR-I (60 km) and RAPTOR-II (rocket boosted, 120 km) series of modular-guidance Automatic Target Recognition (ATR) glide-bombs, with a 600 kg-warhead are in licensed manufacture in Pakistan, where they are called H-2 and H-4, and are used on the (outgoing) MIRAGE-5. H-4 is said to also fit the Sino/Pakistani JF-17, from initial Block-1 to the now design-frozen Block 3 version. Since 2016 Denel has tried to market the “RAPTOR III”, which has a maximum range of 298 km and uses a satellite-aided INS system for midcourse flight, with TV or imaging infrared (IIR) in the terminal stage. Denel is also behind another joint development, this time with United Arab Emirates' TAWAZUN Holdings for the AL TARIQ IN/GPS-guided bomb-kit. Some 600 such weapons – designed to fit the Mk 80 family of 500 lb to 2,000 lb bomb bodies, with pop-out wings and moving control surfaces – have been delivered to the UAE-AF for their MIRAGE-2000/9s, under the MBARC Programme that was earlier delayed by technical challenges. AL TARIQ was already used in combat in Yemen and in Eastern Libya, according to Denel staff, “with very positive feedback from the user”. The Indian Defence and Research Development Organisation (DRDO) has successfully flight tested in captive and released the indigenous “Smart Anti-Airfield Weapon” (SAAW) from an IAF SU-30MKI fighter aircraft of the Indian Air Force (IAF). SAAW weighs around 125 kg and is said to be capable of striking concrete runways or shelters up to 100 km away with high precision. It is – all can take quite a while in India – planned for SU-30MKI, HAL JAGUAR and the incoming RAFALE. And with the tests of the GARUTHMAA and GARUDAA 1,000 kg smart glide bombs, the DRDO embodies India's moving closer to technological independence also in the ordnance-sector.

Paramount's MWARI: All-Seeing, All-Knowing; Precision from Above

(sb) In February 2018 Paramount Group and its partners celebrated full operational status for their new factory, and the start of ramping up for full production of the AHRLAC aircraft. At the time the second AHRLAC prototype was also introduced. Known as the Production Development Model (PDM), it embodied a range of new features, including revised cockpit canopies with OBOGS oxygen system; retractable landing gear; onboard mission systems; ejection seats; open-architecture avionics systems; upgrades to the fuselage including a lighter 8G rated airframe; a new propeller and exhaust system; and improved manoeuvrability.



Photo: Paramount

The new production facility (described by The Economist ‘as one of the most modern aerospace assembly plants anywhere in the world’) is a vertically integrated and modular factory, located north of Pretoria, and draws on extensive manufacturing experience in the large-scale-production of components for Boeing and Airbus.

The first prototype (XDM) successfully completed testing for austere environment deployments. It delivered over 300 engine hours, and has been the testbed for activities such as sensor and man-machine interface development. Various sensors have been integrated, including stabilised electro-optical sight (EOS) with a high-powered laser designator, wide area infrared line scanner and synthetic aperture search radar. The military variant of AHRLAC is the MWARI. As MWARI the aircraft can be equipped with mission systems to convert it into a highly sophisticated command and control centre, with outstanding ISR and CAS capabilities. The word MWARI is from the Shona language and means ‘all-seeing and all-knowing being’. Ivor Ichikowitz, Founder and Executive Chairman of Paramount Group, said “The AHRLAC aircraft and its military version, the MWARI, are real game-changers... We have created a truly-intelligent, SMART’ platform... not simply an armed variant of a civilian crop-duster, but an aircraft for ISR and CAS missions in every millimetre of its design. It is designed specifically for the kind of remote, hybrid ISR and CAS missions that the world’s air forces are increasingly being called upon to perform. We have created a truly versatile and cost effective aircraft that will maintain pace with ever-changing technological and security demands: this aircraft is ideally suited to be equipped with weapons systems from the inventory of any air force, where the mission requires that they be able to see and detect, to track and transmit data and, if necessary, strike with surgical effect.”

One of the MWARI's key features is an Interchangeable Multi-Mission Pod System (IMPS) under the cockpit, which allows a single airframe to be used in multiple roles with nearly zero down time between role changes. The pod can carry various systems including ELINT, COMINT, SAR, FLIR and cargo.

Paramount Group is Africa's largest privately-owned defence and aerospace business, and MWARI is one of several world-standard products of the Group. In the US the MWARI is known as BRONCO II, and is marketed by Bronco Combat Systems, a US-based entity founded by Paramount Group USA, Fulcrum Concepts LLC, and ADC, who designed the AHRLAC. Bronco Combat Systems are actively seeking domestic US partners.

Airborne Situation Awareness

Jack Richardson

As airspace around the world becomes more complex, the defence industry has to provide capable, yet affordable, solutions to ensure airborne situational awareness.

As legacy Airborne Early Warning and Control (AEW&C) Systems require costly upgrades and/or reach the end of their service lives, new technology enables the procurement of more capable systems. However, as defence budgets around the world shrink and anti-aircraft weapons and electronic warfare systems become more complex, there may have to be changes to how airborne situational awareness is provided.

The NATO Side

On the NATO side, a stalwart aircraft utilised in this role is the E-3 SENTRY Airborne Warning and Control System. Derived from the Boeing 707 civil airliner; this platform is operated by the Air Forces of the US, UK, France and Saudi Arabia (a similar system is deployed by the Japanese Air Self Defence Force (JASDF) from a more modern Boeing 767 airframe, whilst the NATO alliance itself operates a pooled fleet of E-3 aircraft). This aircraft entered service with the USAF in 1977 to replace the E12 WARNING STAR in the original Block 30/35 form. Since then, the aircraft has been crucial for monitoring movements in the airspace of its users beyond the scope of land-based radar systems and direct air defence aircraft accordingly. For expeditionary operations, the type has been crucial during the conflicts in Bosnia-Herzegovina, Serbia, Iraq, Libya and Syria, for coordinating both air strikes and rendezvous with tankers whilst ensuring overall situational awareness. The aircraft has additional functions, in the form of utilising Electronic Support Measures (ESMs) to detect and classify radar emitters (on land, sea and air) whilst also acting as an airborne relay for information to be distributed around the battle space. The centrepiece of this aircraft is the AN/APY-1/2 radar housed in the iconic

Photo: John K. McDowell, US Air Force



An E-3 SENTRY aircraft from Tinker Air Force Base, Oklahoma. The E-3 SENTRY is a modified Boeing 707/320 with a rotating radar dome that permits surveillance from the Earth's surface up into the stratosphere. The radar has a range of more than 200 miles.

Photo: Danny Cummings



The E7A WEDGETAIL flown by the Royal Australian Air Force is a twin-engine airborne early warning and control aircraft based on a Boeing 737. It is lighter than the E-3 SENTRY and mounts a fixed, active electronically scanned array radar instead of a rotating one.

rotating dish mounted atop the fuselage, a system with a range of between 400 and 555 km (dependent on the target altitude). In recent years, the USAF and French Air Force fleet has been upgraded to Block 40/45 standard. This supplied the aircraft with a glass cockpit and advanced software more suited to modern airborne environments and is intended to ensure the aircraft remains relevant until a replacement can enter service around 2035. Despite a strong operational record, however, the E-3 risks obsolescence. This is because its legacy radar is not optimised for detecting low observable, 4.5/5th-generation fighter designs. As these designs proliferate, so do

Anti-Access/Area Denial (A2AD) technologies, with more effective Surface-to-Air Missiles (SAMs) such as the Russian S4000 system. There are concerns, therefore, that traditional, large AEW&C aircraft such as the E-3 are becoming too vulnerable to operate, not only in this environment, but also in a fiscal context, where air forces have scarce resources to modernise their inventories. This factor is made worse by the fact that the E-3 is based on a 1950s vintage airliner, for which spare parts are becoming rarer and the age of which increases manpower requirements (a flight crew of four is needed, in addition to fourteen mission crew).

Author

Jack Richardson is a professional UK-based author specialising in defence and security.

Despite this debate over the long-term viability of traditional AEW&C platforms, the E7A WEDGETAIL flown by the Royal Australian Air Force (RAAF) stands out as a continued evolution of this class of platform. Based on the ubiquitous Boeing 737 airliner, reducing costs through economies of scale, this aircraft also has an immediately distinguishable feature, in the form of the 'top hat'-shaped Multi-role Electronically Scanned Array (MESA) radar mounted on the fuselage. Produced by Northrop Grumman, this advanced radar provides 360-degree coverage at ranges over 400 km in cluttered land, sea and air environments. At a time when fifth-generation fighter aircraft are entering service, the compact, yet highly advanced radar is described as being able to link with these types of fighter aircraft to investigate airspace areas as required. With a crew of two pilots and up to ten mission system operators on identical consoles in the rear cabin, this is a highly future-proofed aircraft, as an open architecture software system enables upgrades to be readily installed as needed. In RAAF service, this aircraft has gained a strong record in both combat and civil operations, respectively coordinating air strikes over Iraq and Syria in addition to running the search for Malaysian Airlines Flight MH370. With six on RAAF strength, Turkey and South Korea operate another four each.

