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Photo: author

Witnessing Prigozhin's Drive Down the Fury Road

While few who have followed his statements over the past year were surprised at Yevgeniy Prigozhin's hostility toward the Russian Armed Forces' leadership, few thought this enmity would go as far as mutiny and capture of the Southern Military District (SMD) headquarters in Rostov, as was the case in the early hours of 24 June. Along with the SMD HQ, Prigozhin managed to capture senior members of the Russian General Staff (referred to as the 'GenShtab' in Russian), including Deputy Defence Minister Colonel General Yunusbek Bamatgireyevich Yevkurov and Deputy Chief of Staff Lieutenant General Staff Vladimir Stepanovich Alekseyev.

The capture of the SMD HQ was followed by a Wagner contingent driving northward along the M-4 motorway, downing around seven Russian Aerospace Forces (VKS) aircraft on the way, and reportedly taking control of at least one military site in Voronezh Oblast. In the meantime, Putin's presidential plane was reported to have left Moscow for St Petersburg, indicating that the leader had fled the capital. When the column was approximately 200 km from Moscow, thought to be somewhere before the town of Tula, Prigozhin announced that the Wagner column would be turning around and the troops would return to their bases, since a deal had been reached with the help of the President of Belarus Aleksandr Lukashenko. A few hours later the Kremlin announced that the deal included legal amnesty for Prigozhin and Wagner members who participated in the mutiny, but they would be relocated to Belarus, in a move that seemed to indicate de facto exile.

A major question which repeatedly surfaced was why Russian aviation didn't destroy the column. While on paper, this should have been perfectly possible for a VKS operating within its own airspace, there are various factors to consider. For starters, Wagner had high-ranking GenShtab hostages at the SMD HQ, discouraging action against the column. The second is that the remaining MoD may have thought that attacking the convoy could aggravate the situation and result in unpredictable behaviour, therefore providing an additional incentive to resolve the situation peacefully. Lastly, since Prigozhin was in contact with the Russian leadership for at least part of the day to work out a deal, this may have given the MoD additional hope that everything could be resolved through negotiation.

Having said that, footage has surfaced showing at least two such strikes purporting to be on the Wagner column, but it is difficult to confirm the effectiveness of these strikes, or if the vehicles hit even belonged to Wagner. On the other hand, Wagner were reported to have downed a fixed-wing aircraft and at least six helicopters, one of which was a Ka-52 attack helicopter. These figures do not reflect particularly well on the VKS.

While Prigozhin appears to have secured himself a deal which appears to include his and the mutineer portion of Wagner's effective exile to Belarus, the fine details are not known. Given that this incident was deeply embarrassing to Putin personally, along with much of his circle, it is hard to accept the notion that the situation has been truly settled, and the working assumption is that this will result in retribution down the line, if for no other reason but to secure the regime against direct challengers.

Furthermore, Putin and his circle will have likely been taking notes on how various actors behaved toward Wagner during the incident, using their statements as a litmus test of loyalty. Reactions ranged from criticising both Wagner and the Russian leadership in the case of Igor Girkin, to the soft condemnation of Wagner and calls to halt the infighting by Sergey Surovikin, to comparisons of the incident to the "tragedy" of the 1917 revolution by the head of Russia's SVR Sergey Naryshkin, to the outright support for Wagner shown by Aleksey Milchakov, leader of the neo-Nazi Rusich paramilitary group, which is closely aligned with Wagner. Elsewhere, Ramzan Kadyrov and his Akhmat force declared their loyalty to the President and filmed themselves driving at least two columns to Rostov, ostensibly to fight Wagner. Yet despite entering Rostov by the afternoon, they opted not to engage Wagner in combat.

It may yet be a while before we see any retaliation against actors deemed disloyal, but such action is likely to come once when the Putin regime feels that it is relatively safe to do so. Presumably Prigozhin is aware of this possibility, and will take measures to secure his own safety in Belarus. Yet it is difficult to make any hard predictions, as the fallout from the incident will likely be ongoing for some time, and the situation will remain dynamic. Possibly above all else, by exposing the regime's internal and external weaknesses so starkly, the incident has opened up the conceptual space for change at the top. Yet the form this change may take remains difficult to predict. In the power game among the Kremlin elite, Prigozhin was a threat to the regime that day, but tomorrow it could be someone else.

Mark Cazalet

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Cover Photo: A Dassault Rafale of the French Air Force deploys flares during a training flight.
Credit: Armée de l'air et de l'espace

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PAS 2023: MBDA, Rafael, Brief on Plans to Counter Hypersonic Weapons

(pf) Major missile manufacturers MBDA and Rafael Advanced Defense Systems took the opportunity of the 2023 Paris Air Show, held at Le Bourget from 19-25 June, to brief on their plans to address the challenge of countering hypersonic weapons.

European missile house MBDA announced the launch of the Hypersonic Defence Interceptor Study, known as HYDIS2, at the show on 20 June 2023.

The HYDIS2 effort – which involves partner nations France, Italy, Germany and the Netherlands – brings together a consortium of 19 partners and 30 subcontractors in 14 European countries, with MBDA gathering round it national champions of missile defence, from aerospace and defence companies and institutions to niche specialists in both industry and academia.

The work will be conducted under a three-year concept phase study contract worth EUR 80 M from the European Defence Fund (EDF) Work Programme 2023; the company received an invitation to tender for the work in March 2023 and its response, submitted in May, is currently under evaluation.

Credit: MBDA

Under this concept phase study the design of various interceptor concepts will be developed before one is selected and its critical technologies pursued with the support of the four partner nations involved.

The HYDIS2 consortium met at the Paris Air Show on 20 June to prepare short-term actions to launch the project, but MBDA has already been working on a counter-hypersonics initiative called the Aquila project for the last five years. This builds on the company's expertise with its Aster anti-missile interceptor and its knowledge of hypersonic threat systems already fielded.

Rafael, meanwhile, has also been working on a counter-hypersonic weapon capability for several years. This work has now manifested itself in the Sky Sonic system unveiled at the Paris Air Show.

Little information is currently being released on the Sky Sonic system, but a Rafael official involved with the programme did confirm to ESD at Le Bourget on 21 June that it is a hit-to-kill system using a two-stage interceptor comprising a booster and a powered kill vehicle. This was also reflected in artwork displayed by Rafael at the air show.

Credit: Rafael

"Either you hit it, or you've missed it," said the official. "I'm not saying there are no munitions [on the kill vehicle], but no blast in the vicinity of the target is any good." He did add, however, that even just damaging rather than immediately destroying a threat hypersonic weapon is ultimately likely to seal its fate, given the velocity and consequent heat-build-up it will be subject to as it descends through the atmosphere to its target.

Citing the key attributes of hypersonic weapons as being not just their sheer velocity but also their accuracy and unpredictability, the official noted that to intercept them you "need height; you have to hit the target before it dives, ideally at an altitude above 10 km". That said, he also noted that multiple interceptors might have to be launched to close any potential gaps in a given air defence environment. This then drives a cost challenge; the interceptors need to be cost-effective, he said, "so you don't have to think twice about shooting multiple interceptors".

The official also said that a very long-range seeker is required to successfully intercept hypersonic missiles and that this "usually would need a bigger rocket". The implication of that statement, surely, is that Rafael has successfully developed modestly sized long-range seeker that is nevertheless effective.

GDLS, American Rheinmetall Vehicles Downselected for Rebadged OMFV Contest

(pf) The US Army announced the award of two firm-fixed price contracts for the Optionally Manned Fighting Vehicle (OMFV) Phase III and IV detailed design and prototype build and testing phases on 26 June 2023.

The contracts were competitively awarded to General Dynamics Land Systems (GDLS), which has proposed its Griffin III infantry fighting vehicle (IFV) technology demonstrator, and American Rheinmetall Vehicles, which uses the Lynx KF41 IFV as the basis for its candidate vehicle.

The total award value for both contracts is approximately USD 1.6 Bn (EUR 1.46 Bn).

Bids led by BAE Systems, Oshkosh Defense/Hanwha, and Point Blank Enterprises have not been chosen to proceed to the next phase.

Meanwhile, with the initial digital design phase of the programme now complete, the army is redesignating the OMFV programme as the XM30 Mechanized Infantry Combat Vehicle (MICV) programme.

"The XM30 programme has been highly successful," Major General Glenn Dean, the US Army's Program Executive Officer for Ground Combat Systems, was quoted as saying in a 26 June press release. "The army's iterative concepting and digital design approach, combined with increased emphasis on competition, continues to allow the programme to quickly design a transformational capability for the army of 2030 and beyond."

Destined to replace the US Army's Bradley Fighting Vehicle fleet (a task that has seen multiple aborted programmes over the last several years), the XM30 programme is expected bring new capabilities that will transform the way US armour formations fight. Developed with a modular open-system architecture (MOSA), the XM30 will allow new, developing technologies to be added to the vehicle as they mature, ensuring the XM30 stays ahead of the threat.

Credit: American Rheinmetall Vehicles

Regarding the oncoming run-off between GDLS and American Rheinmetall Vehicles, Doug Bush, Assistant Secretary of the Army for Acquisition, Logistics and Technology, stated, "Competition remains a vital aspect of the XM30 programme. Fully funding two companies for the next phases of the programme will allow the army to place the XM30 on a rock-solid foundation from a re-sourcing perspective, while also maintaining a competitive environment."

During the next two phases of the programme, the army will conduct activities to mature XM30 designs and will verify prototype performance during test activities, including a limited user test. The awardees will be required to deliver up to 11 prototype vehicles, as well as two ballistic hulls and turrets, armour coupons and digital engineering data.

Following the detailed design and prototype build and testing phases, the army intends to

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have a limited competition to downselect to one vendor at the programme's 'Milestone C' near the end of fiscal year 2027, with first unit equipped anticipated in fiscal year 2029.

Accord Signed on Transfer of Leopard 2A4 MBTs to Ukraine

(pf) Officials of the Netherlands, Denmark and Germany, together with representatives from Germany's Rheinmetall, have recently signed an agreement to effect the transfer of 14 Leopard 2A4 main battle tanks (MBTs) to Ukraine, Rheinmetall announced on 27 June 2023.

Credit: Rheinmetall

The Dutch and Danish governments first announced their intention to jointly acquire Leopard 2A4 MBTs for donation to Ukraine in April 2023. The Dutch government then contracted Rheinmetall to supply 14 Leopard 2A4s, worth a figure "in the lower three-digit-million-euro range", according to Rheinmetall. The Dutch and Danish government are jointly financing the order as part of the international tank coalition to provide effective support for Ukraine.

The first MBT is scheduled for delivery in January 2024, with the last due to ship over the course of the year. The tanks are upgraded Leopard 2A4s acquired by Rheinmetall from the inventories of user nations.

"The transaction underscores Rheinmetall's role as an important supplier of materiel to the Ukrainian armed forces," the company stated in a press release. It is just the latest in a series of actions taken by the company in support of Ukraine's defensive war effort. In the meantime, Rheinmetall is the embattled country's sole source of large-volume shipments of new medium- and large-calibre ammunition, including 20 mm rounds for the Marder IFVs' automatic cannon and 105 mm and 120 mm tank ammunition for the main armament of the Ukrainian Army's Leopard 1 and Leopard 2 MBTs. A first lot of 35 mm ammunition for donated Gepard anti-aircraft tanks will soon be ready for shipment as well."

Rheinmetall has been instrumental in supplying the Ukrainian military with substantial numbers of armoured fighting vehicles, either through multilateral Ringtausch exchange programmes with partner nations or via direct deliveries at the behest of the German government. In March 2023, for example, Rheinmetall shipped 20 Marder infantry fighting vehicles (IFVs) to Ukraine, while a second lot of 20 of these IFVs is due to ship this summer.

"By the end of 2023 Rheinmetall will also be supplying Ukraine with 26 brand-new military trucks and two state-of-the-art air defence systems," the company added. "The support effort also encompasses SurveilSPIRE mobile reconnaissance systems with day- and night-capable cameras and autopiloted mini-drones. The group is also furnishing Ukraine with a field hospital system consisting of containers and tents as well as a container-based mobile surgical station for initial treatment of trauma cases, both of which will be a vital source of support for the Ukrainian military in the coming months."

Ukrainian-Released Storm Shadows Target One of Russian Forces' Few Links to Crimea

(pf) In an attack that Russia would have widely expected, the Ukrainian military targeted the dual road and rail bridges at Chonhar that link Russian-occupied Crimea to the rest of Ukraine on the night of 21/22 June 2022.

Photographs and video posted on Telegram by the Kremlin-backed governor of occupied Kherson, Vladimir Saldo, show that the road bridge, at least, was heavily damaged, although not destroyed. Saldo played down the effects of the strikes, stating on Telegram, "We know how to repair bridges quickly; vehicle passage will be restored in the very near future."

Saldo also stated that "According to preliminary estimates British Storm Shadow missiles have been used", while The Times newspaper reported that a source in Ukrainian military intelligence had confirmed this. Again, it would have been expected by the Russians that infrastructure like bridges would be targeted by Ukraine's UK-supplied Storm Shadow air-launched cruise missiles, although striking targets in Crimea is likely to heighten tensions between Russia and Ukraine's Western allies. Moscow has even mentioned the potential use of nuclear weapons should its occupation of Crimea, which it illegally annexed in 2014, be threatened.

Credit: V Saldo/Telegram

Ukraine's targeting of the bridges at Chonhar is significant; only three main roads link Crimea to Russian-occupied Kherson Oblast and, of those, the road bridge at Chonhar links the Crimean peninsula directly to the strategic hub city of Melitopol in Russian-occupied Zaporizhia Oblast in southeastern Ukraine. Beyond these routes there is only the Kerch Strait Bridge that links eastern Crimea to Russia directly: a crossing built by Moscow after it annexed the peninsula in 2014 that was targeted and heavily damaged by a large truck bomb on 8 October 2022.

If Kyiv can strangle the logistical links between Crimea and Russian-occupied southeastern Ukraine, then the position of the Russian forces on the peninsula will become increasingly difficult to retain quite regardless of any Ukrainian counter-offensive, which would run into considerable Russian defensive lines. For the recent attacks on the Chonhar crossings to be more than symbolic, however, Ukraine would need to follow up its initial strikes to cause more comprehensive damage or to harass Russian forces repairing or still using the bridges.

Certainly for both sides it is clear that Russia's continued occupation of Crimea is central to the credibility of the regime of Russian President Vladimir Putin, making the peninsula territory of great strategic importance.

PAS 2023: New Eurofighter CEO Sounds Upbeat Note on New Sales

(pf) The new CEO of Eurofighter struck an upbeat note on the prospects for new sales of the aircraft during a press conference at the Paris Air Show on 21 June 2023.

Giancarlo Mezzanatto, who began his new role on 1 May, told journalists that he sees opportunities to sell an additional 150 to 200 new Eurofighters over the next two years, noting that the company is "much more optimistic than we were some years ago".

The situation in Ukraine – and Russian President Vladimir Putin's February 2022 invasion of that sovereign European na-

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Credit: Eurofighter

tion – "has had a huge impact", said Mezzanatto, who noted that this has led countries to re-examine both what they consider to be adequate armed forces capabilities as well as their previous attitudes to defence exports.

Most crucially, Mezzanatto, suggested that Germany's refusal to sanction export licences for further Eurofighter sales to Saudi Arabia (a stance taken in light of the October 2018 murder of US-Saudi journalist Jamal Khashoggi and Riyadh's involvement in the war in Yemen) might soften in light of the Ukraine conflict, adding that "The UK, as lead nation for Saudi Arabia [regarding Eurofighter exports], is really active".

A future Eurofighter order for Saudi Arabia, which currently operates 72 of the type, could be substantial, involving at least 48 or possibly as many as 72 aircraft.

An order for another 15 Eurofighters could come in the form of electronic warfare (EW) variants for Germany (where they are known as EK variants). Eurofighter is hoping these EK variants will be new-build Tranche 4 aircraft, although it is still likely that Germany will include them within its Project Quadriga order, which covered the acquisition of 38 Eurofighters and was signed in November 2020. In the run-up to the Paris Air Show Saab's Araxis EW system was declared to be the preferred bid for the Eurofighter EK variants, yet there has been no contract and Saab has been reticent to detail what Araxis solution the Eurofighter would receive; the system can either be fully integrated into the aircraft or come in the form of a missionised pod.

Meanwhile, Eurofighter is anticipating that Spain will soon order 25 new aircraft under its Halcon II project, which is aimed at replacing the EF-18 Hornets operated by the Spanish Air Force out of Torrejon and Zaragoza air bases.

"Spain have an operational requirement to replace their Hornets," said Mezzanatto, although he noted that a Halcon II contract could be delayed – or even brought forward – by Spain's national elections in July.