The Russian Side

In order to keep pace with these advances, former Soviet aircraft designs continue to provide highly capable AEW&C platforms. Derived from the Ilyushin 76 cargo aircraft, the Beriev A-50 first entered service in 1984, with sixteen delivered to the Russian Air Force. This platform has followed a similar upgrade path to the E-3 with a modernised version, the A-50U, which has seen service coordinating Russian air strikes over Syria, entering service in 2011 (China also operates a number of examples). Additionally, the Indian Air Force has seen a more advanced version, the A-50I, enter service. Though like the E-3 and previous members of the A-50 family it carries a disk-mounted radar, this is an Active Electronically Scanned Array (AESA). This means that the disk does not physically rotate and operates on the basis of the radar beams being steered electronically, giving it the ability to be trained on a particular part of the battle space to generate a better picture of a given sector as required. The radar fitted to this variant is the PHALCON EL/W-2090, produced by Israel Aerospace Industries. Three of these systems were purchased by the Indian MoD in 2003 to equip as many A-50 aircraft, before the



A Beriev A-50EI MAINSTAY operated by the India Air Force

Photo: Michael Sender



Saab's new GLOBAL EYE AEW&C, introduced in 2016

Photo: Saab

purchase of a further two was authorised in 2016, adding up to a fleet of five highly-advanced AEW&C aircraft, whose radar has a reported range of 800 km, in addition to a 'look down' mode to observe surface, as well as aerial, movements. This highly-advanced solution has capacity for ten mission crew in the rear cabin in addition to five flight crew, but is one system in a broad portfolio of Airborne Situational Awareness solutions offered by Israel's Elta Systems. The Conformal Airborne Early Warning (CAEW) was first unveiled at the 2008 Farnborough Air Show and also offers a third-generation capability. Based around the Gulfstream 550 business jet, this solution works by fitting Elta's EL/W-2085 radars (no range is publically available) to the nose and tail of the aircraft in addition to two extra arrays running down each side of the fuselage to provide 360-degree coverage. As a high-flying, long-endurance, commercially available platform, this solution is marketed as providing high-level Airborne Situational Awareness capabilities at a far lower cost than rival platforms. Equipped with six operator stations, the CAEW also benefits from a fully integrated ESM, Electronic Intelligence (ELINT), Communications Support Measures (CSM) and Com-

munications Intelligence (COMINT) suite alongside Identify Friend or Foe (IFF) measures. Combined with an extensive range of self-defence measures, this is a highly capable aircraft, able to provide Airborne Situational Awareness and operate as a C2 post for complex operations involving air, land and sea assets. The CAEW solution is to date operated by the Israeli Air and Space Force, the Republic of Singapore Air Force, with three each, whereas the Italian Air Force is currently in the process of receiving two examples and the USN is procuring a single aircraft for testing purposes.

Cheaper Solutions

As well as these high-end solutions, there is also a market for lower-end platforms geared towards civil law enforcement and the more basic Airborne Early Warning (AEW) role. The ERIEYE system, produced by Saab since 1996, was the first compact, 360-degree AESA radar system to be mounted on an aircraft, making the key selling point of this solution the large number of platforms it can be integrated on. Originally, it was fitted to the Saab 340 commuter airliner as the baseline platform delivered to the Swedish Air Force as the

launch customer in 1997. Compatible with NATO data links, this constituted an affordable solution for providing situational awareness in Swedish airspace. Able to detect fighter aircraft up to 350 km away whilst maintaining the capability to search for maritime contacts up to the horizon, this solution has been widely exported including to the Royal Thai Air Force and the Pakistani Air Force (on the Saab 2000 regional airliner for the latter). The ERIEYE system is also fitted to the Embraer 145 airliner (known as the R-99) and has also been purchased by Greece, Brazil and India (the latter with indigenous modifications). With a crew of up to eight (this varies depending on the configuration), the ERIEYE solution is equipped with IFF, ESM and SIGINT suites (the latter was a key requirement in Brazil for intelligence gathering in the vast Amazon region). However, as defence budgets around the world tighten, demand grows for assets that can perform multiple roles to justify the often significant expenditure. Saab has responded to this trend by launching, at the 2016 Singapore Air Show, the GLOBAL EYE AEW&C system. This is described as the ERIEYE Extended Range (ER) and for an airframe uses the Bombardier GLOBAL EXPRESS 6000 ultra-long-range business jet. With the number of mission crew increased to seven, GLOBAL EYE, depending on the variant, offers a platform capable of airborne, maritime and land surveillance in a single solution. This is achieved by complementing the ERIEYE radar with another mounted on the bottom of the fuselage, alongside a nose-mounted EO/IR sensor. To date, three GLOBAL EYE examples have been purchased by the United Arab Emirates Air Force as the market for airborne situational awareness becomes more competitive and diverse.

UAV Networks

Not only do high- and low-end platforms for this important role face emerging competition for market share, the naval systems theatre provides many offerings, from the latest generation of the iconic E2 HAWKEYE AEW aircraft to more basic helicopter-mounted systems; technology is changing the terms of airborne situational awareness. As fifth-generation aircraft begin to enter service across the world, the radar systems fitted to these mainly tactical aircraft become far more capable. The most important example of this is the F-35 LIGHTNING II Joint Strike Fighter. In addition to low observability features, this aircraft benefits from highly advanced sensor fusion technology. With a nosecone-mounted Northrop Grumman AN/APG-81 AESA ra-

dar, the F-35 possesses a highly advanced active search capability. This system is able to generate high-resolution SAR images of the land domain whilst also tracking sea and air targets. The radar also has the capability to jam and disrupt hostile radar systems. As fifth-generation fighters proliferate and technology such as high-frequency radars to defeat them materialises, passive situational awareness measures become more important. The F-35 therefore possesses the Northrop Grumman AN/AAQ-37 Distributed Aperture System (DAS), six infrared cameras mounted all around the aircraft to provide 360-degree coverage to passively

borne situational awareness. One example is the Chinese DIVINE EAGLE high altitude UAV which carries an AESA radar. This concept operates through multiple airframes scanning airspace, which are then fed into a ground-based C2 centre to provide an overall situational picture with, it is claimed, the capability to detect stealth platforms. Although addressing some of the issues around the cost and vulnerability of traditional AEW&C platforms, air forces would still have to consider the issue of bandwidth capacity and the vulnerability of key data link nodes. Indeed, if more fifth-generation fighters are needed to form such a network,

Photo: Saab



Saab's ERIEYE system, produced since 1996, was the first compact, 360-degree AESA radar system to be mounted on an aircraft.

Photo: Owen65



A Republic of Singapore Air Force Gulfstream G550 CAEW landing at RAAF Base Darwin during Exercise Pitch Black 2012

detect incoming aircraft and missile threats. Another function of DAS is to grant the F-35 external camera coverage which can be projected onto the visor worn by the pilot (in addition to that provided by the Electro Optical Targeting System (EOTS)) mounted below the nose. All of these advances in airborne situational awareness raise important questions around whether less conventional airborne situational awareness solutions are required. Several nations are investing in Unmanned Aerial Vehicles (UAVs) to construct a network of systems (including other UAVs, fighter aircraft, traditional AEW&C systems and even low orbit satellites) to offer air-

providing these assets in greater numbers has cost implications. Although technology for providing airborne situational awareness is becoming more advanced, meaning traditional platforms associated with this role become more capable, this has to be balanced against increasing procurement and operating costs in addition to the vulnerability of such systems. As well as examining the requirements and whether solutions with lower specifications should be bought, there is also the question as to whether airborne situational awareness can be better provided by emerging technology. ■

Multi- and Special Mission Aircraft

Georg Mader

In approaching today's sprawling segment of sensor-bristling jet- and prop-derivations, one could easily fall into the traditional German-invented designation of multi- & special-mission-aircraft (MMA/SMA) as the "flying, egg-laying, milk-bearing woolly sow".

But this negative impetus, from a time when platforms were not truly satisfying any of the different mission-sets, is lesser or even nowhere justified today. Data- & Signal-processing and miniaturisation for these platforms have enabled a new segment to solve very different tasks with common performance characteristics over the last decade.

And while these tasks are very different indeed, thankfully-, for most of the operators of such platforms there is not always an ongoing war. They are ideal tools for "the absence of peace" as well, often used to get insights into a conflict in the neighbourhood, or just to monitor various tensions which might turn into a conflict. Therefore their monitoring, maritime shipping-lane surveillance, fishery inspection, to civil or police-like law-enforcement against smuggling or illegal migration. Last but not least, their deployment may include finding a window to step into multi-engine training for guys from other units. Not to mention the most interdisciplinary support of national- or alliance-run special- or covert ops.

To master such a hotchpotch of interdependent mission-sets, so-called multi-sensor data-fusion or distributed-sensing attempts are needed to combine and present data from several sensors in order to allow conclusions which would not be possible from the results of a single source. For all of these roles, air-based sensor-platforms – like the third Saab GLOBAL EYE for the UAE worth US\$236M – are and will increasingly be the preferred while expensive tools, also because of many hours of availability on station. Today, however, none of these platforms fights alone. It is an important aspect of future designs to integrate the constantly growing technical innovations

Image: Saab



GLOBAL EYE AEW&C from Saab provides air, maritime and ground surveillance. It combines a new extended range radar with the ultra-long range GLOBAL 6000 jet aircraft from Bombardier.

for operation in the extended area of application, also called the battlespace. A wide range of sensors and subsystems is required for the SMA/MMA-concept, all of which are integrated in a mission management system that offers a uniform surface for image and real-time situation overview. The quality of the chosen integrator solution can sometimes be more important than the platform itself, given the variety of a sensor pallet that includes (ideally, but gradually depending on the payload capacity):

- Active electronically scanning pulsedoppler radar, in a bar or conformal
- Synthetic aperture radar with ground target indicator (SAR / GMTI) – for all-weather large-area surveillance to detect or locate targets of interest
- If geographically relevant, a maritime surface-contact search radar
- If geographically relevant, detectors or equipment for anti-submarine warfare
- Electro-optical and infrared sensor (EO/IR) – for high-resolution day and night images or videos, even from long distances
- Multi-sensor information system (MSIS) or C4I mission management system

- Communication intelligence antennas (COMINT) – for detection, classification, finding and analysis of RF signals, connected to corresponding libraries
- Electronic signal detectors (ELINT) – for detection, identification and storage of the characteristics of electronic emitters, which also
- can be used for the acquisition and storage of other signal sources (SIGINT), connected to the appropriate libraries
- Self-protection system based on UV-IR and / or laser, to protect the valuable platform from ground-to-air missile threats
- DATALINK – for transmissions of real-time video and data into combat-centres or the 'cloud'

Possibly weapons related to one or some of the above-mentioned deployment roles

"The Combat Cloud..."

The corroborative "cloud" was also mentioned to the author by Group Captain Taylor, commander of the British ISTAR unit (ISR + target acquisition). At Fairford 2017 and in relation to the recent UK procured nine

Author

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Boeing P-8A-MPA/MMA he warned: "It will be a mistake to see this new platform only as a substitute in the maritime reconnaissance role, as just a new Nimrod and not as an expanded and networking agent over the entire maritime and littoral domain. Otherwise, you will never get the full benefits of this three billion pound investment and achieve the operational efficiency that the future British Joint Force would require. The fusion of data in the airplane is a key piece for us. It will provide the opportunity to integrate the Typhoons with P-8s with the F-35s, which will operate off shore from the new carriers. In other words, they are shaping a "kill-web" to protect the homeland and to anchor the defense of the northern NATO countries. Future successes or battles will be measured by how information is harnessed and processed to achieve a mixture of the right time, right place, and the right strength. The traditional boundaries that segregate airspace, space, oceans or cyberspace are increasingly blurred or disappearing, in order to achieve the desired effect of a concept which is called Combat Cloud. Finally, for all this flying multi- and special-mission platforms are the key!"

Photo: Diamond Aircraft



The Diamond DA62 MPP (Multi Purpose Platform) has been in operation since 2016. It is well suited for law enforcement operations, search and rescue missions, land and sea border surveillance, disaster management, infrastructure and environmental monitoring, and airport landing systems calibration.

Any Plane to Mutate into a "Jack of All Trades"?

Well, not really – or not without accepting too many limitations in either performance-parameters or mission-equipment. But more and more types than military authorities would hardly have considered a decade ago. The fuselage-sizes for those ISR / early-warning combinations as well as SIGINT and ELINT collectors are varying from 'matured' airliners over high-end business-jets down to twin- and even single-engine propliners or commuters like Airbus CN235/295, Bombardier Q400(with L3) or even a PC-12. For the experienced observer it sometimes seems as if one or the other less successful civilian type or a type for which the glory commercial days are over, almost inevitably returns as an SMA/MMA. Without claiming lexical completeness, the following article gives an overview of the most dominant or latest "players" in this promising segment.

Boeing P-8A POSEIDON

The most prominent – or dominant – military sibling from a highly successful airliner-series is Boeing's P-8A. It combines the fuselage of the 737-800 with the wings of the -900 and has an operating radius of 2,200 km and a four-hour stay in the target area. 53 out of a planned 117 of these have already been delivered in March

Photo: Mader



The P-8A POSEIDON from Boeing is designed for long-range anti-submarine warfare, anti-surface warfare as well as intelligence, surveillance and reconnaissance missions.

to replace the US-Navy's 300km/h slower Lockheed P-3C ORION for maritime-patrol, reconnaissance and anti-submarine warfare (ASW). In addition, Australia requested eight, four of which have been approved and funded and the first was delivered in November. India signed a contract for eight P-8I in 2009, added four more in July 2016 and currently has eight. The UK – thus fixing the serious error of stopping and even scraping the NIMROD Mk.4 by the Gordon Brown administration – confirmed plans for nine at the last Farnborough. On March 30 2017, Boeing was awarded a US\$2.2Bn contract that covers another 17, including the first for the UK. The framework also includes options for 32 more, which – if exercised – would bring the contract value up to US\$6.8Bn. The latest addition will be five P-8A cleared for Norway via FMS by the State Department in December, with a planned in-service date of 2023 and at a cost of NOK10Bn (€1.1Bn). The POSEIDON is carrying the high-resolution Raytheon AN/APY-10 radar for maritime-surface, littoral- and ground-target

indication in addition to the EIOp and COMINT sensors. Its armament currently is the HARPOON Block-II ASM and in the future, a so-called, "High Altitude Anti-submarine Warfare Capability" (HAAWC) should add the Mk.54 "light anti-submarine" air-launched torpedo which will be dropped from altitudes up to six kilometres, thereby ending decades of shaky routines by ORION-crews to skim the wave tops at 100ft. In years to come the US POSEIDON may evolve into a multi-sensor strategic reconnaissance aircraft which, unsurprisingly is a candidate to replace several very specialized MMA platforms in US inventory. The Navy has to replace the EP-3E and the USAF the E-8 JSTARS, E-3 AWACS, RC-135 SIGINT and WC-135 CONSTANT PHOENIX (detector for nuclear events) over the next decade. Those SMAs are all flying on the basis of the classic Boeing-707 airliner. And while four-engined airliners have globally melted down to three types (A380, B747-8 and A346) for financial reasons and increasing liability of big twins, even the planned E-10MC2A programme on the

basis of the B767-400ER was stopped for the same reasons in 2007. Thus a second generation P-8B based on the 737MAX 8 could very well replace them all.

Or at least partly, as Boeing confirmed that one is pushing its commercial 737X airliner as a solution for the USAF's Joint Surveillance Target Attack Radar System (JSTARS) recapitalisation effort, ahead of an expected service platform decision to replace the four-engined E-8C later this year.

Boeing-737-AEW&C

A very different platform in terms of its conception but yet another SMA based on the Boeing-737 (version 700ER) is the 737-AEW&C early warning and control aircraft. But compared to the later POSEIDON, it has emerged only in moderate numbers. 14 aircraft were built – or better converted from former airliners. The extensive modifications include the non-moveable or electronically beam-rotating L-band AESA 360° radar by Northrop Grumman with a weight of 2,950 kg and a maximum range in excess of 370 km against fighter-sized targets. Under Project Peace Eagle, the Turkish Air Force has four of these in service ("Barış Kartalı"), original launch-customer Australia flies six ("Wedgetail") and South Korea four. Their total price was approximately US\$2Bn. In 2014, Qatar has announced it would acquire three 737-AEW&C, but no contract or delivery date is known yet.

Gulfstream's "Special Mission Enablers"

Georgia-based Gulfstream-Aircraft is well known among the globe's rich and famous but also among CEOs for its advanced business-jet solutions, with more than 2,500 units delivered. However there is an evolving special missions-portfolio for military and other government users. 200 Gulfstreams in more than 30 countries are on ORBAT for government and military-service special missions, covering roles like airborne early-warning, ground surveillance, maritime patrol, SAR, ELINT etc. Especially the G550 platform has mutated into heavily modified CAEW (Conformal Airborne Early Warning & Control System) versions. That system was mainly developed by ELTA systems, an Israel Aerospace Industries (IAI) subsidiary. Based on the dual-band sensor package EL/W-2085 (the world's first flying dual S- and L-band radar) in large side-blisters, the Heyl Ha'Avir (Israeli Air Force) has five such G550s in service, called EITAM. Simpler and much cheaper to operate than the former IAI-ELTA combination, are the PHALCON EL/M-2075 on a

Boeing-707. These aircrafts reach altitudes of 51,000 ft (15,545 m) and are used to monitor the Russian air war in Syria. The fleet is completed by two IAI/ELTA G550 SHAVIT, equipped with the usual canoe-like radar system under the fuselage and with many antennas optimised for ground surveillance and ELINT signature collection. In 2007, Singapore ordered four such Israeli-modified platforms to replace its E-2C HAWKEYE. Italy's Aeronautica Militare (AMI) is receiving two EITAM-like platforms as an offset for 30 M346 for Israel, for about US\$750M.

Recently Gulfstream announced broadband enhancements via Ka-band, available for the G650 and G650ER and later this year on the G550. And the future USAF 'jammer'-MMA will be a Gulfstream-550/L3-combo, replacing the EC-130Hs. The

platform GLOBAL-6000. A new ERIEYE-ER derivative of Saab-Microwave Systems (former ERICSSON) PS890 'skibox-type' radar from horizon to horizon will cover the battlespace – or littoral or border area – in much greater quality than on the Saab-340/2000 platforms that, apart from Sweden, are operated by Pakistan or the UAE. Saab manager Söderström explained to the author the challenge as "in the past we also saw and tracked that fighter – but today it's a stealth-fighter!" The PS890 can picture land-targets much better and in being "swing role" yet, GLOBAL-EYE combines this with a surface-contact MPA-radar, an EIOp/IR-turret and ELINT-sensors on the wingtips. Again the "fidelity" of sensor-integration is described as a challenging process, before the first of three such platforms – presented in February to



In 2015 Israel Aerospace Industries (IAI) introduced the new generation ELI-3360 Maritime Patrol Aircraft (MPA) based on a modified Bombardier GLOBAL 5000 business-jet platform.