Interestingly, Mezzanatto also said, "I think for Eurofighter Poland is a very good opportunity," citing the fact that the Polish Air Force has become familiar with the Eurofighter through the type's deployment to Malbork Air Base in Poland as part of NATO's enhanced Air Policing (eAP) mission in the Baltic region. The Italian Air Force deployed four Eurofighters to Malbork for four months from August 2022, having completed a seven-month deployment of Eurofighters to Romania on 1 July 2022 (extended from four months due to the Russian invasion of Ukraine).

Mezzanatto's optimism regarding a Eurofighter sale to Poland is perhaps a little surprising, however, given that Poland has already opted to procure the F-35, of which it ordered 32 in 2020, and in 2022 ordered 48 KAI FA-50 light strike aircraft.

Lastly, Mezzanatto also referenced Turkey, where the UK is leading a sales campaign for the Eurofighter. Turkey was kicked out of the F-35 Joint Strike Fighter programme in 2019 for buying the Russian S-400 air defence system and, although Turkish Aerospace is developing the indigenous Kaan next-generation fighter, the prototype has yet to fly.

Regarding his goals for Eurofighter as a business, Mezzanatto said he wanted to: deliver the Eurofighter's capability roadmap to keep the aircraft operationally effective out to 2060; be ready to support and ramp up production when additional sales are secured; support the mission readiness of the customer; and continue to promote the strength of the Eurofighter procurement model.

Beyond these goals, however, Mezzanatto is also looking to streamline and harmonise the upgrading of the various national Eurofighter fleets. "One of my objectives is to align as much as possible the configurations of our customers," he said.

This will be quite a challenge, given the disparities between the user nations in both aspirations and budgets.

LIMA 2023: Multiple Malaysian Aircraft Contracts Finalised

(pf) The 16th LIMA 2023 defence exhibition, held in Langkawi from 23-27 May 2023, saw the signing of 20 contracts, 21 letters of acceptance and two letters of intent worth a total of MYR 10.128 Bn (EUR 2.05 Bn), according to the Malaysian Ministry of Defence (MoD). Among the deals a number of aircraft acquisitions were finalised.

The most notable of these was a contract for 18 Korea Aircraft Industries (KAI) FA-50 light combat aircraft worth USD 920 M (EUR 858 M). This contract was officially signed at LIMA on 23 May after a Letter of Acceptance for the aircraft was agreed on 24 February 2023. The FA-50s will replace BAE Systems Hawks in the Royal Malaysian Air Force (RMAF) fleet, which currently operates 12 Hawk 208 light attack aircraft and four Hawk 108 advanced jet trainers.

The Malaysian MoD described its future FA-50s as "fighter lead-in trainer/light combat aircraft (FLIT-LCA)", with reports suggesting that eight aircraft will be used lead-in fighter trainers with the rest operating as light fighters.

Credit: Leonardo

Raytheon announced on 15 May 2023 that it will be furnishing KAI's FA-50s with its PhantomStrike compact active electronically scanned-array fire control radar. This system will be integrated in the RMAF aircraft, the first deliveries of which will take place in August 2026.

On 25 May, meanwhile, LIMA witnessed the Malaysian MoD signing a contract with Leonardo for two ATR 72 Maritime Patrol Aircraft (MPA) variants plus related integrated logistic support and training services. The contract, worth MYR 789.6 M (EUR 159.03 M), follows the selection of the aircraft by Malaysia in October 2022 and was described as a "Phase 1" deal by the Malaysian MoD, suggesting that a follow-on purchase could ultimately take place.

The twin-turboprop ATR 72 MPA, the latest specialised variant of the ATR 72 regional transport aircraft, is designed to conduct missions including maritime surveillance, anti-submarine warfare (ASW), anti-surface unit warfare (AsuW), search and rescue (SAR), environmental monitoring, medical evacuation and transport of personnel and materials.

According to a Leonardo press release on 25 May, the aircraft chosen by Malaysia will be equipped "with a flexible mission system, advanced sensors and a complete communications suite for

command, control, communications, intelligence, surveillance and reconnaissance (C4ISR) missions over land and sea". Although the specific mission and sensor fit of the Malaysian order was not disclosed, Leonardo stated that the Malaysian ATR 72 MPAs would be "optimised for maritime patrol, electronic intelligence (ELINT) gathering, sea surface and submerged target detection and tracking, SAR, countering illegal activities (drug trafficking, piracy and smuggling) and protecting territorial waters". The company added that there is growth potential for the aircraft to evolve into fully fledged ASW and AsuW platforms.

Leonardo did confirm that the Malaysian ATR 72 MPAs would feature the modular Leonardo Airborne Tactical Observation and Surveillance (ATOS) mission system. This manages the aircraft's onboard sensors, fusing the information gathered and presenting a comprehensive and continuously updated tactical picture to the mission system operators.

Also on 25 May the Malaysian MoD signed a contract with Turkish Aerospace for three Anka medium-altitude, long-endurance (MALE) unmanned aerial systems (UASs). This contract, also described as a "Phase 1" deal, is worth more than MYR 400 M (EUR 80.56 M) and covers an unspecified number of Anka unmanned aerial vehicles (UAVs) and ground control stations as well as a training and logistics package. Its signing brings to a close an open-tender contest that lasted around five years.

Erol Oguz, UAS programme manager at Turkish Aerospace, told ESD at LIMA that the UAV type being supplied to Malaysia will be a new version of the Anka-S with modified wings. Oguz also confirmed that the Ankas will not be armed, but will carry a maritime intelligence, surveillance and reconnaissance (ISR) payload that includes a synthetic aperture radar and an electro-optical/infra-red sensor.

The training of Royal Malaysian Air Force (RMAF) personnel on the Anka UAS will begin next year, while deliveries of the systems will take two years.

Although it appears clear that the RMAF will procure additional UAVs in a second phase, Oguz told ESD that it is "not 100% clear" what these would be, but that their type would be defined during delivery of the programme's Phase 1.

Beyond the RMAF, the Malaysian MoD also announced at LIMA that a contract had been signed for the Malaysian Army to receive four Sikorsky UH-60A+ Black Hawk helicopters leased from Aerotree Defence & Services Sdn Bhd. The MoD stated that these aircraft will be used both for training as well as "operational flight duty". The Malaysian Army currently operates two Sikorsky S-61A-4 Nuri medium transport helicopters, according to the IISS's 2023 edition of The Military Balance, along with 10 AW109 light transport helicopters. The S-61 Nuris were originally operated by the RMAF, which first received the type in 1967 but retired the last 12 in 2020 after they become too expensive to continue operating. Nevertheless, a couple of S-61s have been used by the Malaysian Army to stand up its first air transport units. The value of the Black Hawk leasing deal was not specified.

Hercules Says its Farewells in UK Service

(pf) Three Royal Air Force (RAF) C-130J Hercules transport aircraft performed a flypast across the United Kingdom on 14 June 2023 to mark the type's imminent official retirement from RAF service on 30 June.

Credit: UK MoD/Crown Copyright

The C-130s, which are operated by the RAF's 47 Squadron, took off from their base at RAF Brize Norton at 10.00 BST to overfly locations of significance throughout the UK before landing back at Brize Norton at 17.05.

The Hercules has been the workhorse of UK operational tactical mobility since the RAF's first C-130Ks (which the RAF designated Hercules C1s) entered service in 1967.

The RAF's outgoing Hercules fleet consists of 14 C-130Js from a fleet of 25 brought into service from 1999; 13 of the remaining aircraft are stretched C-130J-30 models (Hercules C4s), with just one C-130J (Hercules C5).

The C-130J/J-30s are being replaced in RAF service by a fleet of 22 Airbus Atlas C1 A400Ms, the last of which arrived at RAF Brize Norton on 22 May 2023. The first A400M entered service in 2014.

While the Atlas can carry more troops and has a greater payload capacity than the C-130J – 37,000 kg as opposed to 21,772 for the C-130J-30 – there will something of a capability gap when the RAF retires the Hercules relating the type's special forces duties.

These capabilities, which relate largely to airdropping special forces and their equipment, are not scheduled to be fully resident in the Atlas fleet until 2025.

Lithuania to Provide Ukraine with Two NASAMS Units, More M113s

(pf) The Lithuanian Ministry of National Defence (MND) announced on 28 June 2023 that it will contribute a military assistance package to Ukraine that will include the purchase two National Advanced Surface-to-Air Missile Systems (NASAMS) from Norway's Kongsberg Defence & Aerospace (KDA).

Photo: Kongsberg

An acquisition contract worth around EUR 9.8 M for the NASAMS units was signed between Lithuanian's Defence Materiel Agency and KDA on 27 June, the MND stated.

"We are purchasing upgraded NASAMS missile launchers, which will be fully ready for integration with the armed forces of Ukraine fire control units, thus supplementing and extending its NASAMS operational capability donated by Norway and [the] US," Minister of National Defence Arvydas Anušauskas was quoted as saying in a 28 June press release.

Lithuania is also arranging the transfer and hand-over of the equipment to the Ukrainian armed forces, which will take place in the coming three months, according to the MND. The Norwegian Ministry of Defence, meanwhile, is contributing to the package with a donation of NASAMS launcher maintenance equipment.

Lithuania is itself a NASAMS user, having received its first systems in October 2020.

The Lithuanian military assistance package is also planned to include 10 M113 armoured personnel carriers, thus making a total of 72 such vehicles donated by Lithuania to Ukraine.

Additionally, the MND noted that Lithuania has placed an order for 12.5 million rounds of ammunition for Ukraine to be produced in 2023, 2.5 million rounds of which will be handed over to Ukraine shortly.

"Thousands of rounds of anti-tank ammunition for grenade launchers will follow soon as well. With this assistance package, Lithuania's contribution to Ukraine's defence will exceed half a billion euros," the MND stated.

Lithuania has also committed to continue supporting Ukraine in the long term by endorsing a military assistance plan worth at least EUR 200 M in the period 2024-2026.

In March 2023 Lithuania raised its defence spending by EUR 97.5 M, ensuring it reaches a level of 2.52% of GDP, on top of a 2023 defence budget of EUR 1.775 Bn, which was itself about EUR 573 M more than what was approved in 2022.

As a former Soviet territory that shares a border with the Russian exclave of Kaliningrad, Lithuania has keenly felt the plight of Ukraine since the Russian invasion of February 2022.

Design Contract Issued For New Danish Patrol Ship

(Thomas Lauge Nielsen) The Danish Ministry of Defence's Acquisition and Logistics Organisation (DALO) has awarded a contract to the Danish Patrol Ships consortium (comprising Terma, Odense Maritime Technology and PensionDanmark) for the design of a new class of patrol vessel for the Royal Danish Navy (RDN), the ministry body announced on 23 June 2023.

The project will be conducted in cooperation with the Danish armed forces and with potential subcontractors in the Danish maritime and defence industry to ensure a sustainable, future-proof and affordable design.

Image: OMT

The intent is that the practical work on the design will start in the summer of 2023 and be finalised by mid-2025. At that point the Danish government will then decide on the procurement and construction of the new vessels.

The design itself is intended to incorporate features such as 'green' technologies, for example, in order to reduce reliance on fossil fuels, as well as advanced decision support systems and modular mission equipment. For the latter, the Danish ship design and construction industry has significant experience from the previous Flyvefisken (Flying Fish)-class patrol ships and Absalon-class frigates. Both of these classes house most of their mission equipment in interchangeable, containerised modules, allowing rapid switching between missions.

The design contract has its origins in a decision by the Danish government in June 2021 to start the development of a new class of patrol ship for the RDN that will be capable of sovereignty patrols and environmental protection. A little over a year ago, in April 2022, DALO announced its intention to award contracts for the new patrol ships to the Danish Patrol Ships consortium, making the consortium responsible for the overall design, system integration, construction and initial maintenance of the new ships. With this latest contract the design part of the project has been initiated.

The decision to make a Danish consortium responsible for the patrol ship project has undoubtedly been influenced by the desire, following the Russian invasion of Ukraine in February 2022, to bolster the Danish defence industry and to increase the assurance of supply, especially for important defence assets. There can also be little doubt that the war in Ukraine, and the resultant new European security environment, has influenced the intended roles of the new ships, with an increased focus on potential combat operations, to safeguard Denmark's and NATO's sea lanes of communication and to defend Danish territorial waters.

The project also constitutes a novel approach to new ship design for DALO and the RDN. Traditionally, DALO and the navy themselves have retained primary responsibility for design and system integration, with just the actual construction of the ships being contracted to industry. By making a single industry partner, in this case the Danish Patrol Ships consortium, responsible for the complete project, DALO and the RDN wish to further leverage industry expertise. Should the project become a success, DALO and the Danish government expect it to become a model for the future contracting of complex capabilities.

The Danish Patrol Ships consortium is one of the largest defence contractors in Denmark, with a focus on radar systems, avionics and space technology. As previously reported by EST, Terma was also recently awarded the contract to act as system integrator for the Danish Army's new very-short-range air defence system. Odense Maritime Technology is a maritime consulting firm specialising in, among other things, ship design and integration, while PensionDanmark is a labour market pension fund with more than 800,000 members and, as such, brings to the table not only funding but also skills in project and risk management.

Saab CEO Johansson Appointed Vice Chairman of the Board at ASD

(pf) Saab President and CEO Micael Johansson was appointed vice chairman of the board at the Aerospace and Defence Industries Association of Europe (ASD) on 15 June 2023, the company announced in a press release.

Photo: Saab

The company noted that Johansson's appointment "comes at a time when defence and security in Europe are more important than they have been in decades, and where the European defence industry is seen as a crucial component for maintaining peace in the region".

"It is an honour to be elected to this position by my CEO peers and the national associations of ASD," Johansson was quoted as saying. "I very much look forward to helping to steer ASD in these challenging times for Europe, together with the newly elected ASD President and Chairman of the board, Airbus CEO Guillaume Faury,"

"Through my role as Vice Chairman of the board at ASD, I will be able to advocate for ASD's interests, drive concrete initiatives, and foster the technological advancements necessary to address emerging security challenges in Europe," Johansson added.

ASD represents the European aerospace, defence and security industries, mainly in relation to EU institutions but also on a global level in relation to other international bodies of importance to the sector. It serves as a collective voice for more than 3,000 companies, ranging from small and medium-sized enterprises to larger corporations.

ASD members together employ 879,000 people and generated a turnover of EUR 238 billion in 2021. The organisation works closely with policymakers, institutions, and other stakeholders to foster a secure and innovative defence industry ecosystem in Europe.

PAS 2023: Elettronica Emerges as ELT Group

(pf) The former Elettronica Group emerged on the first day of the 2023 Paris Air Show on 19 June as the newly rebranded ELT Group. The company explained that its new identity and image came about "in light of the ambitious strategic evolution set forth by our TENET 2030 plan".

The Tenet 2030 industrial plan focuses ELT Group on "an increasingly global, multi-domain dimension, reflecting new trends in the realm of sixth-generation air platforms, chiefly the multi-national Global Combat Air Programme (GCAP), which ELT Group is involved with", the company stated.

"Following Tenet 2030, ELT Group is evolving to respond more effectively to new technological challenges and increasingly complex protection demands," the group's president and CEO, Enzo Benigni, was quoted as saying in a company press release. "This evolution has been possible thanks to the deep expertise, gained over seven decades, in the innovative use of the electromagnetic spectrum through proprietary technologies, and through continuous work in research and development.

Image: ELT Group

"Today, ELT is a group showcasing its expertise in new domains and in new geographies, without losing focus of its core business, where the company continues to invest in innovative solutions to provide armed forces with advanced proprietary systems," Benigni added.

A new area of emphasis for the group, known for its heritage and expertise across the electromagnetic spectrum, is operations in the space and cyber domains.

"Space is becoming an increasingly strategic business sector, which, at the same time, is attracting cyber criminals," the company explained. "Examining emergent threats in this sector, ELT Group is leveraging its electromagnetic spectrum expertise by making the first payload, SCORPIO, for space-based signals intelligence collection placed in a low Earth orbit. The satellite carrying the payload was launched on 15th April on board a SpaceX Falcon 9 rocket."

Regarding the cyber domain, ELT Group stated that, via its CY4GATE investee, it has enhanced the capabilities of its Anti-Drone Interception, Acquisition and Neutralization (ADRIAN) system with a new feature called Cyber RF (Radio Frequency), which makes it capable of effectively detecting and reacting to new and more complex civilian and military operational scenarios involving new-generation malicious unmanned aerial vehicles (UAVs). Cyber RF is a complement to ADRIAN's jamming, radar and visual modules, allowing it to perform a full takeover of a hostile UAV to achieve a safe landing, avoiding impacts in the locale where the UAV is flying.