Flygvapnet (Swedish Air Force) operates a pair of Gulfstream IVSPs, called the S102B KORPEN. They have replaced the vintage CARAVELLE platform in the ELINT/SIGINT role in their mission to routinely conduct surveillance and library-update-missions over the currently heated Baltic Sea arena. Recently they made headlines when jumped and 'nudged' by Russian Su-27s from Kaliningrad. The Americans would call the distances in these encounters unprofessional, but we have to thank the KORPEN-crews for these great 'Flanker'-shots.

Saab's GLOBALEYE and SWORDFISH

What now yet is SRSS? It is just the Swedish approach to MMA, called Swing Role Surveillance System, based on top and throughout Bombardier's latest and largest

ESD as well and flown shortly after – will be delivered to launch-customer UAE and another customer not to be named.

In addition to SRSS, Saab is working and marketing the SWORDFISH concept, either – depending on the budget – on the basis of the Bombardier Q400 (turboprop) or again the GLOBAL-6000. Like several other designs it reaches into the MPA (Maritime-Patrol) arena, in combining multi sonobuoys, torpedoes and even the mighty Swedish Saab RBS-15 anti-ship missile.

Embraer Solutions

The mentioned Swedish ERIEYE radar with its 460 km coverage has inspired the Brazilian manufacturer EMBRAER to a whole family of SMA/MMA platforms which are operated not only by the FAB (Força Aérea Brasileira) but also by several export customers. There is the E-99 (formerly R-99A)

multi-mission/surveillance-version of the passenger jet ERJ-145LR, but with Rolls-Royce AE3007 turbofans and 20% more power. Also based on the ERJ-145LR, is the R-99- a multi-intel SIGINT and C3I sensor carrier with down-and side-looking 3D synthetic-aperture radar in 'cheeks' (from MacDonald-Dettwiler, Canada). The FAB operates five E-99 and three R-99s from Anapolis. The family is rounded up by the EMB-145MP, a MP-version based on the sensor package of the R-99 but without 'cheeks' and spectral scanner but with most of the ELINT and C3I abilities of the R-99. Mexico was the first customer for this variant. Greece and India are customers of the E-99 variant, in the case of India however including indigenous changes like another (Israeli) radar-bar and in-flight refuelling.

Photo: Mader



Three Embraer R-99s are operated by the Brazilian Air Force as part of the Amazon Surveillance System (SIVAM).

Leonardo's Platforms

Last but not least there are two concepts based on very different but highly popular Italian platforms, representing the sector's latest and most interesting players in the turboprop-segment. Based on the 1989-launched commuter-airliner ATR-72 (-600), Leonardo (once Alenia then Finmeccanica) has come out with a new MMA which's main focus clearly is maritime-surveillance. At Langkawi/Malaysia, the author was shown around and taken in to see the first of two ATR-72MP which had been delivered to the Italian Air Force only last December. It is equipped with a sensor-package that includes the Selex-ES SEASPRAY 7300E AESA-radar, the EOST-23 electro-optical turret and a suite of

self-protection measures that comes with chaff/flare dispensers and missile-warners. According to LEONARDO's fixed-wing segment manager E. Munhos De Campos, the "-MP" has the potential to grow into a fully capable ASW-platform with sonobuoys, a magnetic anomaly detector and an acoustic processor. Weapon racks are possible. Malaysia has recently shifted its acquisition-priorities away from fighters to SMA/MMA-platforms. And the Turkish Navy flies eight 72-600 TMU/TMPA predecessors. The final MMA of this survey is one which – an exemption – once was just a 'plain' military transport. Initially the Alenia G222 was a pure lifter, then joined Lockheed-Martin to become the C-27 SPARTAN and now returns – as shown in Dubai and Farnborough – as the LEONARDO MC-27J PRETORIAN. Developed together with ORBITAL ATK-Defense Group on their own initiative, the machine is quite similar to a two-engine C-

130J and for the purpose combines reconnaissance sensors with AGM-119 HELLFIRE and a large GAU 30mm BUSHMASTER machine-cannon.

The armament is remotely controlled by a console, but both can be rapidly removed via a cabin floor configured as roll-on/roll-off freight. Thus it is easy to convert the spacious type into a sensor-equipped SMA. The Italian Air Force is expected to receive three PRETORIANS for its special forces, while the MMA-kit is offered also to the other current 11 operators of the basic C-27J transport.

The Other Side – Russians and Chinese...

The West of course is not the exclusive inventor or user of MMAs or SMAs. This approach has also been taken up by Russia and China – for decades. Soviet / Russian platforms sniffing and observing along NATO-borders or US-ships in faded "Aeroflot"-liveries are somewhat legendary, and since 2015 they are back in the Baltics or around Japan. Their two latest SMA-examples are the Tu-214R, based on the medium-range airliner Tu-204 and the Ilyushin Il-22PP PORUBSHCHIK. The Tu-214R is based around the FRAKZIA sensor-set, which covers ELINT, SIGINT and COMINT (up to GSM networks) as well as EIOp equipment in various spectral ranges for the production of high-resolution photos and videos. So far, two out of three such machines have been operating in Kazan, one of them was temporarily assigned to the Russian AF (VKS)-detachment in Hmeimim in Syria in 2016. There was a fine opportunity for Russia to grasp and classify the characteristics of modern Western weapons – while in return Israel's EITAMS and SHAVITs have carefully plotted those

Photo: Mader



The Russian Ilyushin Il-22PP PORUBSHCHIK special mission aircraft made its public debut in August 2017.

Tu-214R flights. Thus for the first known time, MMA have electronically ,exploited' one another.

On 12 August 2017, on the occasion of the 105th anniversary of the VKS at Kubinka, their new Ilyushin Il-22PP PORUBSHCHIK SMA was shown for the first time. The ,rebuilt' escort jammer and SIGINT platform has emerged from a converted Il-22 COOT-B airframe, which is itself a theatre-level airborne command post and radio relay aircraft (called Il-22M11-RT SOKOL)

ture of PORUBSHCHIK's equipment is its selectivity, both on frequencies and directions. It is digital equipment with improved characteristics of selectivity and response. Besides, the aeriels can work in the narrow angle that increases their efficiency in the necessary direction. It excludes jamming of similar equipment by blue forces, even if it works at the same frequency as the one of the opponent." KNIRTI predicted that the PORUBSHCHIK-M jamming suite would be integrated with the larger and of

the four WJ-6C turbo-props. Unlike previous Y-8W, High New 8, a designation given to the sometimes confusing variety of elder, upgraded Y-8/-9 versions, features four large rectangular bar-shaped ELINT antennas on both sides of the forward and rear fuselage, indicating an advanced integrated ELINT system. Additional antennas are installed inside fairings at the wingtips, beneath and on top of the mid-fuselage, on top of the vertical tailfin, underneath the nose as well as inside the nose/tail



Photo: via author

At least four Y-9JB are currently in service with the Chinese PLA Navy flying ELINT missions over the East China Sea. After re-numbering, GX-9 is the new Y-8XZ, GX-10 is KJ-500 and GX-11 is the new Y-8G.

– based on the Ilyushin Il-18D turboprop airliner – of which 18 to 20 are in service. Il-22PP carries four large fairings located symmetrically on both sides of the fuselage. These contain antennas of the L-415 electronic countermeasures (ECM) system made by the KNIRTI-Institute at Kaluga. Another antenna is fitted to the tail, and another one is located under the fuselage. Responsible for the conversion is the Myasishchev design bureau, who at Kubinka stated that “the airplane is intended for detection and suppression of state-of-the-art secretive and jam-proof systems of combat control of various functions. These are radars, guidance channels of surface-to-air missile systems, mid-course flight path correction channels of cruise missiles, as well as tactical data exchange networks such as Link 16. Other objects to jam for the Il-22PP are various navigation aids, including commercial GPS, which are widely used by NATO armies. The main task is to cut down intermediate data-transmission stations, which are vulnerable. Main fea-

course more powerful Tu-214R at a later date as well. At Kubinka it also was announced that the Beriev Company is working on an alternative design based on the A-90 airborne jammer (itself based on the Il-76MD-90A transport) as well as another SMA aircraft using the Be-200 unique jet-amphibian as a basis airframe.

Y-9JB or ,High New 8'...

Meanwhile, the Chinese PLAAF and PLANAF (Naval Airforce) has deployed a variety of SMA/MMA assets up to 1,000 km into what they call 'Second Island Chain' (US Anderson-AFB at Guam in ALCM-range) or versus Japan. Most Chinese MMA and SMAs are based on the Y-8 (or Yunshuji-8) by the Shaanxi Aircraft Corporation, which itself is based on the 1960s Russian Antonov-12 four-turboprop design and on the subsequent domestic successor, the Y-9. The latest known derivative of that series is the Y-9JB, easy to recognize by its 6-blade high-efficiency propellers fitted to

cone. An EO turret (containing FLIR/TV) is also mounted underneath the fuselage for optical/video observation. The first two Y-9JBs were constructed in spring 2012 and the (sub-) type entered PLAN-service in early 2013. Currently four tail-numbers are known as in service (9211, 9221, 9231 and 9241) and since late 2016 / early 2017 they began to fly routine ELINT missions over the East China Sea near Japan. The Japanese JSDFAF reported its fighters had scrambled 561 times over 12 months until last September, with it's F-15 jets headed off to identify and ward-off 287 Chinese H-6K bombers and ELINT/MMA-planes over the East China Sea, which counted for 51% of all the intercepted targets. Another large percentage were Russian MMAs or bombers. We aircraft-interested and OSINT-addicted ones really have to thank these F-15J-pilots for the first good images of ,High New 8' and earlier ELINT- and SIGINT-platforms based on Y-8, noted over the disputed South China Sea within the Chinese claimed 'Nine Dash Line'. ■

Lockheed Martin: From Watermelons to Sovereign Capabilities

During the Berlin Air Show (ILA 2018) ESD met with Rick Edwards, Executive Vice President of Lockheed Martin International

ESD: How do you see the European business going forward?

Edwards: It's really fascinating. For ten years Europe from a defence spending standpoint was in decline, not a lot of programmes and the industrial base suffered greatly. Then based on world events we see a significant resurgence represented by all the programmes we've got cooking here in Germany, whether TLVS or the CH53K or F35, and Germany and France buying C130s. If I go back to our long range plan a decade ago Europe was a "rounding error" and now it's significant. For example, a year ago we didn't have an order for Romania and suddenly Romania buys PAC-3 missiles as part of their PATRIOT order, they buy HIMARS launchers and guided MLRS rockets. That all happened in eight months. And that fact shows the world that we can move quickly when we need to and when both sides want something to happen fast; it didn't take five years like a lot of projects do. We've also got Bulgaria buying stuff. There are good opportunities in Europe and I think it's going to continue for quite some time.

ESD: So the German market is buoyant, but talk to me briefly about the French.

Edwards: We do a little: the French now bought C130s in cooperation with Germany and I think there's more opportunity there. They've done buys of HELLFIRE missiles, guided MLRS, programmes like that but generally speaking they buy home-grown.

ESD: Are you going it alone in the French market? You're not in Germany, are you?

Edwards: In Germany the market is all about partnerships: on helicopters we have twelve German companies on our team now and we understand that the days when you had offsets and you sold watermelons or that kind of thing, those are long gone and you're going to have



Photo: Lockheed Martin

to input direct industrial efforts, hopefully in the defence area, that's an expectation. Doing business in Germany is actually easier because there's a competent, capable defence base that you can draw upon.

ESD: Would you say offset requirements globally have gone away?



Photo: MBDA

Lockheed Martin and European missile company MBDA have formed a joint venture known as TLVS GmbH to meet the German missile defence requirement. TLVS is based on the MEADS solution.

Edwards: I think the term "offsets" has gone away in most places but the industrialisation – or in the Kingdom Saudi Arabia, the Saudiasation to support Vision 2030 – is making investments in local industry,

giving them capabilities so that they can become viable players in the world market. It's much more directly product focused. We used to fund building hospitals and doing energy projects and things like that; it's much more focused on building up indigenous defence capability now.

ESD: But that's driven by domestic capability and domestic potential and in some places the workforce is not simply available or capable. So how do you overcome that in the short to medium term?

Edwards: So, I think it's important for these countries to set realistic goals and do this gradually. It took 50 years to grow the defence base in Turkey to where it is now, where they can do a lot of things – maybe not 100%, maybe not 100% as capable, but for their domestic use at least they have the ability to design and build weapons and that's something that you have to create. For example in the KSA you've got lots of engineers but they don't have practical experience and they're not systems or defence and aerospace engineers, so for a lot of those programmes where you're

going to partner with them you need to give them the training, to give them the experience. We just had a great experience with about a dozen Saudi engineers on the ARABSAT programme where a satellite is

going to be launched next year – the Crown Prince just saw that in California two weeks ago – and those engineers came and lived with us in our Denver facility, and then out to Sunnyvale California, and learned about spacecraft testing and qualification and they're now certified test engineers and they'll work on their product. So you have to do that in multiple domains for multiple generations. In India we've had very good success working with Tata on C130 tails but they went through a lot of training, a lot of maturation: they've done pretty well.

ESD: Coming back to the European side, we've got the UK as a primary partner on F-35 but we're still getting occasional news of resistance from the Pentagon or DC generally. Are there serious problems back there in the States?

Edwards: No. Negotiating in the media seems to be in vogue and the plane's performing incredibly well; once you get a pilot in it he'll never want to go back. It's a complete quantum shift in capability and once somebody sees that and understands it, they no longer question the value of a fifth generation aircraft and if you look at it, it's coming down a price curve that is better than any fourth generation plane ever did, and by 2020 the flyaway cost is going to be less than every other plane on the market. An 80 million dollar F-35: that's where we're headed.

ESD: Moving on, Romania is a story all of its own with the F16 now 40 years old: Are there any other F16 potential European customers at the moment?

Edwards: Bulgaria, Romania, occasionally Poland talks to us. I think there's a recapitalisation programme probably going to happen in Greece, but there will be upgrades and Hungary is talking to us. The Bahrain order that the corporation won in the last year, which restarts the line, was very strategically important, and that enables us to be competitive in the rest of the markets. In South America we have discussions with Chile and Colombia as well. And don't forget that though the name might be the same over 40 years it's a very different aircraft – it's a Block 70 now.

ESD: Let's talk about TLVS briefly. Where's the path forward for that?

Edwards: We've completed negotiations with the government, we've completed forming our joint venture so we have a legal joint venture here in Germany with MBDA. We understand that the RFP for a formal proposal will be issued sometime soon, with a 60 day response. Based on the fact that we've been working together



Photo: Lockheed Martin

The CH53-K manufactured by Lockheed Martin's Sikorsky subsidiary is a prime contender for heavy-lift programmes in Europe.

and with the customer for so long we think there's a good chance to get under contract by the end of the year.

ESD: And elsewhere on the European scene?

Edwards: Well, in conjunction with Raytheon we've made a PAC-3 PATRIOT sale to Poland, that's all PAC-3 missiles which is good for Lockheed Martin and there's other interest, discussions, ongoing in several countries, but I think Germany has the lead for Europe and NATO in air defence and with Germany taking that lead we think the need for a 360 degree radar is compelling. If you look at world events it's hard to argue that you don't need 360 degrees and no matter what anybody says, TLVS is going to provide that 360 degrees – and it also provides an interesting and very important capability in that it is truly a modular system that is plug and play. So we're putting in the Diehl IRST system as part of Germany's requirement for IRST, with pretty seamless integration. You can't integrate anything into legacy PATRIOT, so the fact that you can take the existing capabilities in a given country and integrate them into a TLVS battle manager and whatever radars they have and any other systems; TLVS was designed around that so we think that's going to be pretty attractive. And it's going to be done long before the US upgrade programme is done.

ESD: Potential in Turkey?

Edwards: We've done an incredible amount of business in Turkey over the years. We've got very good industrial partnerships there. I've been doing business with Kale Aerospace for years and they are a great supplier; they do good quality work. And we're a partner with Roketsan in developing SOM-J, a missile for the F-35. So from that standpoint Turkey has been great, but politics notwithstanding we'll have to see how it all plays out.

ESD: What about the Baltics and Scandinavia?

Edwards: We've got some small projects in Estonia, and we've sold JAVELIN to Lithuania. There's probably some BLACK HAWK business in those countries for Sikorsky, but the target is small here. In Scandinavia, obviously Norway and Denmark are important for the F-35 and we think we've got a good opportunity in Finland, we'll see. We've done other business there, JASSM cruise missiles in Finland and we've got a lot of partnering with Norwegian Industry. It's very similar to Germany; they have a good capable industry, particularly in energetics, warheads and rocket motors and items where there's no great capability or not much competition in the States any more so we tend to rely on and get them involved in a lot of projects.

ESD: Lockheed Martin Europe deals with Europe. Is it a springboard to anywhere else, worldwide, or are there any particular functionalities or product lines out of Lockheed Martin that are driven by your European entities?

Edwards: Certainly, depending on which side of Brexit you're on, we do a lot of business in the UK, building the turrets for both WARRIOR and AJAX, so we would like to become an exporter out of that facility and we think there are opportunities that are vehicle agnostic; everybody's got a vehicle, a 4x4 or 8x8, so we can pursue those opportunities. The British Government has been very supportive in helping us pursue some of these lines, both globally and potentially into Europe, but that's harder. Some of the East European platforms are very capable; stabilising the turrets so that they can actually perform well and create a viable mission is not an easy task – but we're pretty good at it. So we're always interested in those pursuits where we can partner with a vehicle platform, and we've got a few things going on. But the UK is the only place where we have a substantial manufacturing base: we don't have any manufacturing facilities in Europe per se, except Poland where we have PZL Mielec and we build BLACK HAWKS.

Masthead

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ESD: In conclusion?

Edwards: We have such a broad portfolio of products and that positions us well in a lot of markets. But there are certain markets and countries where we're like "Leave me alone: I've given you seven bids and it's been going on for ten years, you know, call me when..." That's the thing: you have limited resources, it costs a lot of money to pursue these and so you've got to pick where can you win and how serious is a country. That's the real trick of this; it's hard to be everywhere. But I think integrated air missile defence is going to continue to be a big deal. I don't see the threats changing any time soon and how to link all that, integrate with air or space-based early warning radars – Lockheed Martin can deliver the whole package. We're probably the only company in the world that can deliver the whole capability.