"Cyber RF ensures 100% detection of most commercial drones being used for hostile purposes," the company stated. "It also allows the real-time tracking of the drone and pilot, the possibility of aircraft identification and obtaining related telemetry (cyber detection) and finally selective drone takeover and countermeasures (cyber countermeasures)."

Also relating to the cyber domain, ELT Group entity Cy4Gate used the Paris Air Show to present its Hybrid Cyber Digital Twin platform, which can simulate an information technology/operational technology network to identify potential vulnerabilities and preventively implement countermeasures that facilitate a more effective and timely response to a hacker. Digital twin technology makes it possible to improve the cyber resilience of networks and their technologies; to make red and blue team training more effective by having them practise on simulated attack scenarios using real and current threats; and to implement a 'honey net' – a simulated network identical to the real one that is used as 'cyber bait' for an attacker in order to isolate it, study its behaviour and attack techniques, and then adjust defensive measures.

ELT Group says its new logo, featuring a sphere from which electromagnetic waves propagate, summarises three messages at the heart of the company's evolution: the dominance of the electromagnetic spectrum in every domain; the global projection of the company; and the increased ability to protect assets, people and data.

Growing the SEAD

Thomas Withington

The North Atlantic Treaty Organisation (NATO) has a clear roadmap to revitalise its Suppression of Enemy Air Defence capabilities.

The North Atlantic Treaty Organisation's (NATO's) Suppression of Enemy Air Defence (SEAD) and Destruction of Enemy Air Defence (DEAD) posture arguably took a back seat during alliance Counter-Insurgency (COIN) operations in Afghanistan. NATO SEAD/DEAD came to the fore once again during the alliance's Operation Unified Protector (OUP) in 2011. OUP was waged to protect Libyan civilians against forces loyal to the country's erstwhile dictator Colonel Muammar Gaddafi. The operation Unified Protector was performed on the high seas in and around Libya's Mediterranean coastline. Meanwhile, NATO special forces were deployed on the ground. However, much of the effort was taken up by NATO air forces which mounted a seven-month air campaign.

Unlike Afghanistan, Libya boasted relatively capable albeit dated radar-equipped Ground-Based Air Defences (GBAD). According to the International Institute of Strategic Studies (IISS), a London-based thinktank, these included medium-range, medium-altitude Surface-to-Air Missile (SAM) systems like the S-125 Neva/Pechora (NATO reporting name SA-3 Goa) and the medium-long range S-75 Dvina (SA-2 Guideline). Complementing these was the S-200 (SA-5 Gammon) high-altitude, long-range system. Lower altitudes were protected by SHORAD (Short-Range Air Defence) assets including the French-supplied Rockwell International/Thomson Crotale SAM system. Soviet-supplied SHORAD systems included the 9K33 Osa (SA-8 Gecko) and PK35 Strela-10 (SA-13 Gopher). SAM batteries had organic radar providing initial target detection and tracking, and missile fire control. Alternatively, batteries would use data provided by radars elsewhere. Libya's GBAD and the Libyan Air Force fighter fleet were networked into an Integrated Air Defence System (IADS) protecting the country's airspace and air approaches. Nonetheless, it had vulnerabilities and was approaching obsolescence by 2011. As the air defence expert Dr. Carlo Kopp observed, "Libya operated one of the few remaining unadulterated 1980s Soviet air defence systems worldwide" at the time of OUP.

Credit: USAF

USAF Capt. Jason Blodzinski, 77th Fighter Squadron F-16 Fighting Falcon pilot, lands at Aviano Air Base, Italy, following an Operation Unified Protector sortie.

The antiquated nature of Libya's IADS was rightly not taken on trust by NATO and the alliance deployed a formidable array of SEAD assets to protect its aircraft. The Aeronautica Militare (Italian Air Force) dispatched four of its Panavia Tornado-ECR dedicated SEAD jets. These aircraft deployed Texas Instruments/Raytheon AGM-88B/C High Speed Anti-Radiation Missiles (HARMs). HARMs were also deployed by US Navy Boeing E/A-18G Growler electronic warfare jets supporting the operation. While not dedicated SEAD assets per se, Royal Air Force (RAF) Panavia Tornado GR4A combat aircraft deployed the last RAF stocks of British Aerospace/MBDA ALARMs (Air-Launched Anti-Radiation Missiles) against Libyan radars. ALARM was finally retired from British use in 2013.

Electronic attack was provided by US Air Force (USAF) Lockheed Martin EC-130H Compass Call jamming aircraft. Compass Call attacked the radio communications networking the Libyan IADS and the Libyan armed forces in general. Additional electronic attack and HARM support against Libyan radars was provided by US Marine Corps' Northrop Grumman EA-6B Prowler jets.

The need to detect and locate Libyan ground-based air defence and Fire Control/Ground Controlled Interception (FC/GCI) radars necessitated a significant Signals Intelligence (SIGINT) collection effort. This effort collected data on Libyan radars and the radio communications networking the IADS and Libyan military. Italian Air Force Aeritalia/Alenia Aeronautica G222VS SIGINT aircraft supported this. They were joined by US Navy Lockheed Martin EP-3E Aries, USAF Boeing RC-135V/W Rivet Joint, Armée de l'Air (French Air Force) TransportAllianz C-160G Gabriel and Svenska flygvapnet (Royal Swedish Air Force) Gulfstream S-102B SIGINT platforms. NATO's SEAD/DEAD effort paid off. The alliance experienced a single aircraft loss during the operation, comprising a US Navy Northrop Grumman MQ-8B Fire Scout Unmanned

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Credit: Russian MoD

The kinetic elements of Russia's modern ground-based air defence assets in the form of a Pantsir-S SHORAD system with the launch tubes of an S-400 SAM battery visible in the background.

Aerial Vehicle (UAV) shot down by Gaddaffi loyalist forces on 21 June 2011.

Several NATO nations subsequently found themselves involved in Syria's civil war which erupted three days before the alliance's involvement in Libya began. The Syrian Air Defence Force (SADF) possessed a similar vintage of Soviet GBAD to Libya which formed the bulk of its IADS. Since 2014 the US has led a coalition of partners against the Islamic State (IS) insurgent organisation founded in 1999. IS' operations in Syria and Iraq came to global attention as the movement gained control of parts of northwest Iraq. Operation Inherent Resolve was mounted by the US to drive IS out of areas it controlled and to curtail the group's activities in Syria. Although Inherent Resolve can arguably be seen through the lens of post-9/11 counter-insurgency operations in Afghanistan and Iraq, it contained one important difference.

Putin's Temper Tantrum

In September 2015, Russia's President Vladimir Putin deployed his country's forces to Syria ostensibly to help his ally President Bashir al-Assad against the forces seeking to depose him. Moscow was also no doubt mindful of the Russian Navy's access to Tartus naval base on Syria's Mediterranean coast. Tartus is Russia's only permanent naval facility on this stretch of water. While the war in Libya featured antiquated air defences, and those of Syria were not much better, Russia's deployment to the troubled country changed this dynamic. Her armed forces brought with them some of the country's most advanced ground-based air defence systems. These threats included the S-400 (SA-21 Growler) high-altitude, long-range SAM system and Pantsir-S (SA-20 Greyhound) SHORAD platform.

Ostensibly, these were not aimed at US and allied aircraft. After all, the US, her allies and Russia shared some of the same foes in Syria, notably IS. Nonetheless, the deployment occurred against a backdrop of worsening NATO–Russian relations. Mr. Putin's distrust of the alliance had continued to grow since 2007. That year, he gave a hawkish speech to the Munich Security Conference held in the southern German city: "I think it is obvious that NATO expansion does not have any relation with the modernisation of the alliance itself or with ensuring security in Europe. On the contrary, it represents a serious provocation that reduces the level of mutual trust … We have the right to ask: against whom is this expansion intended?" A host of former Warsaw Pact countries, and three former Soviet republics namely Estonia, Latvia and Lithuania, joined NATO in 2009. Mr. Putin believes NATO expansion into what he perceives as Russia's sphere of influence is a danger to his regime. He felt a similar way about perceived Western support for so-called 'colour coded' revolutions in Georgia (2003) and Ukraine (2004) which he deemed contrary to Russia's interests. This paranoia crystalised in Russia's 2014 invasion of Ukraine. This action saw Russia's occupation of Ukraine's southern Crimea region and parts of her south-eastern Donbass area. In February 2022, Russia's strategic muscles flexed once more, albeit in what seems to have been a major geopolitical blunder, with her second invasion of Ukraine. As of May 2023, Mr. Putin's attempts to occupy the country and depose the government in Kyiv have been unsuccessful.

How do these geopolitical machinations affect NATO's SEAD posture? The enmity existing between the alliance and Moscow has consequences. At the tactical, operational and strategic levels it means sophisticated air defences like the S-400 and Pantsir-S could be used against NATO aircraft should the alliance and Russia come to blows. This existential threat means that NATO must double down on its SEAD capabilities and posture.

Credit: Thomas Withington

A model of the Eurofighter Typhoon-EW electronic warfare and SEAD aircraft was on display during this year's Association of Old Crows' EW Europe conference and exhibition in Bonn.

The good news is that work is forging ahead in this regard. Delegates at the 2023 Association of Old Crows' Electronic Warfare Europe conference and exhibition held in the western German city of Bonn from 15-17 May were updated on NATO's efforts thus far. Momentum gathered following NATO's summit in September 2014 held in Newport, South Wales. The event yielded a Defence Planning Package which committed the alliance "to further enhancing our capabilities," according to the declaration issued by the heads of government attending. The purpose of the package was to inform the direction of national defence investments by members and "improve the capabilities that allies have in national inventories." Chiefly NATO airpower needed to be capable of meeting and surpassing a near-peer threat. Air operations was one of the package's work strands, specifically NATO's joint airpower capabilities. Two areas requiring attention were flagged as AEA and SEAD, both of which are in the midst of being overhauled.

NATO's SEAD capacity has arguably been left to atrophy since the Cold War. The decline of superpower rivalry and lack of major GBAD threat during NATO's COIN operations being two contributing factors. NATO did face contested airspace during operations in the Balkans in the 1990s and in Libya last decade. These GBAD threats were prosecuted using similar SEAD capabilities to those fielded by the US and her allies during Operation Desert Storm in 1991 when Iraq was evicted from Kuwait. A decade of Russian military modernisation launched after the 2008 Russo-Georgian war shows that today's GBAD threats faced by NATO are more sophisticated.

Credit: Raytheon

Three ADM-160D MALD-J decoys adorn the underwing hardpoints of a USAF Boeing B-52H Stratofortress strategic bomber. Legacy ADM-160B variants were supplied to Ukraine.

Visions for the Medium-Term

The first step in revitalising NATO SEAD involved drafting a vision paper establishing current alliance SEAD baselines and shortfalls. In a nutshell, this paper asked: what SEAD capabilities will be needed by

Credit: Thomas Withington

Also on display at the EW Europe event was a model of an Airbus A400M strategic airlifter configured with a stand-off jamming payload. This could form part of the Luftwaffe's future LUWES SEAD force structure.

2030? Efforts to revitalise NATO's SEAD posture are being led by its Aerospace Capability Group, Sub-Group 2. Collectively known as ACG3/SG2 this supports "the development of a joint NATO SEAD, and associated Airborne Electronic Attack (AEA) capability," according to the alliance. ACG3/SG2 is focusing on SEAD capabilities that can be delivered from circa 2030.

A capability audit follows the vision paper. This looks at the SEAD capabilities NATO currently possesses and where capability shortfalls exist. Capabilities in NATO's possession include stand-off and escort jamming support in the form of the E/A-18G. As well as deploying the AGM-88 HARM, this aircraft is receiving the Next Generation Jammer (NGJ) ensemble. The NGJ detects and electronically (and possibly cybernetically) attacks hostile radars and radio communications on frequencies of 500 megahertz to at least 18 GHz. Communications jamming capabilities include the EC-130H and the USAF's new Gulfstream EC-37B Compass Call platforms which will assume this mission in the future.

Some SEAD shortfalls could be answered by technologies like support jamming to provide tactical and/or operational level electronic attack against hostile radars. Deception decoys are considered another 'must have' item. These can be used to deceive radars by transmitting false radar signatures. Current capabilities include Raytheon's ADM-160C Miniature Air-Launched Decoy (MALD) used by the USAF. The earlier Raytheon ADM-160B version is believed to have been deployed in Ukraine by that country's military. MALD could be joined by systems like MBDA's Selected Precision Effects at Range – Electronic Warfare (SPEAR-EW). SPEAR-EW is an air-launched decoy under development and expected to enter service with the RAF in the coming five years.

The alliance is also looking at what kinetic options could be germane to the SEAD fight. As noted above, NATO already has dedicated SEAD weapons at its disposal like the legacy AGM-88B/C HARM missile. This weapon is being replaced by the extensively modified Northrop Grumman/Raytheon AGM-88E/F. We may see additional anti-radiation weapons in the future. It is noteworthy that some years ago MBDA proposed an anti-radiation variant of its Meteor radar-guided air-to-air missile.

Nonetheless, these efforts do not rest solely on materiel. The alliance will update its doctrine to reflect the findings of the vision papers and capability audit. NATO's SEAD doctrine is enshrined in its Allied Joint Doctrine for Air and Space Operations. Future editions will not only fold in lessons learned for the alliance from Ukraine, but also reflect technological evolutions in the SEAD mission. A guiding principle of the doctrine will focus on the SEAD mantra of diversity and synchronisation of effects (kinetic, electronic and cyber), survivable delivery systems, connectivity, and coordinated information capture and distribution.

From an effects perspective, it is imperative that kinetic, electronic and cyber weapons can degrade, disrupt, deceive, destroy and/or deny red force GBAD capabilities at all levels of war. SEAD is not only about hitting the hostile radars – it needs to be seen holistically. Today's IADS depend on sophisticated communications for command and control. They use a host of intelligence, surveillance and reconnaissance assets from satellites collecting transponder information from aircraft to global navigation satellite systems providing position, navigation and timing information. All IADS elements must be held at risk if SEAD efforts are to succeed. This requires capabilities beyond dedicated aircraft and weapons. For example, cyber effects could implant malicious code into the battle management systems an IADS depends upon. The USAF is already believed to possess such tools in the form of BAE Systems' 'Suter' computer programme.

NATO's Industrial Advisory Group (NAIG) will play a key role in helping address these capability gaps and the technologies and materiel relevant to supporting the SEAD mission. One of the NAIG's study groups will provide a list of relevant capabilities that should be available to allies between now and 2030.

Use LUWES

As previous operations underscore, the US has provided the bulk of dedicated SEAD capabilities in previous operations. This dependence may diminish in the future. The Luftwaffe (German Air Force) is embarking on its ambitious LUWES (Luftgestützte Wirkung im Elektromagnetischen Spektrum; ENG: Airborne Effects in the Electromagnetic Spectrum) initiative. LUWES is procuring an array of new capabilities for the force. These include Eurofighter Typhoon-EW electronic warfare and SEAD/DEAD jets. Using kinetic, electronic and possibly cyber effects, these will perform the escort jamming role for strike packages of aircraft in contested airspace. A new airborne stand-off jamming platform will provide electronic and cyber effects beyond these lethal ranges. Airborne decoys and UAVs will provide these effects in the so-called 'no escape' zone. These are the ranges at which SAM batteries are at their most dangerous. All these capabilities will be networked together to receive timely intelligence and share data at the speed of light.

Germany provides Europe's dedicated SEAD support and LUWES represents an important shot-in-the-arm to this end. Strongly contested airspace is back on the agenda as a hallmark of contemporary warfare as exemplified by Russia's actions in Ukraine. NATO is not only addressing this threat but is seeking to overtake it as shown by the alliance's evolving SEAD posture giving Mr. Putin and his cronies something else to worry about.

Eurofighter Approaches True Maturity as a Combat Air Platform

Peter Felstead

Having now been in service for almost 20 years, the Eurofighter Typhoon is reaching full maturity as a combat air platform. While most of its users, in Europe at least, have now joined the 'F-35 club', the Typhoon will continue to operate as a potent complement to the F-35 for some years to come. Peter Felstead reports

As the dominant indigenous fighter in Europe, the Eurofighter Typhoon began entering service with the four Eurofighter countries – Germany, Italy, Spain and the United Kingdom – from 2003.

The UK's Royal Air Force (RAF) has 160 Typhoons but intends to retire its older Tranche 1 aircraft by 2025, leaving the force with 107 Typhoons: 67 Tranche 2 and 40 Tranche 3 aircraft. The RAF currently operates the Typhoon alongside the F-35 Lightning II. In terms of the future UK fighter force mix an RAF spokesperson stated on 20 January 2022, "The UK is committed to developing its Combat Air capability through continued capability growth in both the Lightning and Typhoon fleets as well as significant investment in the Future Combat Air System (FCAS, now the Anglo-Italian-Japanese Global Combat Air Programme (GCAP)).