If you really want to architect this thing right, set up a command and control structure and link it into early warning and missile defence we're the ones who can do it and so I think you are going to continue to see that play out over time because the threats are getting more plentiful and they're getting cheaper, and with that they're proliferating. In Saudi Arabia and the UAE, by most published reports, they've knocked down 110+ SCUDs fired from Yemen. Not a lot of countries in the world could even engage 110 targets. It's an expensive business, but if one of those missiles gets through and hits the Ritz Carlton or the royal palace that's an expensive business, too.

Another thing I'd like to get across is that doing business with a US company isn't necessarily a threat to the indigenous industry, as some of our competitors are suggesting here in Germany. We're very comfortable doing business and it makes our job easier if there are capable subcontractors on the team.

ESD: The prognosis for the European market point of view?

Edwards: I think the assessment is for steady growth, and I think you're going to continue to see budget growth and we're in it for the long term. We'll be here, we'll invest where it makes sense and we've got products that meet this and the other thing that's going to be interesting is – and this is not intended to be a shot at my competitors but – how long can you afford, for the sake of having an indigenous capability, how long can you afford and which domains should you be in, because the UK is faced with that. Can you have an Army an Air Force and a Navy and do it competently and how much money does it take to do that? The fact is that you can buy three JAGM missiles for the price of one BRIMSTONE. How important is it – it's important to MBDA, but – how important is keeping that strategic national capability in the country versus being able to build an aircraft carrier or being part of the F35 or pay for the National Health Service? Those are questions that all of these countries are going to have to deal with but generally speaking there's still too much excess capacity out there. Somebody has to make a decision but it's a decision that has to be done at NATO level not national level and it has to be NATO saying ok, you guys are good at this so do that and you guys are good at that so you do that. It can be done less painfully, much faster and more cost effectively if there was some supranational authority that would do it.

ESD: Thank you very much.

Edwards: My pleasure.

The interview was conducted by Stephen Barnard.

T-X: “Why aren’t we just buying it?”

Georg Mader

The race for 350 new trainer jets for USAF and perhaps other nations has developed like a reality TV show since its beginning in December 2016: There were industry teams that split up, companies that got off unexpectedly and last-minute newcomers. In addition, President Trump has personal influence in the acquisition of defence assets with his “America first” mantra. The closer the selection decision comes, the more often we hear: “If there is a large jet in production that meets all requirements – why don’t we just buy it?”

It would take POTUS only 45 seconds to turn the T-50 into the T-X. The T-50 should not be confused with the Russian T-50 aircraft Su-57 fighter from which the Indians have recently withdrawn; it is of course the Lockheed/KAI MONGREL T-50A, whose basic model GOLDEN EAGLE and its armed FA-50 version are already in production and have thousands of flying hours in Korea, Indonesia, the Philippines and Iraq. Boeing – still a player in the fast jet business with running F-15 (Saudi) and F-18 (Kuwait, USN) lines – has teamed up with Saab for a clean sheet design. But this only serious competitor, which is not yet in production, has to face a hard and painful price-dumping battle to win the contract. The Italian Leonardo T-100 is also “a great in-production jet”, but given Trump’s “America First” tuning, this special version of the M-346 high-end trainer already in successful use in Italy, Israel, Singapore and Poland, and which, as announced, could be produced in Tuskegee (Alabama), might remain a foreign bystander. The new populist, and partly even ‘Putinist’ Italian administration, does not make it easier for Leonardo.

Some Figures

Here are some of the basics: A trainer aircraft is an aircraft primarily designed to facilitate aircrew or pilot flight training. Trainer aircraft features include tandem flight controls, simplified cockpit arrangements, and other elements like embedded virtual radar and adversaries, which all allow student pilots to learn to safely and tactically operate this aircraft and its future combat

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Photo: Georg Mader



Roll-out of the Boeing/Saab T-X prototype in September 2016

versions. USAF trainer aircraft are assigned to the USAF’s Air Education and Training Command’s (AETC) 19th Air Force, which operates 19 training locations, 10 regular Air Force wings supported by six Guard and Reserve wings with about 32,000 personnel and around 1,350 aircraft of 29 different models.

Aiming High

The T-X is to replace the Northrop T-38 TALON, which has long been the cornerstone of the AETC and served very well as an advanced pilot trainer for all the long-gone CENTURY series fighters (F-100, F-101, F-102, F-104 and F-106) and then to this day for all future F-16 and F-15 pilots. The incredible number of 60,000 USAF pilots who have trained and earned their wings on the TALON since it entered service in 1961 shows just how important the aircraft was. In addition to the US forces (including NASA, which once trained space shuttle pilots), the T-38 is deployed for the German Air Force (in Sheppard, Texas), South Korea, Portugal, Taiwan and Turkey. In 2007, Boeing completed an extensive avionics upgrade of the T-38A/B

models and equipped 463 of the 1,100 models delivered by 1972 with basic glass cockpits. Of these, 430 T-38C aircraft currently remain in the active inventory of the AETC and are expected to have a service life until 2034, when the APT or T-X – the type of which should be determined this summer – should reach its FOC.

The USAF claims that by 2031 60% of all combat aircraft will belong to the fifth generation (F-35 and B-21A and what remains of the 187 F-22s), which is why the troops need a more modern aircraft to train future fighters and bomber pilots. Although the T-38C will have to produce new pilots for modern fighter aircraft in the coming years, the service needs a modern aircraft to adequately train those pilots who are now still small children. An Initial Capabilities Document (ICD) of the USAF of October 2009 identified and documented gaps in its ability to meet the requirements of the Advanced Pilot Training (APT) after 2018 and beyond. It has been determined that the T-38C cannot perform 12 of the 18 mission tasks required for APT. These tasks include high-G training, advanced air-to-air skills, advanced cockpit/crew resource management and situational tasks



Photo: Boeing

The Boeing/SAAB T-X prototype over St. Louis, Missouri

such as data fusion by modern sensors. Currently, the FTUs (formal training units) perform the 12 tasks; the flight students train with real fourth- and fifth-generation aircraft at higher operating costs. Before 2014, the “F-16 Bridging Course” mitigated the risk of students being sent directly into the cockpit of an F-22, using a fourth-generation fighter under the guidance of instructors before switching to the fifth-generation fighter. However, AETC considered the bridging course inefficient and ended it.

Progress Unnoticed

When it comes to military aviation acquisitions, US President Donald Trump pays more attention to the F-35, the 747-8 AIR FORCE ONE and perhaps the B-21 stealth bomber, which is why the T-X as USAF’s largest ongoing aircraft procurement with a volume of US\$16Bn has so far gone relatively unnoticed. As FY2018 ends on 30 September, 30, Air Force Secretary Heather Wilson said at the Atlantic Council at the end of May: “The Air Force will be ready to award a contract for the T-X programme sometime in the coming months. I understand that we are still on the right track to take this decision this summer; they have all submitted their proposals and they are in the tender evaluation phase. I deliberately do not ask for the details of the evaluation of proposals, but they told me that they were on time for a summer decision. So, summer means when? July, maybe August.”

T-X stepped into the lights with the final solicitation RFP for the Advanced Pilot Training (APT) requirement released on 30 December 2016 with following basic data:

- The planned procurement includes 350 new trainers and might have a total value of US\$18Bn for the winning team.

- US\$1.5Bn is estimated for the R&DTE phase.
- 46 Ground-Based Training Systems (GBTS) have to be included.
- The USAF expected to select the winner of the T-X competition in 2017, but this has been postponed to summer 2018.
- Production would be in 11 annual batches: Nine full-rate lots will follow two low-rate initial lots and production could reach 37 aircraft annually.
- The aircraft is expected to enter service no later than FY2024.
- According to AETC, the T-X will operate from 2026 until 2045 and the aircraft is

The RFP was sent to the four expected main competitors Lockheed Martin, Boeing/Saab, then Raytheon-Leonardo and Northrop Grumman. But since then major and surprising reshuffles among the vendors have taken place. Northrop Grumman (the OEM of the T-38) teamed with composite specialist Scaled Composites, BAE Systems and L3, and the four companies put together a quite attractive clean sheet, single tail design. But then they unexpectedly pulled out of the competition, stating that “the companies have decided not to submit a proposal for the T-X Trainer programme, as it would not be in the best interest of the companies and their shareholders. The T-X bid is not beneficial for the company.”

Leonardo also faced problems as Raytheon dissolved its partnership, and the Italian company had to team up with its US subsidiary DRS Technologies. Allegedly, Raytheon’s inability to agree with Leonardo on the T-100 offer led to the dissolution of the partnership. General Dynamics had also left the T-100. The fact that two prime contractors separated from the T-100 led to speculation that the costly price was a sticking point. Many saw the T-100 as one of the leading competitors, because it had won a sizeable number of customers and has excellent live-virtual embedded training qualities – up to Italian ‘Red Air’/aggressor work.

Photo: Scaled Composites



Test flight of the T-X prototype produced by Scaled Composites (a subsidiary of Northrop Grumman)

set to fly 360 hours a year at a mission readiness rate of at least 80%.