Germany's Luftwaffe, which has a total of 143 Eurofighters, is ultimately slated to replace that fleet with the Franco-German 'other FCAS' programme's New Generation Fighter. However, in November 2020, under Project Quadriga, Berlin ordered 38 Tranche 4 Eurofighters to replace a similar number of Tranche 1 Eurofighters in the Luftwaffe inventory.

Beyond this buy, meanwhile, was the Luftwaffe requirement to replace its Panavia Tornado Interdiction/Strike (IDS) and Electronic Combat/Reconnaissance (ECR) fleets. In 2019 the German Ministry of Defence announced plans to acquire 30 Boeing F/A-18E/F Super Hornets and 15 Boeing EA-18G Growlers to address these respective requirements. However, following a change of government in Berlin at the end of 2021, in March 2022 Germany made the decision to buy 35 Lockheed Martin F-35s as strike platforms as well as 15 Typhoons for the ECR mission, with these aircraft now known as Eurofighter EK (Elektronischer Kampf) variants.

In Italy the country's final Eurofighter was received into service in October 2020, completing a fleet of 96 aircraft. However, given that 26 of these are Tranche 1 aircraft and another 15 are ECR variants, it has been reported that Italy could yet make an additional Eurofighter purchase to cover the retirement of its 50 Panavia Tornado IDS strike aircraft and 13 Tornado ECR variants.

Spain, with 73 aircraft delivered, had up to recently operated the smallest fleet of the Eurofighter countries. However, in December 2021 Madrid approved the procurement of 20 new fighters to replace the Spanish Air Force EF-18 Hornets based on the Canary Islands under Project Halcón (Hawk). In June 2022 it was announced that Madrid had ordered 20 new Eurofighters to fulfil that requirement. Under that EUR 2.04 Bn (USD 2.15 Bn) deal Spain will acquire 16 single-seat and four twin-seat Tranche 4 Eurofighters, with deliveries to commence in 2026.

Beyond the Eurofighter Consortium nations the only other European operator of the type is Austria, where fighter plans were in a state of disarray in recent years. After deciding in 2017 that its 15 Tranche 1 Typhoons, in service since 2007, were too expensive to operate, Vienna then made a U-turn on that decision in 2020 after cracks were found in tail-section bolts of the Austrian Air Force's dozen remaining Saab 105 jet trainers, which

Credit: USAF

A German Eurofighter lands at Selfridge Air National Guard Base in Michigan on 20 March 2020 on its way back from 'Red Flag' air manoeuvres at Nellis Air Force base in Nevada.

Credit: Leonardo

The first ECRS Mk2 prototype alongside a Typhoon test aircraft at BAE Systems' Warton facility.

had been used as cheaper-to-operate air policing platforms. Austria thus continues as a Eurofighter operator, but is unlikely to invest in further enhancements to its fleet.

In the Middle East, meanwhile, the Eurofighter is operated by Oman, Kuwait, Qatar and Saudi Arabia, with fleets numbering 12, 28, 24 and 72 aircraft respectively.

Radars

In terms of enhancements to the Eurofighter's combat capabilities, the most significant ongoing development is the adoption of active electronically scanned array (AESA) radar technology. Unlike the mechanically scanned radars typically installed in fourth-generation aircraft, AESA radars radiate multiple beams at multiple frequencies simultaneously, making them more difficult to detect and more resistant to jamming.

The first Eurofighter users to operate with this technology are the air forces of Kuwait and Qatar. Kuwait ordered 28 AESA-equipped Eurofighters in April 2016, while Qatar followed suit in December 2017 with an order for 24 aircraft. The AESA radar in these aircraft is what is now known as the European Common Radar System Mark 0 (ECRS Mk 0), which was developed by Leonardo.

European users of the Eurofighter, meanwhile, are pursuing two parallel paths with regard to AESA technology. Berlin ordered ECRS Mk 1 radars for its Project Quadriga Eurofighters under a contract awarded to Germany's Hensoldt, supported by Spanish firm Indra, in April 2021, while Madrid's Project Halcón order in June 2022 also covered Eurofighters equipped with the ECRS Mk 1.

The UK, meanwhile, is playing a longer game with regard to AESA technology and in July 2022 the UK Ministry of Defence (MoD) committed GBP 2.35 Bn (EUR 2.68 Bn) to a Typhoon upgrade that will see the adoption of the more advanced ECRS Mk 2 AESA radar developed by Leonardo UK. The MoD's current planning assumption is that the ECRS Mk 2 will be fitted to the RAF's 40 Tranche 3 Typhoons, although any further rollout of the technology is being kept under review.

On 21 April 2023 it was announced that the first ECRS Mk 2 had been delivered by Leonardo UK to BAE Systems' site in Warton, Lancashire, where it will undergo integration work and ground-based testing in preparation for first flights on a Typhoon in 2024.

The UK is paying a time penalty with the ECRS Mk 2 – it is essentially a completely new radar and its initial operational capability is forecast for 2030 – while its integration presents a considerably intrusive modification to the nose of the aircraft, but its capabilities offer a significant advantage.

While the ECRS Mk 1 is essentially an improvement to the ECRS Mk 0, both of those radars are essentially narrow-band arrays, so although they have many of the design advantages of a high-speed electronically scanned antenna, they are still designed primarily detect other airborne targets. The ECRS Mk 2, on the other hand, is a wide-band array that will not only detect its own emissions and find other targets in that way, but will also passively detect emissions through a far broader range of the frequency spectrum.

As Andrew Mallery-Blythe, Typhoon Operational Requirements Manager at BAE Systems, told ES&T on 5 May 2023, the ECRS Mk 2 will be able to passively track airborne targets and other surface-based emitters as well without having to emit itself. "It's a very, very high-gain sensor," he explained, "and it can also emit throughout that wide band, that wide frequency range, and it can emit and potentially attack all of those emitters: surface emitters, airborne emitters, etc, so as an electronic attack and electronic warfare tool it's hugely capable to do all of that while performing its primary role as an air-to-air sensor as well. And that's why the UK have pursued it."

With Leonardo UK leading the development of the ECRS Mk 2, it was announced in September 2021 that engineers from parent company Leonardo in Italy had joined the UK development team at its site in Edinburgh. Thus, while Italy has not formally committed to the ECRS Mk 2 for its Eurofighters, there is what may be described as 'mood music' implying that Italy may well adopt the ECRS Mk 2 for its Eurofighters.

Beyond Europe, the Royal Saudi Air Force (RSAF) has yet to decide on an AESA radar for its Eurofighter fleet. However, given that the RSAF typically aligns itself with UK capabilities, it is more likely than not that Saudi Arabia will ultimately also adopt the ECRS Mk 2.

Weapons

Beyond the Eurofighter's internal 27 mm Mauser cannon, a wide array of missiles and bombs have been integrated onto the Eurofighter, although not all user nations operate every type of weapon. Short-range air-to-air missiles (AAMs) integrated onto the Eurofighter include the ASRAAM, IRIS-T and AIM-9 Sidewinder, while beyond-visual-range AAMs include the AIM-120 AMRAAM and Meteor. In terms of air-to-surface missiles UK, Italian and Saudi Eurofighters can deploy the Storm Shadow cruise missile, German and Spanish Eurofighters the KEPD 350 cruise missile, while UK, German and Saudi aircraft can also carry the Brimstone family of missiles. Precision-guided bombs inte-

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Eurofighter Typhoon

nothing comes close

Credit: Eurofighter

Eurofighters flying in formation during the NATO Tiger Meet at Poznan-Krzesiny Air Base in May 2018

grated onto the Eurofighter include the Paveway II series of laser-guided bombs and Paveway IV dual-mode GPS/INS and laser-guided bomb, while Germany has also integrated the GPS/INS-guided GBU-54 Joint Direct Attack Munition (JDAM) onto the aircraft.

Regarding future weapons integration, MBDA UK is going into production with the Brimstone 3 later in 2023, which, as Mike Mew, the company's director of UK sales and business development, explained in a briefing on 10 May 2023, "has been modernised top to tail; the only thing that's consistent with the original Brimstone is the external shape. [It has] new energetics, additional modes in the seeker, additional software modes for use from a wider range of launch platforms."

Given that Brimstone is already integrated on the Eurofighter, just a brief requalification process will be required for the aircraft to carry the Brimstone 3.

MBDA is also working on two largely classified concepts for a Future Cruise/Anti-Ship Weapon, which will be a successor to Storm Shadow. One is subsonic and designed to be very survivable through the use of stealth, while the other is supersonic and would rely more on high speed to defeat any air defences. Both concepts will move into the development phase from 2025, with a view to being put into service at the end of the decade. Whatever weapons proceed, they are likely to be integrated onto the UK's Typhoons.

The Eurofighters in the RAF are currently at the Phase Three Enhancement A (P3EA) core avionics standard. While P4E has not yet finished its system definition phase, that package will bring integration of MBDA's Select Precision Effects At Range (SPEAR) Capability 3 stand-off attack missile plus an electronic warfare (EW) variant of that weapon, SPEAR EW, in which the missile's warhead is replaced by an EW payload to suppress enemy air defence radars.

Apart from weapons specifically, another key development in the UK is the implementation of enhancements to the RAF's Rafael Litening V targeting pods, which first entered squadron service on RAF Typhoons in February 2022. The enhancements are being made under the UK's National Delta Package (NDP) 1b Increment 2.2 in what BAE's Mallery-Blythe bills as "the product of the year". This standard is currently being tested and will be released later this year.

"Litening 5 is the most advanced targeted pod in the world," said Mallery-Blythe. "It's brought some amazing capability, both in the area of optics – much more powerful optics than have been seen before – and the ability to generate coordinates accurately. It's vastly, vastly superior to the Litening III and that has brought real, tangible capability improvements on operations right now. It particularly helps you employ Brimstone."

Mallery-Blythe explained that the Litening V enhancements under NDP 1.1 Increment 2.2 have added some improvements to the pod's usability. "One capability is there's a nudge feature, [which] just makes that tracking task easier for the operator," he explained. "The autofocus capabilities have [also] been significantly improved, and I would just say that the overall slickness of the integration has been improved for the Litening V, and that's going to make a real difference on operations."

Beyond the UK, in August 2021 the Luftwaffe declared that its Eurofighters had become operational with the Meteor, which thus joined the IRIS-T and AIM-120 AMRAAM in the German Eurofighters' air-to-air inventory.

Credit: Eurofighter

Future iterations of the Eurofighter will still be in service for decades to come.

Meanwhile, in December 2021 it was announced that MBDA's Marte ER anti-ship missile had successfully completed its final test firing the previous month. Derived from the Marte MK2/S anti-ship missile, which is already in service with Italy and Qatar as a helicopter-launched weapon, the Marte ER is propelled by a turbojet in place of its predecessor's rocket engine. While it is known that a feasibility study has been conducted by MBDA in relation to integrating the Marte ER on the Eurofighter, which was reportedly due to a request to Leonardo from a foreign customer that is likely to have been Qatar, it remains unclear how much further this development has progressed. However, one military aerospace analyst told ESD that he would not be surprised if the Marte ER was already in operation on Qatari Eurofighters.

Future Systems

As well as being fitted with the ECRS Mk 1 radar, the Tranche 4 Eurofighters being delivered to the Luftwaffe under Project Quadriga and to the Spanish Air Force under Project Halcón will also be equipped with the Praetorian Defensive Aids Sub-System (DASS). This system, provided by the EuroDASS consortium, will provide enhanced protection and situational awareness, as well as facilitating advanced electronic deception techniques.

Regarding the Luftwaffe's 15 Eurofighter EK variants, these are likely to receive a new EW pod being developed by Hensoldt in association with Israel's Rafael Advanced Defense Systems. Integrating Hensoldt's Kalaetron Attack technology into Rafael's Sky Shield EW pod, this new system is expected to be integrated onto the Eurofighter EK variants around 2030.

Meanwhile, since 2019 the Eurofighter consortium has been working on a Long Term Evolution (LTE) study for the aircraft that aims to secure its operational relevance for some decades to come. This will cover every aspect of the platform, from its avionics to its powerplants. While any plans under the LTE study have yet to solidify, one key development is likely to be replacement of the Eurofighter's three existing multi-function displays with a new touchscreen large area display (LAD). This would especially useful for presenting sensor fusion to the pilot in a manner found on fifth-generation combat aircraft like the F-35.

A Frequency Issue

One upcoming issue that the Eurofighter community will have to address is Multifunctional Information Distribution System (MIDS) frequency remapping in relation to the aircraft's Link 16 datalink. MIDS frequency remapping is required to operate in a country that is changing the frequencies available to Link 16 to free up frequencies available to cell phones and other systems that use the radio frequency spectrum. Given the United States is a country that will be implementing these changes by 2025, air forces wanting to participate in the US 'Red Flag' air manoeuvres from that year, for example, will need to be compliant.

Additionally, changes to the IFF transponders of military aircraft will also be required in order to fly in controlled airspace around the world from 1 January 2025.

The UK is tackling these issues under its NDP 1c, which will be implemented in time for full international compliance in 2025, meaning that the RAF will not have to operate under any exemptions and will retain full operational flexibility with its Typhoon fleet.

Europe Offers Counter-UAV Solutions

Doug Richardson

As the UAV threat continues to proliferate, thanks primarily to the low cost of entry provided by commercial drone manufacturers, they continue to make their presence felt on the battlefield. Dealing with these threats is very possible, but the solutions pose economic as well as technical challenges. As such, the C-UAV market is now teeming with competitors offering various solutions for different niches and user requirements. Doug Richardson examines some of these solutions on offer in Europe.

In December 2020, the publication *NATO Review* warned that "all competitors, from peers to terrorists and non-state actors, are including drone technologies in their standard tactics and concept of operations, challenging Allies' traditional air superiority in most conflicts." Since then, the potential threat posed by unmanned aerial vehicles (UAVs) has increased. A May 2023 report *Making the Most of the European Sky Shield Initiative* by the Center for Strategic & International Studies (CSIS) described how in a survey researchers had conducted with 16 unidentified "European defense experts" in February 2023, most responders had singled out UAVs as an important target set that needs to be addressed.

In many cases, UAVs are custom-designed military platforms systems, but there is a growing trend to weaponise commercially-available hardware such as the relatively-inexpensive drones flown by enthusiasts. Press reports tend to describe any form of UAV as being a 'drone', but the term is best used for commercial and consumer systems, which tend to be smaller and less sophisticated than military UAVs.

Finding an effective counter to the UAV threat has not been easy. Although a growing range of counter-UAV (C-UAV) systems has been shown at recent defence exhibitions, a Joint Air Power Competence Centre report published in January 2021 described C-UAV as "a wicked problem", and noted that "it involves a multitude of aspects and problems for which solutions are not trivial or not practical in many typical scenarios." Such factors have not deterred companies working in the C-UAV field. With hundreds of systems now being offered by companies in Europe and beyond, all that this article can do is to use a small number of these to illustrate different approaches to countering the UAV.

Methods of Detection

Potential methods of detecting UAVs include radar, passive RF sensors designed to detect transmissions to or from the intruder (such as direction finders), acoustic sensors able to recognise its sound signature, and optoelectronic systems intended to recognise its presence against a sky or terrain background. Data fusion can be applied to the simultaneous output from several types of sensor in order to achieve a higher possibility of detection that is available from a single source.

Passive RF

Passive RF sensors try to detect and analyse any RF signals used for communications between the air vehicle and its ground-based control station. The characteristics of such uplink or downlink transmissions may serve to identify the specific model of UAV.

Developed by the Ukrainian company Proximus, the Bukovel-AD was designed to use a passive RF sensor to detect UAVs at ranges of up to 100 km, then when the intruder was less than 20 km away to jam data transmission between the air-vehicle and its controllers. Available in vehicle or tripod-mounted form, it is currently in service with the armed forces of Ukraine and Morocco. During the 2014-2022 war in Donbass, the system was able to bring down Russian Orlan-10 UAV.

Active Radar

Large UAVs can be detected by existing radar systems, but smaller examples may prove hard to distinguish from radar clutter. Many types of small air-surveillance radar are useable against UAVs, but a more specialised radar may be needed to detect the smallest threats. According to the Spanish company Advanced Radar Technologies, its

Credit: VoidWanderer, via Wikimedia Commons

The Proximus Bukovel-AD, shown at a the 'Zbroya Ta Bezpeka' defence exhibition in Kyiv, from 15-18 June 2021.

Author

Following an earlier career in engineering, **Doug Richardson** is a defence journalist specialising in topics such as aircraft, missiles, and military electronics.

Credit: Patria

Close-up of the antenna of the Patria MUSCL passive radar system. MUSCL can be operated as a standalone system, or as part of a multi-static array for improved effectiveness.

Midrange 3D radar uses a 3D multi-beam antenna system, an additional high-power amplifier stage, and a 1 Hz scan rate to detect, track, and classify objects with a radar cross section (RCS) of less than 0.01 m2, such as micro quadcopters and micro fixed-wing UAVs. This level of performance makes it suitable for unmanned aircraft traffic management (UTM), and for the C-UAV role, says the company.

Most radars used for the detection of UAVs will themselves be targets for enemy ESM, since their signal will indicate the presence and approximate location of C-UAV defences. However, the Finnish company Patria includes UAVs in the potential list of targets for its MUSCL passive radar system. Designed to exploit existing FM radio and DVB-T/T2 TV broadcasting signals as illuminators of opportunity, MUSCL uses passive coherent location (PCL) technology to detect, locate and track targets. Target location is obtained by measuring both the time-difference-of-arrival (TDOA) of the signal reflected by the target and the direct path signal, as well as the target azimuth angle of the arrival. This angular measurement capability allows targets to be tracked even if only a single transmitter is available to be exploited. According to Patria, the use of operating frequencies lower than those used by conventional air surveillance radars improves the system's ability to track aerial targets that exploit stealth technology, and those that are small and fly at low speeds and low altitudes.

Optoelectronics

Deployed in the form of multiple fixed cameras, or mounted on a rotating gimbal, then paired with suitable software, optoelectronic sensors operating in the visible-light or infrared bands can automatically detect and track UAV targets including those that do not emit RF energy. They can also be used to identify potential targets initially detected by radar or other sensors.

The Estonian companies Milrem Robotics and Marduk Technologies have teamed to create a mobile autonomous C-UAV platform that combines the Milrem Robotics THeMIS unmanned ground vehicle and the Marduk Shark optoelectronic C-UAV system. While many current C-UAV systems are intended to intercept and jam RF communications between a UAV and its operator, Marduk Technologies believes that current advances in computer-vision technology will allow UAVs to conduct their mission in conditions of radio silence. Such threats can best be countered by using a combination of sensor fusion and machine-learning algorithms to detect, classify and target loitering munitions and other small threats at ranges of up to 2 km, says the company.

Acoustics

Spinning propellers and the motors that drive them create sounds that can often be unique to that particular combination. Acoustic sensors based on high-sensitivity microphone arrays and audio analysis techniques can not only detect the presence of a UAV by its sound signature, but can automatically compare this to a library of acoustic signatures in order to determine what type of air vehicle the intruder is.

Given a number of spatially-separated microphones, triangulation can be used to determine the approximate location of the intruder, while Doppler shift in sound frequency of the source signal over a period of time may allow its approximate speed and direction to be assessed. However the performance of acoustic sensors can be degraded by the presence of background noise, and by weather.

Microflown AVISA offers Skysentry, an acoustic sensor array able to track drones ranging from toy-shop multicopters to larger UAVs of fixed-wing configuration, as well as manned platforms such as helicopters and propeller-driven aircraft. Its basic senor package is the 'Castle', which consists of an array of four hard-wired and spatially distributed acoustic multi mission sensors, an acoustic master (AMR), and a weather station. It normally also incorporates two satnav receivers used to determine the unit's position and heading. A single Castle unit can typically be deployed by one person in less than 10 minutes. In practice, several can be deployed to create a network of sensor posts which are either hard-wired, or interconnected by radio.

The system divides the entire acoustic frequency spectrum into what the company terms 'frequency bins'. The direction of arrival for potential threat signatures is determined for a number of frequency bins. The more bins that point in a same direction, the higher the likelihood that this indicates the presence of a potential airborne threat. Detection range will depend on the type of drone, weather conditions such as wind speed and wind direction, the intrinsic noise level of target. Initial tests have demonstrated detection range up to 250 m for

Credit: Marduk

Optoelectronic systems such as the Marduk Shark provide a portable and passive means for UAV detections and identification.

Credit: Microflown AVISA

Acoustic sensors, such as Microflown AVISA's Castle sensor package are capable of detecting targets even without a direct line-of-sight.

a small (2 kg) quadcopter drone and up to 1 km for a fixed-wing drone of similar weight. While the system can be deployed as a self-contained C-UAV system, it has the interfaces needed for integration in a multi-sensor C-UAV system.

Potential Counters

While there is no 'one size fits all' solutions to the problem of countering UAVs, the alternatives to shooting down the intruder must include jamming the RF links used by the target in order to bring its mission to an end, taking electronic control of the intruder and ordering a change of course or even an unplanned landing, or even physically capturing it. There should be a minimal risk of collateral damage, while in a world where the number of UAV incidents seem likely to keep rising, a low cost per engagement is to be desired.

The most obvious threat of public safety is the operation of UAVs within air lanes or into the airspace over an airport, creating a risk that the device could collide with a fixed or rotary-winged aircraft either because its operator is sufficiently distant to not be aware of aircraft, or could even have lost control of the UAV due to a failure of the communications link between the UAV and the user's control unit. From 19-21 December 2018, hundreds of flights had to be cancelled at London's Gatwick Airport following reports that unidentified UAVs were flying close to the runway.

Other threats to public safety threats could be posed by UAV flying over large groups of people attending function such as a political rally or major sport, or over disaster areas caused by fire or bad weather. In most counties it is illegal to drive a road vehicle while under the influence of alcohol or drugs, but we must recognise the possibility of a UAV operator flying his air vehicle in the same undesirable condition.

Inevitably there is a 'grey area' between a military UAV taking part in combat operations, and the non-military situations listed above. A UAV attempting to fly over security facilities such as military bases may require a harsher response than that used against one flying over a sports event.

Jammers

When jamming interferes with the RF connection between a UAV and its control station, or denies it the use of GNSS, the UAV may respond with in a pre-programmed manner such as hovering in place, attempting to land in place, or attempting to fly to a user-defined location, such as their original launch location.

Kirintec is the UK company whose C-UAV systems seem to have been named by someone with an interest in archery. Longbow+ is a 41 kg modular jammer designed for use on land and maritime platforms and in static locations. It covers three frequency bands – low-band (20-520 MHz), mid-band (500 MHz - 2.7 GHz), and high-band (2.4-6 GHz) with an output power output of up to 450 W. Intended as a smaller tactical solution, Sky Net Recurve Max+ covers the same frequency bands as the vehicle installed system, but weighs only 22.6 kg. Output power is 90 W. While Longbow+ uses an omnidirectional antenna, Recurve Max+ can operate with omni-directional antenna, but directional low-, mid- and high-band antennas are available if required.

With commercially-available drones now posing a potential threat to public events, fixed-site civil, political, or military facilities, or being used to smuggle contraband such as drugs, mobile phones, and even firearms into secure facilities such as prisons, there is a need for jammers custom-designed for this class of target. One example is the MinKa (fixed) C-UAV Jammer offered by the French company KEAS, along with its MinKam (mobile) equivalent. Both cover all the frequency bands used by commercial drones, as well as GNSS systems, and are available in three variants offering detection only, jamming on detection, and continuous jamming respectively.

The UK-based Repulse company has developed its Repulse 24 unit for applications that include internal installation on an aircraft or helicopter on order to provide a forward-facing beam of 2.4 GHz jamming at ranges of up to 1 km. If fitted with an optional Yagi antenna, the unit could counter drones at ranges of 8 km or more, says the company, so could be used in ground-based form to protect aircraft on approach or just after take-off.

Credit: Repulse

The Repulse 24 is capable of jamming UAVS out to 1 km as standard, or out to 8 km when equipped with the longer-range Yagi antenna pictured.

Many manufacturers offer small man-portable jammers configured for use from the shoulder. A typical example is the EDM4S SkyWiper announced by the Lithuanian company NT Service at the 2019 Security and Counter Terror Exhibition in London. Made of aluminium, and shaped like a rifle, it weighs 5.5 kg, and incorporates sighting optics up to six antennas. The default configuration has four antennas – two for the 2.4 GHz and 5.8 GHz frequency bands, one for the 1.5 GHz band used by GPS, and one for the 1.5 GHz band used by GLONASS. All four antennas have an output power of 10 W. Aimed at its target, and activated at a range of 3-5 km, the EDM4S is intended to disrupt the aerial vehicle's communications and satellite navigation capabilities.

The UK company Blighter Surveillance Systems has teamed with Chess Dynamics to offer the AUDS (Anti-UAV Defence System). Its own passive electronically scanned array (PESA) radar uses frequency modulated continuous wave (FMCW) technologies to detect small UAVs in all weather conditions. Modern plastic-bodied drones have a very low RCS, but according to Blighter, the radar's Ku-band operating frequency allows it to detect the radar energy reflected by small structural elements such as control wires, the battery pack, the motor, and the on-board communications system. AUDS uses what the company describes as D3 (Digital Drone Detection) technology intended to extract the tiny radar reflections from these components even when the

target is flying close to the ground or near buildings (conditions where clutter reflections are relatively large).

Chess Dynamics provides the Hawkeye Deployable System and EO Video Tracker used by AUDS. This combines a high definition (HD) daylight camera and a medium-wave infra-red (MWIR) thermal imager that uses sophisticated image-processing electronics to deliver good imaging performance plus a narrow field-of-view electronic-zoom capability.

A non-kinetic radio frequency (RF) subsystem with a directional antenna is intended to selectively interfere with the target's command and control channels. It uses antennas with a stated beamwidth of 20°, and targets the five threat 'bands' commonly used by UAVs – 433 MHz, 915 MHz, 2.4 GHz, 5.8 GHz and the GNSS frequencies.

Given the repeated use of UAVs in its conflict with Russia that began in 2014 with the Donbass war and the Russian occupation of Crimea, it is hardly surprising that Ukraine has developed C-UAV systems. The KVS ANTIDRON system offered by Kvertus Technology in Kyiv combines the company's KVS AD-1 detection system and Vortex Antidron jammer into a single integrated system. According to the manufacturer, it has a detection radius of up to 2 km, and a jamming radius of up to 2 km. Total output power is 500 W, and the system covers all the frequency bands used for remote radio control and video transmission, plus the GPS L2 frequency of 1,227 MHz, and the L1 frequencies of both GPS and GLONASS at 1,575 - 1,620 MHz.

Credit: Kvertus Technology

The Votrex Antidron pictured above represents the jamming component of the KVS Antidron system.

Tracking a small slow-flying air vehicle is a significant challenge for radars, particularly if the target is able to hover. To solve this problem, the Germany company ESG has integrated the Airscout Verify slew-to-cue system developed by Walaris into its own Elysion automated drone detection system. Airscout Verify uses image-recognition algorithms to search the video output of the day/night vision channel of the Elysion. One a target detected by radar has been detected in the video image, Elysion automatically fuses the data derived from the video image with that from the other sensors. If the radar track is briefly lost, the system will maintain its tracking of the target via the video image. AirScout verify uses hardware-agnostic software, so can be rapidly upgraded or downgraded with different sensors or optics.

SAM Versus UAV

At the top end of the spectrum, a large and sophisticated UAVs such as the US Global Hawk can be considered by air defenders to be the equivalent of a manned aircraft, and a suitable target for current surface-to-air missile systems (SAMs). For example, on 20 June 2019 Iran used a locally developed Sevom Khordad medium-range SAM to engage and destroy a US Navy Broad Area Maritime Surveillance-Demonstrator (BAMS-D) version of the Northrop Grumman RQ-4 Global Hawk.

A defensive SAM system needs to locate and track a potential threat before it can be targeted and engagement begun. The smaller the threat's signatures are, the later its detection will be achieved. For smaller UAVs, the ranges and altitudes they operate at mean that the launching point will

Credit: Diehl Defence

The IRIS-T-SLM has been reported to have had a very high successful interception rate during its deployment to Ukraine.

be relatively close to the intercept point, so the engagement will essentially be a point-defence task. Under such conditions the SAM system will have little or no area-defence capability.

European-developed SAM systems are reported to have proven combat-effective during the current conflict between Ukraine and Russia. Ukrainian President Volodymyr Zelenskyy has described the Diehl Defence IRIS-T "a really effective system", and the Ukrainian Air Force claimed a 100% success rate when using the system against a Russian cruise missile attack on 31 October 2022. Ukraine took delivery of its first two Kongsberg Defence & Aerospace NASAMS batteries early in November 2022, and in April 2023 stated that the system had destroyed more than 100 Russian missiles and UAVs.

Medium-sized UAVs may still be viable targets for medium-range or short-range SAMs, but smaller UAVs are likely to be considerably less expensive than this class of missile, making them affordable for use in large numbers for armed forces or even militant groups such as the Houthis. Their low cost makes them useable in quantities that would soon run down the defender's SAM stocks.

As this article was being finalised, on the night of 27/28 May Russia launched what was then its heaviest-ever UAV attack on Ukraine, which claimed that 52 out of the 54 Iranian-made air vehicles that had entered Ukrainian airspace had been shot down. One possible reason for attacks on this scale might be an attempt to draw down Ukraine's stock of defensive missiles.

On 30 May, Russia reported that the Moscow area had been attacked by eight UAVs. Five had been shot down by Pantsir-S surface-to-air missile systems, and three had lost control and deviated from their intended targets as the result of defensive electronic-warfare.

Gunfire – the Low-Cost Solution

Conventional anti-aircraft weapons are one potentially low-cost method of subjecting UAV targets to defensive fire. The era in which low-flying seemed to promise survivability for strike aircraft saw fast-firing anti-aircraft guns being teamed with co-located or even on-mount radars, so these now-elderly weapons could achieve a new lease of life in the C-UAV role. When dealing with small UAVs, even small-arms fire may prove effective. The Kyiv police have released video footage showing a group of its officers using full-automatic fire from assault rifles to engage an unidentified Russian UAV.

Credit: KMW

The Flakpanzer Gepard SPAAG has been a more cost-effective point defence system compared to SAMs, when it comes to for engaging low-cost targets such as Shahed-136 loitering munitions.

According to a November 2022 report by the UK's Royal United Services Institute (RUSI), gun systems are a more effective method of downing UAVs than missiles "due to the much lower cost per engagement and higher availability of ammunition compared with SAMs and MANPADS". It went on to suggest that "A relatively simple new product that combined a small counter-UAV AESA radar with an attachable predictive aiming reticule sight is one option that, if possible, would offer a way to significantly enhance the capability of Ukraine's many traditional anti-aircraft guns such as ZSU-2-23 and 14.5-mm/12.7-mm heavy machine guns against Shahed-136." It also reported that "legacy Soviet and Russian self-propelled anti-aircraft guns (SPAAGs) such as Shilka and Tunguska also struggle to reliably shoot down the Shahed-136, although the German Gepard is highly effective."

By 20 September 2022 Ukraine had received 30 Gepards from Germany, plus 6,000 rounds of ammunition for the vehicle's twin 35 mm cannons. A few days later it reported having taken delivery of about 50,000 Norwegian-made 35 mm rounds. In December 2022, Germany recovered seven additional Gepard vehicles that had been scrapped, and began the task of refurbishing these for delivery to Ukraine. Detection range of the Gepard's radar against an Iranian Shahed-136 loitering munition is reported to be around 16 km. According to a Ukrainian Gepard operator interviewed for a TV news programme, downing a Shahed-136 typically requires the firing of only six rounds - three per barrel.

During the NATO Non-Lethal Technology Exercise (NNTEX-C) held in Sardinia from 4-24 March 2022, FN Herstal demonstrated a container-based perimeter defence solution that incorporated radar and passive RF sensors, and a combination of both soft- and hard-kill effectors. A smart and scalable signal jammer could be used as an initial response once the UAV had been detected, but if a hard kill was required, the system could use a deFNder Light Remote Weapon Station fitted with either

an FN MINIMI 5.56 mm or 7.62 FN MAG 7.62mm machine gun, or a deFNder Medium weapon station armed with 12.7 mm weapons such as the FN M2HB-QCB or FN M3R, or even a 40mm Automatic Grenade Launcher with compatible with air-burst munitions.

The Way Ahead

November 2021 saw NATO conducting C-UAV Technical Interoperability Exercise 2021 (TIE21). Held at Lieutenant General Best Barracks in Vredepeel in the Netherlands, this brought together military, scientific and industrial specialists in order to test emerging technologies and integrate systems able to counter small drones. "Malicious actors have made use of low-cost hobby drones in recent years, creating a potential security threat to Allies," said Dr Cristian Coman, who leads counter-drone activities at the NATO Communications and Information Agency (NCI Agency). "The misuse of small drones represents a significant and growing risk to operations and day-to-day defence activities for NATO and nations."

Goals of the TIE21 testing included identifying a minimum set of standards relevant for the NATO C-UAV domain, demonstrating interoperability between C-UAV components and fully integrated systems in NATO-relevant scenarios; and evaluating C-UAV technical architectures. The exercise was also intended to explore 'zero-second integration' – the ability to link various sensor and detection systems together instantly without the need for software or hardware adaptations.