According to the current USAF basing plan, the APT will retain its five existing T-38C bases: Columbus AFB, Mississippi (SUPT/IFF), Laughlin AFB, Texas (SUPT), Vance AFB, Oklahoma (SUPT), Sheppard AFB, Texas (ENJJPT/IFF/Pilot Instructor Training) and Joint Base San Antonio-Randolph, Texas (IFF/Pilot Instructor Training).

Other smaller companies decided to throw their designs into the ring – companies who had either never been in jets before, like Sierra Nevada, which is appreciated for turboprops, or of which one had never heard before, like Stavatti Aerospace, which came from nowhere and quickly disappeared again. Most analysts say that these unfolding “dramas” have overshadowed the most important point anyway: Competition has

developed between Boeing/Saab's clean sheet design for which Triumph Group, in Red Oak, Texas, provides the wing, as well as the vertical and horizontal tail structures, and Lockheed Martin-Korean Aerospace Industries' T-50A, the US derivative of the jet trainer, which is moderately popular with Asian air forces. Lockheed only added a dorsal air tank, but removed the T-50's internal cannon and weapon stations.

Better Performances, or...

Before Donald Trump entered the Oval Office, it was expected that the selection committee would provide cost incentives, that is to say, a certain price adjustment if particular features such as G and angle of attack were higher than required, then this could influence the competition and the subsequent offer in one way or another. For eight specific requirements, the USAF would offer monetary credits or incentives for a bid that exceeds minimum performance parameters. As an example, one bidder's total evaluated price is, let's say, US\$16Bn. But that bidder is offering an aircraft that can perform a 7.5 G manoeuvre, even though the USAF only requires 6.5 G. Competitors would receive a US\$13.2M decrement to its price for every 0.1 G above the threshold of 6.5 Gs, and US\$4.4M for every 0.1 G above 7 G. In the draft (the final RFP did not differ from the USAF's draft version released a year earlier) the USAF set a 7.5 G ceiling with a maximum possible US\$88M price reduction. In theory, each of the competitors can lower their evaluated prices by up to US\$688M by offering training systems that meet objective requirements rather than threshold values. For the contract estimated by the government to cost about US\$16Bn, that puts a maximum of 4.3% of the contract value in play to trade performance and risk against cost. This approach also explains the postponement to 2018: USAF expected to award the contract in 2017 and to reach the IOC by 2024. "That sounds unusual, but it was really intended to normalise something that was a newly developed product compared to what existed and was modified," explained Ms. Darlene Costello as deputy chief procurement and logistics officer of USAF. "We wanted to make sure that we were very transparent about the skills we value so that companies do not invest where they do not have to." Judging by that, it really would be a sound approach to weigh existing technologies against newly developed ones.

Some, like the Government Accountability Office (GAO), have criticised the fact that the rewards would be given for better flight



Photo: Lockheed

Impression of a T-X Lockheed-KAI T-50A



Photo: Lockheed

Lockheed-KAI's T-50A T-X Nos. 1 and 2

performance than for synthetic training solutions, as the lowest risk here would seem to favour the T-100. But Rob Weiss, executive vice president of Lockheed's Advanced Development Programs department, also known as Skunk Works, says he "has never seen a similar approach in a government call. And I don't think Lockheed Aeronautics has seen it either. I think it's an innovative approach by the government to monetise capabilities they like."

Are Prices and Timelines More Decisive?

But all that could change now. In Trump times, it now looks as if the focus is on the lowest unit price and not much else, or on the lowest price for a technically acceptable aircraft with some technical window dressing. Since there are only two knights in the tournament, Boeing/Saab is slightly at a disadvantage from this point of view. They have high development costs, even if they claim that their T-X is a production aircraft and not a prototype. They must be very affordable, and they have a mixed reputation because of Boeing's repeated postponements of the KC-46A tanker. And

Boeing has many other fish to fry, with the F-18 E/F/G SUPER HORNET and the F-15SAs for Saudi Arabia. That's a big advantage of Lockheed/KAI and that's why Boeing has to be really cheap to win, and they really have to want to. They might end up considering whether they could win in the long run by letting it go.

At this point, we should not forget that the USAF's solicitation contains more than 100 requirements, ranging from the size of pilots that must be accommodated by the cockpit to the visual quality of the graphical display in the full-flight simulator. The USAF tender rewards the competitor who submits the lowest-risk bid but offers no credits for being able to deliver the aircraft earlier. Boasting an existing assembly line for the T-50 in South Korea and an experienced factory in Greenville, South Carolina, where all the future F-16s will be produced (beginning with the ones for Bahrain), has claimed to be able to produce (beginning with the ones for Bahrain), that lost year and still stick to the Air Force's original schedule for achieving IOC in 2024.

The Leonardo/DRS campaign emphasises a similar timeline theme. The company will have to build a new factory in Tuskegee,



Photo: Leonardo

Leonardo's T-100



Photo: Lockheed

A Lockheed-KAI T-50A turning

Alabama, and has already performed a ceremony in Meridian, Mississippi, as the final assembly and checkout (FACO) site when it cooperated with Raytheon. But Leonardo could supply the first T-100 from its existing factory for the M-346 in Venegono near Milan, Italy. "T-100 is the world's most proven integrated pilot training system designed and built to train next-generation military pilots," said William J. Lynn, CEO of Leonardo DRS. As already mentioned and unlike its competitors, no version of the Boeing/SAAB T-X aircraft is already in use by any operator. This is not a disadvantage, Boeing argues, but makes its offer the least risky because the T-X has been redesigned from scratch instead of just making a few changes here and there. In addition, Boeing was keen to

adapt its design to the needs of pilots without relying on risky new technologies. "The customer was very clear what he wanted," says Tom Connard, T-X team leader at Boeing. "We've delivered exactly what they want in the future." In fact, the requirements call for a cockpit size that caused existing bidders to make small adjustments to the position of the control inputs, such as the rudder pedals. Boeing's T-X, in a configuration rare for this manufacturer, features passive sidestick controls such as Lockheed's F-35, which uses an active sidestick and accelerator pedal. The T-50A is the only T-X bidder to use the same type of sidestick as the F-35. The T-100 remains equipped with the same centre stick as the M-346 (T.346A in Italian service). The only bidder with a

"foreign" aircraft must also consider a different price factor. It is no secret that the basic M-346 comes at a fly-away cost of US\$20 -25M. This is almost the same price as for the T-50, but as it lacks some specifications, such as the ability to perform higher g-force manoeuvres, price is even more important an issue here. It should be necessary to pin down the price at US\$18M, but this could be difficult as Italy has high labour costs and rigid working conditions; dependence on the existing domestic market can make a company less entrepreneurial.

Impact on the Markets

It is still too early to assess the impact on the markets, but there probably are. Therefore, the impact of the programme on world markets can only be estimated at present. As the T-X is to be a high-end trainer for USAF as the original requesting authority, the result may be, as with some cousins in the advanced trainer community, an additional state-of-the-art lightweight fighter jet which might be well positioned to bring the F-5A forward to -E. Such a T-X could become a new FREEDOM FIGHTER.

The only foreign air force to comment on the T-X was Col. Magnus Liljegren, head of the Flygvapnet department at the Swedish Armed Forces. Liljegren said the Flygvapnet could consider buying the trainer if Boeing and Saab's trainer won the T-X competition. If another company were to win the megacontract, Sweden would probably not buy the USAF aircraft, but would opt for a much cheaper turboprop training aircraft such as the PC-21.

Sweden currently has a stock of 50 Saab Sk60 trainers, which were introduced at the end of the 1960s. These aircraft are ageing and becoming more and more expensive to maintain. Although Flygvapnet had planned to let it expire in the early 2020s, the government decided to continue to operate it until about 2026. Flygvapnet could consider the T-X when it becomes available, and this new "kid on the block" will then also be mature. And maybe also cheaper. Swedish Col. Liljegren spelled out what other acquisition officials are thinking when you tell them that this is "just a trainer": "Some of the T-X competitors are probably too expensive for us." But maybe this can be alleviated a little, and that's where POTUS Donald Trump comes in again. When Swedish Prime Minister Stefan Löfven visited him at the White House, he was accompanied by Industry Minister Mikael Damberg, Chairman Marcus Wallenberg and Saab CEO Håkan Buskhe. ■

“Some threats are just malicious...”

Raytheon’s Training Capability in the Cyber Domain



Interview with Howard Miller, Senior Capture Manager and Strategist at Raytheon

ESD: The best training tends to comprise systems of systems: does Raytheon distinguish between ground, air and sea, or how do you structure your cyber training?

Miller: We focus across the board. “Cyber warriors” cross all domains, in many cases simultaneously, so we focus on an holistic approach across all domains. The threat is the same, but the tools and techniques that make up the threat may differ. So, depending on the desired result, we will train especially for this environment. We concentrate on the desired results. Attackers can attack a ship, but that may not be the intended result or ultimate goal, so we want to make sure that the cyber warriors have the breadth and depth and situational awareness of the entire cyberspace, regardless of the domain they are defending. We will train them so that they can, for example on a ship, say “These are the control systems, these are the things to take care of, and this or that can be the effects an attack can have on the whole cyber combat space.”

ESD: Do you see different types of cyber threat coming from different areas of the globe?

Miller: Yes. Overall, cyber threats differ in the intended outcomes: there are some that are pure espionage, there are some who want to have a malicious effect, and others that are ideological, if you will. There are different threats everywhere, and this is one of the most difficult aspects for both the training and the operation of cyber, because: What are you dealing with? Some threats are just malicious whereas others are full-

scale cyber attacks. So we try to look at the threat holistically and then, as in any conflict, deconstruct its components to understand the risk to the mission and take it from there.