A follow-on Technical Interoperability 2022 (TIE22) took place at Vredepeel during 13 and 23 September of last year. It involved more than 30 companies and organisations, and demonstrated the capability of their C-UAV systems during the live testing scenarios. Two prototype UAV-detection systems were also deployed to help the NATO Communications and Information (NCI) Agency to understand the commercial technology involved and see if it can support the alliance's evolving requirements.

Two systems deployed during the exercise had been developed by the NCI agency. One was a modified version of its ARTEMIS system seen at TIE21, the other was a Drone IDentification System (DroIDs). Both use machine learning algorithms to detect and classify drones. According to Major General Göksel Sevindik, the Chief of Staff at the NCI Agency, "It is an essential tool to help the Agency understand the technology being used in the market and to identify areas where NATO would benefit from developing standards around [C-UAV] systems."

Dr Cristian Coman was optimistic about the value of the trials. "Through the new innovations tested at this exercise, the Agency sends the message of TIE22 – that [C-UAV] shall be integrated with existing air defence in order to guarantee NATO's airspace remains safe."

Too Many Players?

A 2019 research paper on counter-drone technology by Bard College's Center for the Study of the Drone listed 537 C-UAV systems, but it remains to be seen whether the growing use of UAVs creates a market for C-UAV systems that is large enough to support so many companies and products. As current conflicts see UAVs being pitted against C-UAV systems, the results could show which of the latter are the most combat-effective. Some shake-out of the current range of companies and products seems inevitable. ■

European Ground-Based Air Defence Programmes

Jean Auran

Air defence has returned to the centre of the scene since Russia's invasion of Ukraine. This article focuses on ground-based air defence (GBAD) systems, political initiatives in this area, European capabilities and cooperation, and a review of key acquisition programmes.

Since February 2022, with Russia's invasion of Ukraine, Europe has become acutely aware of its shortcomings in air defence and has launched multiple initiatives to replenish stocks after deliveries of various systems to Ukraine. In October 2022, at the NATO defence ministers meeting in Brussels, plans were unveiled to bolster Europe's air defences, as Russian missiles and drones have continued to strike Ukrainian cities. The European Sky Shield initiative (ESSI) aims to set up an anti-missile shield combining types of equipment such as the IRIS-T, the PATRIOT system, and the Arrow 3, designed to destroy ballistic missiles. Seventeen countries participated in the initiative after Denmark and Sweden joined the programme in February 2023. Austria is also considering participating in the ESSI, even if Poland, Spain, France, and Portugal have remained outside the project. For Paris, this initiative is seen as a significant breach of European sovereignty and, from an industrial point of view, an opportunity to relaunch the IRIS-T.

Credit: Saab

The latest version of RBS70 is highly mobile with the Giraffe 1X 3D multi-mission radar.

European capabilities

Europe's defence industry has a number of champions in the field of anti-aircraft missiles. First and foremost is MBDA, a joint subsidiary of Airbus (37.5%), BAE Systems (37.5%) and Leonardo (25%), resulting from the merger of Matra BAe Dynamics, Aerospatiale Matra Missiles and Alenia Marconi Systems.

After winning a large contract from France and Italy for missiles of the Aster family signed at the end of the year (approximately EUR 2 Bn), MBDA signed for the supply of CAMM medium-range missiles to Poland. The European missile builder has already secured more orders amounting to EUR 4 Bn in four months.

Thales produces high-quality radars and Command and Control (C2) capabilities for air defence systems, in addition to well-known missiles such as StarStreak and LMM. Germany has the support of Diehl, which produces the IRIS-T missile and its land-based version, in both short- and medium-range variants. Added to this, in April 2022, Diehl and Hensoldt decided to intensify their cooperation. Swedish manufacturer Saab produces the RBS70, which includes its NG version. The company also offers radar such as the Giraffe 1X multi-mission 3D. In partnership with Raytheon, Norway's Kongsberg has been developing the National Advanced Surface-to-Air Missile System (NASAMS) whose model 3 is already fully operational.

Lower layers of air defence

The return of the threat of so-called high-intensity conflicts has revived very short-range air defence (VSHORAD) programmes, a good example of which is the Skyranger 30, produced by Germany's Rheinmetall Air Defence. Denmark announced on 16 May 2023 that they had selected this piece of equipment. The turret is equipped with a radar, infrared sensors, and a laser rangefinder. The armament is an Oerlikon KCE 30 × 173 mm automatic cannon that fires Advanced Hit Efficiency and Destruction (AHEAD) air bursting munitions, each of which releases 160 tungsten projectiles. The 1,200 rpm gun is extremely precise, allowing it to engage small aerial targets such as drones. The Thales rapid fire cannon is also a solution to counter armed drones and loitering ammunition. The system results from a Thales partnership with Nexter. Its 40 mm Case Telescoped Armament (CTA) cannon has the compactness of a 25 mm cannon and provides heavy firepower up to 4,000 m, with a reduced logistics footprint compared to a conventional cannon of the same calibre.

MBDA's Mistral 3 is still in production, and the company announced in March 2023 months ago that production of the armament would increase from 20 to 30 units per month. After Serbia and Croatia, Spain is the third country to order

Author

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the latest version. The Spanish Ministry of Defence placed a EUR 330 M order to upgrade its MISTRAL fleet to standard 3 between 2023 and 2032. During the next Military Programming Law, the French Army will also receive 24 Serval armoured vehicles equipped with a MISTRAL 3 turret. The Serval Atlas RC uses the MBDA remotely operated turret armed with two missiles and a 7.62 mm machine gun for self-defence. The turret should also be installed on the TITUS mine-resistant ambush-protected vehicle (MRAP) produced by Nexter. Norway and France have provided Ukraine with hundreds of missiles and firing units. The demand for Saab's RBS 70 NG man-portable air defence system (MANPAD) is rising, with the company receiving fresh orders from several countries. In December 2022, Saab received an order from Finland for this system with the order valued at approximately SEK 800 M, and deliveries due to take place between 2023 and 2026. This order includes the latest version of Saab's missile for the RBS 70 system, BOLIDE, which can engage armoured airborne targets and drones. The RBS 70 NG has an effective range of over 9 km and can hit targets up to a height of 5 km with a maximum velocity of Mach 2.

Air defence units are combining VSHORAD systems with ultra-mobile radars such as the Giraffe 1X. The RBS 70 New Generation (NG) is fitted with an advanced sighting system, capable of operating at night with advanced training functions and systems allowing revisualisation of the firing sequence. This equipment weighs less than 150 kg with a topside weight of 100 kg. The system can be operated remotely or locally. The Ground Master 60 is also an ultra-tactical air defence radar system with a detection range of 80 km (150 km optional) able to detect all types of targets from a moving carrier. The radar is deployable in less than two minutes and easily integrated into a C2 system. The Stinger surface-to-air missile remains essential in Europe with three main variants: the Stinger Basic, Stinger-Passive Optical Seeker Technique (POST), and the Reprogrammable Microprocessor (RMP). The United States and its allies have shipped 2,800 Stingers to Ukraine according to the Pentagon. The Stinger production line was due to close in 2020, but Raytheon Missiles & Defense has since been awarded several US Army contracts.

Medium-range GBAD

For medium-range systems, European companies produce several different missiles. In this regard, there are recent developments regarding the Aster missile. At the beginning of the year, Italy and France signed a new contract with Eurosam to produce 700 Aster missiles. This order includes Aster 15 and Aster 30 B1 missiles for both navies, the Aster 30 B1NT (New Technology) missile for the French Air Force, and Italy's three Army branches. Royal Navy ships, the Italian Horizon class frigates and future Greek FDI frigates are also equipped with the Aster B1NT. The Aster 30B1NT will have a capability against missiles with a range of 1,500 km. Thales has designed a new Ka-band seeker for the missile and the system will also receive the new multifunction radar Ground Fire 300.

In 2018, MBDA launched the technological development of the VL MICA NG. The Missile d'Interception de Combat Aérien (MICA) uses an infrared or electromagnetic seeker, depending on the threat. MICA NG offers improved capabilities to engage atypical targets such as drones and small aircraft. The missile is capable of intercepting targets beyond 40 km. Fifteen countries use naval and land versions, which is an alternative to the Aster 15 and is less expensive. Existing ground systems can combine missiles of both generations due to their compatibility. The latest version will be available in series from 2026.

Credit: Jean François Auran

Nexter exhibited a surface-to-air Serval project at Eurosatory 2022. This configuration is not definitive but demonstrates what this system could look like.

CAMM and CAMM-ER form the basis for MBDA's Enhanced Modular Air Defence Solutions (EMADS) range. The Sky Sabre or Land Ceptor (operationally BMC4I Sky Sabre) is the land-based version of the British Armed Force's CAMM (Common Anti-Air Modular Missile). CAMM has similar characteristics to ASRAAM, with the main differences being the use of an active electromagnetic seeker and a two-way data link. CAMM weighs 99 kg, provides an operational range of up to

Credit: Diehl Defence

The IRIS-T SLM launcher uses the traditional configuration of vertical launchers. The system has been very successful since the Russian invasion of Ukraine.

Credit: Raytheon Missiles & Defense

The GhostEye MR is an advanced medium-range air and missile defence radar, unveiled in October 2021.

25 km, and can achieve a speed of 1,028 m/s (3,702 km/h) and engage threats such as fighter aircraft, laser-guided smart bombs, and drones. The MIC4AD is a unified, integrated command, control, communications, computers, and intelligence (C4I) developed by Rafael for a different air and missile defence system. Italy and the UK developed the CAMM extended range version.

Credit: UK MoD

The Sky Sabre system replaced the venerable Rapier. The system is armed with MBDA's CAMM missile, and can engage multiple targets simultaneously.

Another popular system is the NASAMS, a surface-to-air missile designed for medium- and long-range warfare, utilising the American AIM-120 AMRAAM missile. The project started in 1994, initiated by Kongsberg and supported by Raytheon. The customer base comprises 12 countries, but 15 have acquired the command-and-control solution. NASAMS-3 is the latest upgrade and has been operational since 2019. It has the capability to fire the AIM-9X-2 Sidewinder, IRIS-T SLS and AMRAAM-ER missiles and introduces mobile air-liftable launchers. The AIM-9X variant includes an internal cooling system, eliminating the need for the launch-rail nitrogen supply required by older missile variants. A NASAMS unit has a modular design comprising a fire distribution centre (FDC), an active 3D Radar AN/MPQ-64F1 Sentinel, a passive electro-optical and infrared sensor, and several missile canister launchers. As NASAMS uses existing air-to-air missiles such as the AIM-9 Sidewinder, AMRAAM, and AMRAAM-ER, there may be thousands of older missiles in NATO's arsenal that can be used without change. The NASAMS system is also able to integrate the GhostEye MR, a medium-range S-band AESA radar based on GhostEye (formerly LTAMDS) technology developed for the PATRIOT system. In April 2023, the Ukrainian Air Force reported that NASAMS had shot down more than 100 missiles and drones since the system became operational.

Diehl Defence developed the surface-launched IRIS-T SL, an upgraded version of the IRIS-T missile equipping fighter aircraft for the Bundeswehr's Tactical Air Defence System (TLVS). The first version was the short-range IRIS-T SLS fielded in 2015. The company has launched a version with a higher extension, which entered service in 2022. The IRIS-T-SLM (Surface-Launched Medium-range) consists of a Multi-Functional Air Surveillance and Target Acquisition Radar System TRS-4D/TRML-4D developed by Hensoldt, a tactical operations centre and a vertical launch vehicle with eight missiles. The radar can track 1,500 targets up to a range of 250 km. It supports IFF Mode 5, and Mode S. A first battery was handed over to Ukraine in October 2022, and another in April 2023.

On the US side, the MIM-104 PATRIOT continues its career on the European continent. Over the years, the system has established itself as the backbone of NATO's air defence. Different sys-

tem versions are in service in Germany, Greece, the Netherlands, Romania, Spain, and also in Sweden. In December 2022, the US provided a battery of PATRIOT to the Ukrainian Army to combat Russian strikes. At the beginning of January 2023, Germany announced it would supply a battery to Ukraine, as did the Netherlands. The PATRIOT PAC-3 CRI is currently operational in Ukraine. This version, specialised in anti-missile defence, represents the most advanced variant of the PAC-3 version. This variant is surpassed only by PAC-3 Missile Segment Enhancement (MSE). Raytheon intends to establish a European regional PATRIOT centre for maintenance, repair, and overhaul in Switzerland with RUAG and Rheinmetall Air Defence AG.

Latest European orders and tenders

Switzerland has chosen to equip itself with the PATRIOT system after a long period of deliberation. The country will spend USD 1.2 Bn to acquire five firing units by 2030, each consisting of a command post, a multifunction radar sensor, and one or more launchers. The system ordered by Switzerland should make it possible to defend an area of 15,000 km², a little more than the Swiss plateau and its most densely populated cities. Switzerland is adding a ballistic missile defence capability to its future PATRIOT batteries by purchasing PAC-3 MSE interceptors. The first missiles should arrive in 2023. Austria is also looking for a mid-range air defence system with a range of up to 40 km, such as the IRIS-SLM or NASAMS.

Poland, which shares a border with Russia (Kaliningrad exclave) and with Belarus and Ukraine, has been trying for years to reinforce its air defence. On

Credit: Jean François Auran

German Patriot launcher. Germany still has eleven firing units equipped with this system.

28 April 2023, the Polish MoD turned to MBDA UK to procure 44 iLaunchers and around 750 CAMM missiles in a contract valued at USD 2.4 Bn. This order is part of the Pilica+ programme, which aims to provide 22 air defence batteries with a range of up to 25 km. Deliveries of launchers and CAMM missiles will take place between 2025 and 2029. Poland is already a user of the CAMM missile after receiving its first battery in 2022 in response to an urgent need under the Narew programme. The Narew system is based on the iLauncher platform mounted on the Jelcz 8×8 truck. The Narew is the result of cooperation between MBDA and PGZ and its subsidiaries JELCZ (responsible for the truck platform), PIT-RADWAR and WZU.

Poland is also waiting for the PATRIOT to expand its defence system and integrate them into NATO's NATINAMDS system. The purchase includes Northrop Grumman's Integrated Air and Missile Defence Battle Command System (IBCS) and four fire units equipped with four AN/MPQ-65 radars, sixteen launchers, four engagement control stations, six engagement operation centres, twelve inte-

Credit: UK MoD

Soldier belonging to the 16th Regiment, T deploying the Agile Multi-Beam surveillance radar of the new Sky Sabre Air defence missile system.

Credit: Kongsberg

NASAMS 3 High Mobility Launcher (HML) is mobile, provides quick-reaction, and is easily deployable by C-130.

grated fire control network (IFCN) Relays and 208 PAC-3 MSE missiles. Raytheon will deliver two batteries in 2023-2024, and then four batteries in 2026-2028. In December 2022, the first equipment reached Poland.

Finland has used NASAMS-2 since 2009 but launched an RFI to procure a long-range air defence system. In April 2023, the Ministry of Defence authorised the Finnish Defence Forces to procure the David's Sling system. Rafael Advanced Defense Systems (Israel) will deliver the system for EUR 316 M. The weapon system has been designed to intercept or counter long-range rockets and slow-flying cruise missiles at ranges of 40-300 km. Both Finland and Latvia ordered the RBS-70 NG. The Finnish order also includes the Giraffe 1X radar, to be delivered between 2023 and 2026.

In 2017, Lithuania ordered the NASAMS-3 to improve its air defence capabilities and received two batteries in 2020. Estonia and Latvia started joint negotiations to acquire the IRIS-T SLM in May. Their goal is to have an operational system in 2025.

Credit: Norwegian Armed Forces

Norwegian NASAMS 3 live fire.

In Germany, the Luftwaffe possessed all ground-to-air defence capabilities of the Bundeswehr for ten years. The Army now wants to restore an accompanying protection capability. On 3 January 2023, German media reported on consultations between Washington and Berlin regarding the Bundeswehr's acquisition of the Arrow 3 system. The two countries are accelerating negotiations and formulating the contract for the sale of the Arrow 3.

In 2019, the Czech Republic prepared for the acquisition of Israeli MADR (Mobile Air Defence Radar) radars, eight sets of medium-range mobile 3D radars and in 2021, a contract for the purchase of Israeli SPYDER (Surface-to-air PYthon and DERby missiles) on the TATRA truck platform. A total of five MADR radars are currently in the Czech Republic's inventory. Military testing on the 3D MADR mobile radar ended in April 2023 and the contractor, ELTA Systems Ltd, has until the end of July to resolve the remaining minor defects.