ESD: As far as threat management is concerned, is it usually the case that you train to deal with a particular threat, and how far do you anticipate into the future when you train a cyber warrior?

Miller: What we are trying to do for cyber warriors is to use the path of possible attack as a starting point, and then we from Raytheon explain how we use machine learning and artificial intelligence to find out what the attack could be. We don’t want to go too far ahead, but most attacks are based on something; they have a baseline, and we use that baseline to train the warriors to give them a causal approach from where they can start making critical decisions that aren’t based on a prescribed scenario, but are primarily based on critical thinking.

ESD: In terms of warfare or indeed any threat, there are various categories that one trains for, including prevention, cure, retaliation, disincentives, and pre-emptive. Would you like to comment on any of these areas from a Raytheon perspective?

Miller: For Raytheon, it is customer-specific. We have solutions that cover all of those categories, but I will not go into detail because they are customer- and mission-specific, and we have as many options and opportunities within Raytheon as we have minutes in this interview. But I will say that one of the things we really focus on is how we integrate real intelligence and real tools as much as possible to be able to train as holistically as possible, regardless of where the operator is or where he or she fits into an attack profile, or what the mission is, defensive or otherwise. Preventative is an aspect that we also train.

ESD: In general, do you train people in squads or groups, or do you train individuals?

Miller: We have what we call a cyber training continuum that starts with individuals, from enrolling in a network to individual development, and then we move on to larger, intermediate and advanced

individual training, and then to crew training, a unit training model that we use to certify a crew for operations in cyberspace and then certify a unit that can have a combination of crews in cyberspace. So we use the continuum from the individual to force exercises. It is about really understanding how these crews and these units and even the armed forces as a whole would work in cyberspace under certain conditions.

ESD: We talked about military crews and units, but Raytheon cyber training is also available to civilian organisations and agencies, right?

Miller: Right. We also work with many commercial companies to bring in this breadth and depth. Cyberspace is a challenge not only from a military and defence point of view; it touches everything, and the commercial area is directly related to defence. We are training on both sides because we want to be sure that when companies build new skills, including on the commercial side, they understand the basic hygiene of cyberspace, so that when we import these skills into our defence systems as well, they already apply best practices from a cyber and a professional perspective so that the practises are designed right from the start and not retrofitted.

ESD: It seems that there are good reasons for cyber defence and cyber security to be taught to young people. Is that Raytheon’s opinion, and are you doing something about it?

Miller: Yes, it is and we are. Children need to understand how cyber “works”, and we cooperate not only with universities, but also with high schools and primary schools to really advance what cyber is. Once you understand what cyber is, it becomes less frightening; and if students have learned this in primary and high schools, they will keep their basic cyber hygiene in mind. We have some really good partnerships with universities to bring students back to Raytheon to understand the real applications of their studies.

ESD: And what about refresher training?

Miller: We do a lot of cyber training; we

have a commercial group that also builds cyber academies, and they also help with refreshing. One of the things we have done specifically for the Persistent Cyber Training Environment - PCTE - and which we are now pushing is what we call Microline. We take commercial best practices for training and learning; instead of standard training, we use innovative training methods so that you can maintain this standard throughout your career so that it does not end with your initial certification as a cyber professional or expert, but throughout your entire career.

ESD: Is there a statutory / currency requirement?

Miller: In most cases yes, but in many cases not. Cyber is one of those domains that changes very quickly. One of the things we pioneer at Raytheon is how we pass this on to people when a new threat appears or when an old threat is no longer applicable. One of the things we focus on is the wholeness of the cyber. When a new threat occurs that we need to know about, or a new technique we need to defend against, we roll it into the training to keep the training current. One of the most important things for cyber - less on planes, ships and ground troops - is the relevance of cyber. Every few months we see a new kind of cyber attack or technique: How do we train for it? This is one of the things we do maintain currency of the operators.

ESD: One of the major concerns for the federal authorities is critical infrastructure: Is there a federal dictate on this aspect of cyberspace?

Miller: I can't speak for the government, but critical infrastructure is a major concern for everyone, and one of the things Raytheon has done is to provide the capabilities. So if federal authorities need to train for it, we have a facility in Virginia that provides just that training for critical infrastructure types of systems. Cyber is not only theft of credit cards or passwords, but extends to critical infrastructures that are unable to defend themselves. We are opening this up, and the platform is flexible enough so that commercial or defence companies can act side by side to identify a threat and find solutions together.

ESD: Is it fair to say that Raytheon offers "cradle to grave" cyber training?

Miller: Yes, it is.

ESD: Raytheon has blazed a trail in the UAE in terms of cyber. Is the cyber academy initiative being replayed elsewhere? And what are the lessons learned so far?



Photo: Raytheon

The Cyber Academy, a four-day cyber educational workshop at Khalifa University in Abu Dhabi, UAE, taught students new cybersecurity skills.

Miller: The first answer is yes: we use it as a platform that we can use worldwide. Among other things, we have found that although cyber is consistent, the applications are different for each customer. With the UAE, we wanted to focus on how we create a partnership, because the most important thing is partnership, because it allows us to understand what the gaps are, what the partner is about, what its threats are, and what the most effective tools will be. With the academies we have built, we have created a baseline and structure, and then we enter into the partnership to find out what the level of your operators are who are entering the course and what the desired level is at the end of the course. This conversation between Raytheon and the host country allows us to develop a tailor-made approach for the country. And experts bring the lessons of this special commitment with them, so that we can adapt what we deliver in such a way that it is very flexible. We have the baseline and the structure and then we add or remove things to achieve the desired result.

ESD: Is Raytheon involved in the raising of the buildings?

Miller: In most cases the customer provides the building, and Raytheon provides the training and the environment, which supports curriculum-based training and learning but also supports exercises and lab events.

ESD: Do you supply teachers?

Miller: We do. One of the things we try to do internationally is partner with academies and universities and with other instructors in-country, but while some things are the same, some training varies between countries.

ESD: What is the international language of cyber?

Miller: The topics are internationally agreed upon, but the language varies. And the language of cyber is the zeroes and ones of digital language. But we don't want language to be a barrier.

ESD: How many international academies are there?

Miller: We are focused on growing our cyber academies business both domestically and globally. With Raytheon's continued expansion globally, we are partnering with institutions and governments to stand up academies in many countries around the world, particularly in the Middle East.

ESD: Raytheon has a strong record in STEM work: Should we expect that to become STEM-C?

Miller: I think you'll see more cyber issues across the board. As we talk about STEM, you see cyber more as part of this conversation. But in the end, cyber will become a field of its own. We are beginning to see a movement in this direction which will ensure that we are prepared for the threats that are coming towards us.

ESD: Any other thoughts?

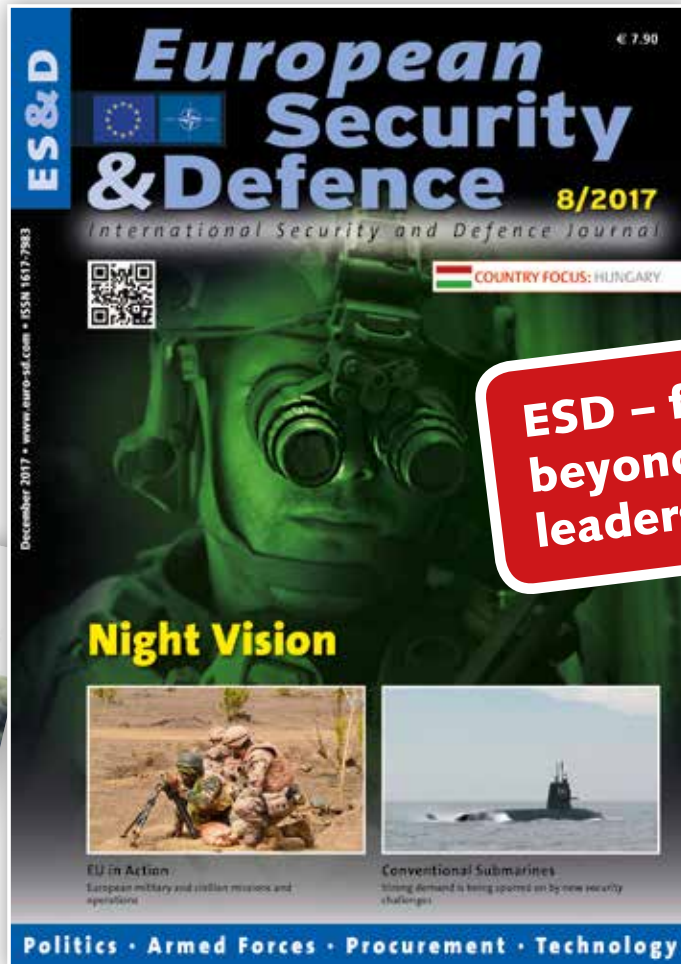
Miller: The most important thing is that Raytheon regards cyber as an holistic environment. Compare a ship or airplane with a simulator: when it comes to cyber, the systems and tools for real life are exactly the same as in training: we integrate cyber so that we can train while we fight and are ready for anything we encounter. This includes uniformed soldiers, but there are more people in cyberspace who do not work in uniform.

The interview was conducted by Stephen Barnard.

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