The French Armed Forces are also involved in the accelerated modernisation of its air defence capabilities. There are a number of ongoing concerns, despite the new military programming law. The 16 NC1-30 and 14 NC1-40 systems, carrying the Army's MISTRAL command posts and radars, will no longer be logistically supported in 2025 and 2030, and will need replacing. The MISTRAL's mid-life renovation (RMV) concerns only 850 missiles out of an initial target of 2,050. The purchase of 24 Serval armoured vehicles with air-defence capabilities appears to be limited, taking into account the requirements of two Army divisions. The Crotale NG's VT1 missile will be withdrawn from service on the French Air Force side in 2026. The Directorate General of Armament (DGA) chose the VL MICA solution (munition and its launcher) as the interim effector to replace the Crotale missile pending the arrival of a future low-level ground-air system.

In the UK, the Sky Sabre has been in service since 2022, and the British Army deployed the new system to Poland as part of NATO's build-up in 2022. The UK Ministry of Defence published a "Prior Information Notice" detailing their intention to purchase a new, fully integrated air defence system. Babcock and Rafael will jointly develop a C2 solution for a GBAD programme in the UK.

Future developments

Hypersonic threats are an important subject for air defence. The ability of these vectors to move and manoeuvre at extremely high speeds and to remain in endo-atmospheric or low exo-atmospheric space complicates their detection and reduces reaction times, thereby increasing their ability to penetrate defended spaces.

The leading players in the air defence industry are taking part in a reflection on the fight against this type of threat. Specific projects are already in progress. For example, the modernisation of the systems should contribute to an initial capability with the development of the SAMP/T NG radars or an ultra-high-frequency radar (UHF). In addition, the Timely Warning and Interception with Space-based TheatER surveillance (TWISTER) project of the Permanent Structured Cooperation (PSC) is based on two pillars: the endo-atmospheric interceptor and early space warning. Regarding endo-atmospheric interceptors, the EU HYDEF (European Hypersonic Defence Interceptor) project was selected for the European Defence Fund (EDF) under the Spanish group SENER Aeroespacial against MBDA's HYDIS project.

Russia's 2022 war against Ukraine has highlighted the effectiveness of air defence as a battlefield enabler, with a concentration of VSHORAD and short-range, medium and long-range systems, thus ensuring a multi-layered bubble protecting the land forces. This layout has hampered the ability of both air forces to conduct air-to-ground support, air combat, and airborne operations.

The French parliament recently issued a report regarding air defence in Europe. One of the report's conclusions was that the proposition to acquire the Arrow 3 was inconsistent in that this system does not respond to any current or developing threat in the strategic environment of Germany and Europe. Having been designed by, and for Israel in response to a specific threat, it is not in compliance with NATO doctrine and is not interoperable with the chain of command. ■

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A Return to Air-to-Air Combat?

David Saw

The fact that Western air forces would achieve and retain air dominance has become the accepted reality of air operations in recent years. The mission spectrum that results from the asymmetric conflicts that have become par for the course for the US and its allies have no place for air-to-air missions, simply because there was no air threat of any serious nature to face. With no peer or even near-peer competitor, Western air forces have not really needed to focus on air-to-air threats or capabilities. That situation is now starting to change.

One event that changed everything in the context of the European security situation was Russia's invasion of Ukraine on 24 February 2022. Any pre-existing assumptions on the solidity of peace and security in Europe were swept aside. On the other hand, the fact that this conflict continues nearly 16 months later, has demonstrated the resilience of Ukraine and its military and exposed many unexpected, or perhaps ignored, weaknesses in the Russian military.

The fact that Russia conducted long-range air assault missions using helicopters and transport aircraft deep into the enemy rear in the initial period of the conflict, was clear proof that they did not expect any serious air threat. Yet, despite their numerical superiority, the Russian Air Force was unable to establish air dominance over Ukraine and the Ukrainian Air Force was able to demonstrate unexpected powers of recovery. Furthermore, the Russian Air Force had no conception that this conflict would last so long and had not taken the necessary steps to prepare for extended combat operations.

When looking at the lessons of air operations in the current Russo-Ukrainian conflict, there are unique circumstances that need to be taken into account. Both sides were fully aware of the operational doctrines and aircraft performance of their opponent, in the main both sides were also fully aware of the of the performance of most air-launched weapons in service with their opponent. Indeed, prior to the collapse of the Soviet Union, one of the main Soviet air-to-air missile (AAM) production sites was located in Ukraine. Post-Ukrainian independence, this missile production and support capability was retained by Ukraine.

What becomes evident when looking at the start of the conflict is that Russia appears to have assumed that it could rapidly establish air dominance without having to truly fight for it.

Credit: USAF

A US Air Force F-16C of the 177th Fighter Wing tanks over the Atlantic, note the AIM-120 and AIM-9 missiles. Ukrainian Air Force pilots are being trained on the F-16 in Europe, indicating that the struggle for air dominance over Ukraine will be contested.

Confronting Reality

While it is obvious that materiel preparations for extended operations in Ukraine were insufficient in the context of both air and ground operations. Is that really a surprise after years of asymmetric conflicts against insurgents? In an air force environment, the main items to acquire would have been stand-off weapons in numbers suitable for low intensity conflict. In these circumstances, it is hardly likely that funding would have been put into place for a significant refresh of the AAM inventory, especially since there was no perceived need for adding to AAM capabilities, that was not the threat. Why invest in what you do not need?

Such logic is not confined to the Russian military, as evidenced by the discovery that Western nations were also happy to delude themselves that they had adequate war stocks for a conventional conflict. Again, years of reduced defence expenditures, added to participation in asymmetric conflicts had seen conventional capabilities diminished to a dangerous degree. How many European air forces would be able to rapidly generate a serious fighter force equipped with modern AAMs to undertake conventional high intensity operations in contested airspace? The sad but inevitable answer to that question is very few! Europe has become too used to meeting its airpower commitments in a limited manner, deploying aircraft in fives or tens to meet international obligations. How many air forces have the ability to do more than limited operations or have the ability to react quickly to conventional threats? The ability of far too many European air forces to contest and win air superiority has been degraded for far too long.

Of course Europe has always taken advantage of the fact that it can make its contribution in terms of airpower, with the US doing the heavy lifting and providing the majority of the capability. But what happens if that US safety blanket is no longer strong enough or no longer


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Credit: Armée de l'Air et de l'Espace

Dassault Rafale M fighters of the French Navy participating in the Arctic Challenge 2023 exercise, having taken on fuel from a Canadian tanker aircraft. France has always looked to sustain critical defence industrial capabilities such as combat aircraft and air-launched weapons to support national strategic autonomy.

present? The US 'Pacific Pivot' should have been warning that European security is no longer the primary focus of the US. They increasingly see China as the primary challenger to the US-dominated security ecosystem. More concerning for Europe is the fact that US military-industrial capabilities are showing their limitations.

Once, it would have been simply inconceivable that US resources would have been severely stretched by providing support to a nation involved in a conventional conflict. Yet the War in Ukraine has demonstrated that the US defence-industrial base has its limits, and that supply chains for all sorts of systems from the simplest to the most sophisticated are not robust and increasingly vulnerable.

The Next Steps

The Ukrainian government has made it plain that it would like the US and Europe to supply it with combat aircraft so that it can continue contest the air over Ukraine. Reluctance to support Ukraine in this manner appears to be weakening, with Ukrainian pilots now receiving training on the F-16 from both the US and European nations in Europe. F-16s armed with western missiles have the potential to transform the air battle in Ukraine. The US has intimated that in the long-term it will supply Ukraine with the F-16, although whether these will new-build Block 70/72 variants or surplus US Block 50/52 variants has yet to be clarified. It is thought that the US would supply an AIM-9/AIM-120 weapons package with these aircraft.

Credit: USAF

An F-16CD Block 52 of the Polish Air Force conducting an interception exercise over Poland. Under the Peace Sky programme Poland acquired 36 F-16C and 12 F-16D Block 52 aircraft and AIM-9X and AIM-120C AAMs. Poland will receive its first F-35 JSF aircraft in 2024, with 32 on order.

At the moment though, much will depend on what numbers and what F-16 variants can be supplied. Another important issue will be the depth of AAM stocks in Europe and/or the US. Will enough weapons be available to support Ukrainian operations? Fortunately, the F-16 platform is highly versatile, and can accept a wide range of armaments, meaning that the burden would not have to fall entirely on the USA to supply AIM-9X and AIM-120 AMRAAM. Other viable air-to-air armament options previously tested on or in use with F-16 could potentially include ASRAAM, MICA, IRIS-T, Derby/I-Derby, and the Python-4/5.

This inevitably brings to the fore the issue of whether Europe could do more to support the Ukrainian Air Force and, if yes, would it be appropriate to supply the Eurofighter Typhoon and its associated air-launched weapons? A difficult conundrum, and one that extends to France and its will and ability to supply Ukraine with combat aircraft, whether they be Rafale or Mirage 2000. These are obviously political questions that leaders in France, Germany, Italy, Spain and the UK will have to resolve one way or another.

For governments and military forces across Europe the invasion of Ukraine should have been a wake- up call that European military capabilities had been allowed to diminish to an unacceptable level after the end of the Cold War. Now we have come to a point where the price to be paid for degraded defence capabilities becomes clear, we must consider the next actions which need to be taken and how rapidly they need to be enacted. The problem is that economic realities would seem to conspire against any serious efforts to truly revive Europe's defensive capabilities in the short-term. The legacy of years of neglect needs to be overcome, before growing new capability can be entertained and that in itself will be expensive.

What needs to be understood is that conventional military threats have returned to become a major issue for European security planners, therefore steps must be taken to deliver a credible deterrent capability. To that end, a logical place to invest would be in having a credible air combat capability that can provide air dominance, the essential pre-requisite for success in conventional conflicts. There is no reason that Europe cannot achieve this, it has a highly capable air-launched weapons industrial base, added to the ability to build or otherwise acquire advanced combat aircraft on top of its existing inventory. It remains to be seen whether Europe will be ready to take the necessary steps to resurrect European air force capabilities as an essential step to re-invigorating conventional deterrence. ■

The F-35 in Europe: a New Way of Flying

Peter Felstead

Widespread acquisition of the Lockheed Martin F-35 across Europe is proving to be a transformational experience for the air forces adopting the type, Peter Felstead reports.

The Lockheed Martin F-35 Lighting II has swept through Europe to become the continent's dominant fifth-generation combat air platform, securing sales not only with former operators of the Lockheed Martin F-16 but also former users of the Panavia Tornado and Boeing F/A-18 Hornet. As it has done so, the aircraft has changed how European air forces not only fly and fight, but also train, support and maintain their combat aircraft fleets.

Credit: Crown Copyright

A pair of F-35Bs, one from the Royal Air Force (top) and one from the US Marine Corps, practise formation flying over the east coast of England on 1 July 2016.

An Expanding User Base

The United Kingdom was the first nation to join the F-35 programme and became a founding Tier 1 partner in 1995, giving the UK some degree of influence in the aircraft's development. The UK had an original aspiration to buy 138 F-35B short take-off/vertical landing (STOVL) variants, although only 48 are currently on order. These are to be in service by 2025, by which time the UK government says it will have decided how many more F-35s it will buy. The UK declared initial operating capability (IOC) Land for its F-35Bs on 10 January 2019 and IOC Maritime in January 2021.

Italy and the Netherlands joined the programme as Tier 2 partners in 1998 and 2002 respectively. Italy has a programme of record (POR) for 60 F-35As and 30 F-35Bs, while the Netherlands has a POR for 52 F-35As. IOC with the F-35A was declared by the Italian Air Force in 2018, while the Royal Netherlands Air Force (RNLAF) declared IOC for its fleet of F-35As in December 2021.

Denmark, Norway and Turkey then joined the programme during its Concept Development Phase (although Turkey was subsequently ejected from the programme in 2019 due to Ankara's procurement of the Russian S-400 air defence system). Denmark signed onto the F-35 programme in 2002 and has a POR for 27 F-35As, while Norway selected the F-35 in 2008 and has a POR for 52 F-35As. Denmark will achieve IOC status in 2024, while Norway declared IOC with the F-35 in 2019.

Belgium became the first European F-35 Foreign Military Sales customer in 2018, ordering 34 F-35As. This was followed by Poland in 2020 (with plans to procure 32 F-35As), Finland and Switzerland in 2021 (64 and 36 F-35As respectively), and the Czech Republic and Germany in 2022 (with plans to buy 24 and 35 F-35As respectively). In June 2022 Greece formally requested to buy 20 F-35s, with an option for 20 more. Ultimately, Lockheed Martin expects more than 550 F-35s to be operating in Europe by 2030, including US Air Force (USAF) squadrons operating out of RAF Lakenheath in the UK.

A New Way of Flying

For European air forces used to operating fourth-generation fighters, adoption of the F-35 has been something of a transformational experience.

"Every country that transitions from a fourth-gen to a fifth-gen fighter goes through a learning curve," J R McDonald, Vice President of F-35 Business Development at Lockheed Martin, told ESD on 4 May 2023. "We did it when we transitioned from F-15s to F-22s. The initial reaction was 'We'll just look at the same tactics … and we'll fly the airplane the same way. Very quickly we realised that you are not optimising this incredible platform with its sensors and its interoperability and its sensor fusion.

"So very, very quickly those tactics started changing dramatically. And now in the US we've been flying those tactics for quite a long time now," said McDonald. "Something as basic as mutual support, wingmen flying together: there's no reason to be a hundred yards apart in these airplanes when you have complete situational awareness of where the other airplane is, so maybe 20 miles apart is the best way to employ the airplane rather than visual mutual support, which

Credit: Lockheed Martin/Angel DelCueto

Monessa 'Siren' Balzhiser, Lockheed Martin's first F-35 female pilot, takes her first flight in the F-35 at Luke Air Force Base on 7 June 2021.

Credit: Lockheed Martin

Dutch F-35As flying in formation during a training sortie over Poland on 21 March 2023 in advance of conducting enhanced air policing and air shielding missions with NATO.

Credit: Lockheed Martin/Angel DelCueto

Front view of a USAF F-35A pictured during 61st Fighter Squadron sustainment and flight operations at Luke Air Force Base on 7 June 2021.

is where we did it with a fourth-gen airplane."

Rich Woods, F-35 Lead Instructor Pilot for BAE Systems at RAF Marham, additionally noted the F-35's two key fifth-generation attributes in a conversation between company representatives and ESD on 5 May 2023: sensor fusion and stealth. "Predominantly aircraft detect other aircraft via their radars," he explained. "Now if you have an aircraft which has a low radar cross-signature, that provides the ability for you to be able to take the first shot on an enemy or penetrate an enemy air defence system without being detected because you will be delaying the detection range, and that alters all of the tactics. So fundamentally you can do a lot more a lot closer to the enemy than you could in a fourth-generation aircraft.

"Fusion is the second-largest part about it," Woods continued, "so in fourth-generation aircraft you may have three different displays: one showing you radar information, another showing you electronic emission information and another showing you infra-red information. The F-35 blends it all together into one display, so you as an individual don't have to waste your brain power trying to match the three up. The aircraft will do that for you to provide a single picture of what the battlespace looks like. That reduces pilot workflow, allowing the pilot to then concentrate on applying whatever tactics they want to do.

"I would say stealth makes the aircraft survivable; fusion make the aircraft lethal – because it's allowing the pilots to leverage the sensors without having to worry too much about it, giving them the combat edge."

A further key attribute of the F-35 is that it is not just an air combat platform but key node in a 21st Century warfighting network, McDonald added. "An F-35 node is a sensor, it's a connector, and it's also an effector," he explained. "So the F-35 can go in and provide a kinetic effect, it can provide a non-kinetic effect, but through the connectivity it can also direct the effects of other weapons in the other domains. So a huge part of the value proposition for F-35 is the interoperability, interconnectivity – and as that interconnectivity expands it will be more and more across the domains, and not just with other F-35s." This latter quality is reaching ever higher levels, so that countries like Germany that are just coming on board the programme are set to benefit significantly.

"It's very significant that Germany's going to be receiving Lot 18 aircraft, which means they will have the Tech Refresh 3 (TR3), and they will have significant elements of what Block IV capabilities are coming forward," McDonald noted. "If you think about TR3 as the hardware enabler for the new capabilities that Block IV comes with, this is the most impressive upgrade of any fighter in the world. It's 75 major upgrades to systems across the airplane, and those upgrades are focused on the things you'd care about, so number one: the interconnectivity – more and better interconnectivity, not just from the airplanes but across the domains. Number two: the sensors on the airplane, while they're already some of the best in the world, are going to be much, much better. So think about that fifth-gen stealth airplane being able to go deep into enemy territory and now the sensors are really stepped significantly. And then the last piece is the weapons capability and capacity: more different types of those weapons and more carriage of those weapons."

A New Way of Training

The standard programme solution for F-35 training is that pilots and maintainers are initially trained in the United States at Luke Air Force Base (AFB) and Eglin AFB respectively, while some European air forces have a degree of training capability in country to conduct continuation training.

The exception to this is the United Kingdom (and also Australia), which decided from the outset to have a fully sovereign capability in training on and maintaining the aircraft. In 2018, therefore, with the UK's first F-35 unit, 617 Squadron, having been formed and trained on its STOVL F-35Bs alongside US Marine Corps pilots at Marine Corps Air Station Beaufort in South Carolina, all UK F-35 pilots and maintainers returned to the UK to set up at RAF Marham: the main operating base of the UK's Lightning Force.

With Europe's other F-35 operators there is currently a discussion ongoing as to whether a European Maintenance Training University (EMTU) should be set up. One key reason for this is that a lot of the European F-35 users have an issue with European Military Air Worthiness Regulation (EMAR) compliance, which is closely related to civil aviation requirements. US personnel have no need to accommodate this, meaning that the F-35 programme does not cover it. An EMTU working group has therefore been established by the European users, which Germany as a new user will probably also be invited to join.

Given that all F-35s are single-seat aircraft and cover a wide variety of mission sets, pilot training on the aircraft is consequently much more simulator intensive. Woods noted that, while the ground school for a fourth-generation would take three to four weeks before a pilot would fly in a two-seat conversion trainer with an instructor, for the F-35 in the UK the ground school takes about eight to nine weeks. Pilots have therefore flown around 35 hours in a simulator before climbing into an actual F-35 for their first flight. From that point onwards the split between synthetic and real flying is around 50:50.

While LM's McDonald noted that: "everybody that I've spoken to who went through the training said it was seamless to go from the simulator to the airplane", Woods pointed out that it was something of a misconception to simply say that the F-35 is an easy aircraft to handle. "It's an easy aircraft to fly, but it's quite hard to operate; the pilots are asked to do a lot more," he explained. "During the training course here at Marham BAE Systems delivers comprehensive training against every single mission set that an F-35 can do, so we're doing air to air, air to surface, we're doing suppression of enemy air defences, and we're doing surface-air counter tactics. So compared to another training system – be that F-16, F-15, Typhoon – the pilots graduate here having a lot more experience of operational mission sets. So traditionally at an operational training unit conversion course [where a pilot typically converts from an advanced jet trainer onto the unit's aircraft type], Typhoon would take about four months, but F-35 takes about a year because we're asking students to do a lot more, and we have to give them a lot more training, so when they come out the door here they're almost ready to go into combat in any type of mission."

Furthermore, Stephen Brown, Head of F-35 Training at BAE Systems, pointed out that simulation "is now more important than ever because you can't really practise

Credit: Lockheed Martin/Angel Del Cueto

Side view of a USAF F-35A pictured during 61st Fighter Squadron sustainment and flight operations at Luke Air Force Base on 9 June 2021.

everything than an F-35 can do in the live environment for various reasons". One key reason for training synthetically on the F-35 is to avoid giving away its true capabilities to any adversaries that might be paying close attention. "It's highly important that simulation capability is concurrent, is accurate and is available," said Brown, "because without the simulation [F-35 pilots] would quickly fall behind on currency and quickly become a less capable force."

One key training advantage is the growing size of the international F-35 fleet itself. "The biggest advantage [as new F-35 user] countries are coming on board – say when Germany gets their airplanes – is there's going to be a thousand-plus airplanes out there flying with a long history of going through this early piece of it," said McDonald. "And the training that they're doing in the US initially but more importantly, I think, at the operational training exercises that they're engaging in around the world, and the air policing, for instance, that we're seeing as a result of [the situation in Ukraine], they're operating the same airplane and they're having conversations with countries that have been operating it for quite a long time." He added: "I think that learning curve from fourth to fifth gen will be much, much quicker for every country going into F-35 because it's a community of operators now, and they can go to the country next door – not just to the United States – to find out the best ways to employ the airplane."

Support

While some European nations have yet to declare how they will support their F-35 fleets, others have been supporting and maintaining their aircraft for a few years now, with senior European partners the UK, Italy and the Netherlands being at the forefront of these activities.

In the UK the joint industry team of Lockheed Martin and BAE Systems has sustained the UK F-35 fleet out of RAF Marham since it arrived from the US in 2018. On 4 April 2023 it was announced that Lockheed Martin and the F-35 Joint Program Office (JPO) had signed the Lightning Air System National Capability Enterprise (LANCE) 23-27 contract with BAE Systems providing the majority of the personnel in support of the UK's F-35 national support solution. The joint industry team will thus continue to deliver air crew, ground crew and mission planning training; technical and operational support; IT support; supply chain management and expertise; as well as maintenance capabilities for the UK F-35 fleet out to 2027. Lockheed Martin Aeronautics will manage the JPO contract and provide the interface to the F-35 Global Support Solution.

Italy, meanwhile, hosts an F-35 final assembly and check-out (FACO) facility in Cameri, which is operated by Leonardo. This was the first fully operational international F-35 production site and delivered the first internationally built F-35 in December 2015. The Cameri site also operates a maintenance, repair, overhaul, and upgrade (MROU) facility that provides depot activities for Italian and international F-35s.

In 2019 the US Department of Defense selected the Netherlands to store, ship and manage spare parts for over five hundred F-35s, with consortium OneLogistics being the umbrella organisation delivering European supply chain support for the F-35 sustainment programme.

"Talking about building up sovereign solutions for Europe, the Netherlands have been very public to say they're going to have a national air vehicle depot, which they want to have to address their sovereignty and capacity needs," Nick Smythe, Director of Sustainment Business Development for Europe at Lockheed Martin, told ESD. "There are other countries that we're in discussion with regarding national air vehicle depots that just haven't revealed themselves publicly yet." Smythe concluded, "But that's essentially the landscape for maintenance, repair and overhaul," adding "It's really knowing how to be flexible to meet a sovereign need and that's what we're going to be focused on."

In terms of the F-35 supply chain, there is essentially a global spares solution. "To make the aircraft affordable – this is the principle – each nation doesn't have its own separate spares holding," explained Brown at BAE Systems. "There is a global spares holding, dotted around the world, that all nations can tap into. So we will hold some spares here at Marham, for instance, but not all, in what's called our retail warehouse here. If we have a spare to hand then it's used. If we don't, then you make a claim into the centralised system, asking for a spare. That system then finds where the nearest spare may be in another country and will literally move it to your location."

The one exception to this, noted Neil 'Shiner' Wright, Ground Training Delivery Manager for the F-35 at BAE Systems, is that the UK holds a deployable spares pack, given that the UK Lightning Force will sometimes need to deploy on board one of the Royal Navy's two aircraft carriers: HMS Queen Elizabeth and HMS Prince of Wales. "If a squadron suddenly had to deploy tomorrow, there is a protected pool of supplies that will get them in [and provide] the first few weeks of stores," Wright explained. "They're ringfenced in the warehouse and ready – 'in case of emergency break glass'-type stuff."

To deploy the F-35 on its carriers the UK also has simulators that are effectively housed in ISO containers. These provide continuation or mission rehearsal training for the UK F-35 pilots once they're on board the carrier. BAE Systems also supports UK deployed operations by embarking its own instructor pilots and synthetic technicians under what are known as 'contractors on deployed operations' (CONDO) regulations. Other aircraft types have never required this capability.

The Challenge of Maintaining Stealth

While the US Air Force has been operating stealth, or low-observable (LO) aircraft for decades now – the Lockheed F-117 Nighthawk attack aircraft was in service from 1983 until 2008, while the Northrop Grumman B-2 Spirit stealth bomber entered service in 1997 – operating a stealthy fifth-generation aircraft in the form of the F-35 has presented a challenge to maintainers in European air forces.

"On legacy aircraft you would have talked about 10 maintainers per aircraft. For an F-35 that ups that to 12, purely based on that extra low-observable restoration work you've got to do," explained Wright at BAE. The problem is essentially twofold: firstly, as the F-35 is a relatively new type, certain parts are needing to be replaced sooner than expected; secondly, the maintenance regime for preserving stealth is perhaps more of an art than a maintenance process.

"The theory is that the things you'll replace regularly should be behind either hinged or powered panels and these have their own way of sealing, so you don't have to do any restoration work as a maintainer with them," Wright noted. "However, we're still in the early days; not all the component parts have been thoroughly life tested, so some items are failing lower than originally planned and they're embedded deeper in the jet because they're supposed to be 'life of the jet'. Now we're probably still a few years from getting all that ironed out. That's one of the problems of buying into a programme really, so we're having to train all maintenance students on how to get into parts of the aircraft that weren't intended to be opened up.

"From a stealth maintenance perspective you're trying to maintain the outer mould line [OML]," Wright continued, "so quite often you hear LO maintenance referred to as OML maintenance; it's maintaining that outer mould line. If you think of it as a monocoque design, the more you keep that intact, the more you can maintain the stealth of the jet."

To address the challenge, BAE Systems has set up a dedicated LO workshop and is training its student maintainers from the outset in the new skillsets required. "It's a specialist skill to look after the coating in an efficient way and it requires people who have artisan skills," Brown added. "People who are good at arts and crafts, quite frankly, are the sort of people who tend to do this the best. And it's not necessarily a single trade; it's people who just have the knack for doing this sort of thing. We've quickly learned that it needs careful selection as to who actually does it and we've adjusted the training accordingly."

"One of the things we learnt early on is that it's recognising damage as well and keeping on top of the aircraft," Wright noted. "It's a different way of thinking, so a little blemish in the wrong place is not good, whereas a big gash in other places is acceptable."

All the required repairs to an F-35 are fed into a low-observable health assessment system that analyses how stealthy the aircraft is. "It's just a case of keeping on top of that continuously," said Wright. "If you follow the programme, you're supposed to send a low-observable specialist out to do that sort of check, but we can't afford that and it's very time consuming, so we're training the youngsters, really, who are coming through at the beginning of their career, how to do that for us."

However, that is not to say that all F-35 users are experiencing LO maintenance in the same way. LM's Smythe told ESD, "There's a common misconception about LO maintenance and the F-35. Where previous stealth aircraft were actually quite heavy on LO maintenance, there have been many design and supportability improvements worked into the F-35 where LO maintenance is now a very small part of maintenance performed on the F-35, less than 1% of all downtime, in fact."

Credit: Lockheed Martin/Angel DelCueto

A USAF pilot with the 62nd Fighter Squadron at Luke Air Force Base prepares for a training flight on 9 June 2021.

A New Level of Interoperability

New fifth-generation challenges notwithstanding, the F-35 is proving to be the transformational platform that it always promised to be – in capability, of course, but also in operation, training, support and maintenance.

Moreover, with such a wide-ranging European adoption of the F-35, air combat interoperability among NATO nations promises to achieve levels never before seen on the continent, or, indeed, around the globe.

Next Generation Interceptor Status Report

Sidney E. Dean

The United States Missile Defense Agency (MDA) is developing a Next Generation Interceptor (NGI) to support homeland defence from ballistic missiles. The first units could be fielded in 2027 or 2028.

The United States began fielding a Ground-based Missile Defense (GMD) system in 2004. It was never feasible or intended to protect North America from a large scale ballistic missile attack from either Russia or China. The impetus for the GMD system lay in the Intermediate Range Ballistic Missile (IRBM), Inter-Continental Ballistic missile (ICBM), and Weapons of Mass Destruction (WMD) programmes of so-called rogue states, especially North Korea and Iran.

The GMD system is designed to intercept a limited number of incoming ballistic warheads in space during their midcourse flight phase. Circa 44 Ground Based Interceptor (GBI) missiles are currently deployed via in-ground missile silos at Fort Greely in Alaska and Vandenberg Air Force Base in California (the precise number became classified in January 2023, with 44 being the last acknowledged figure). The intercept mission is supported through a network of sea-, ground- and space-based sensors as well as command and control systems.

The GBI is composed of a three-stage solid-fuel booster rocket carrying a single Exoatmospheric Kill Vehicle (EKV). Following separation from the booster, the EKV uses guidance data transmitted from ground support and fire control systems as well as its own on-board sensors to identify the target. The EKV closes with the target using on-board thrusters, and destroys the target through kinetic impact – this defeat mechanism is known as 'hit-to-kill'.

Credit: MDA

A Ground-Based Interceptor is launched from Vandenberg Air Force Base, California for a March 2019 test.

Credit: MDA

The In-Flight Interceptor Communications System (IFICS) data terminal at Fort Drum (New York) constantly sends updated targeting data to the Exo-atmospheric Kill Vehicle (EKV) while in flight, and relays data from the EKV back to the GMD fire control system.

A Service Life Extension Programme (SLEP) is currently underway to guarantee the viability of the current GBI arsenal past 2030. Eleven of the currently deployed missiles are being equipped with upgraded boosters, electronics and kill vehicles. The SLEP is expected to be completed in early Fiscal Year (FY) 2025. In addition to these upgrades, the MDA has acquired sixteen additional GBIs – over and above the original 44 – since 2017. One more will be delivered by late 2023. These will serve multiple purposes, including additional flight tests of the interceptor system, and replacement for inoperable missiles.

Next Generation Interceptor

The current GBI arsenal has several limitations. The flight test record is chequered. Since 1999 the system has failed nine of 20 intercept tests. The current concept of operations is thought to call for launching between two and four missiles per incoming ICBM in order to increase the odds of a successful intercept. In the long run, the reliability issue is overshadowed by the fact that the

Credit: Lockheed Martin

Concept image of NGI interceptors in action.

GBI is not designed to deal with multiple reentry vehicles (MRV), decoy warheads, manoeuvrable payloads or electronic countermeasures to thwart intercept systems. Michelle Atkinson, MDA Director for Operations, confirmed in March 2023 that new adversarial ballistic missiles systems feature multiple and manoeuvrable reentry vehicles along with decoys and jamming devices. Defence industry sources involved in missile defence development have separately stated that the complexity and innovations in the threat capability largely centre around improved manoeuvrability and countermeasures, as well as rate of travel.

The NGI is intended to counter this evolving threat environment, and will display enhanced performance against projected threats from North Korea and potentially Iran, Atkinson stated during a 14 March 2023 Pentagon press briefing. As described by MDA director Vice Admiral Jon Hill, "NGI is the result of the first holistic technical assessment of homeland defences the department has conducted since initial system operations began in 2004. [...] Once fielded, this new homeland defence interceptor will be capable of defeating expected threat advances into the 2030s and beyond." New and planned sea-, land- and space-based sensors as well as improved command, control and communications systems will network with the NGI, maximising the interceptor missile's performance.

Given the early stage of development, details regarding the design, capabilities and concept of operations of NGI remain either classified or as yet undetermined. A few factors are known or generally presumed based on the threat picture for which the NGI is being designed. The new interceptors will be based in the same missile silos as the current GBI. NGI will continue to destroy targets during their exoatmospheric midcourse flight phase using the hit-to-kill defeat mechanism. From the beginning, the MDA informed contenders for the development project that the interceptor missile would need to carry a multiple-kill payload in order to deal with MRVs or swarm attacks and to reduce the number of interceptors required to defeat a single ballistic missile threat. The interceptor will also need to be faster than the current GBI in order to deal with faster incoming targets and to provide additional time for the intercept mission. It will likely require multiple sensor types including infrared and radar to improve the ability to discern between legitimate targets and decoys.

The NGI will be required to incorporate sufficient flexibility to be quickly and consistently upgraded over the course of its service life in order to adapt it to emerging threats; open-system hardware and software architecture will be a prerequisite. At this point it remains open whether the NGI could potentially also be deployed against ballistic-missile launched hypersonic glide vehicles.

NGI Development Contracts

The NGI programme was formally initiated in April 2020 with a Request for Proposals, with the intention of selecting two competing industry contenders to develop interceptor concepts and prototypes. On 21 April 2021the MDA awarded the competitive development and demonstration contracts to Northrop Grumman and to Lockheed Martin. Both awards together are valued at USD 7.8 Bn. The contracts cover the rapid development and prototype testing of a new interceptor All-Up Round (AUR) consisting of the multistage booster and the hit-to-kill payload. Each competitor will develop and present a unique design including booster systems and multiple-kill-vehicle solutions. The period of performance runs through 2029. "By planning to carry two vendors through technology development, MDA will maximise the benefits of competition to deliver the most effective and reliable homeland defence missile as soon as possible," said Admiral Hill when the contracts were awarded. Both of the selected industry teams announced that they would base

Credit: US DoD

US Navy Admiral Jon Hill has served as MDA Director since 2019.

Credit: Northrop Grumman

Command centre of the Northrop Grumman/Raytheon Digital Software Factory for the NGI programme.

Credit: Northrop Grumman

In June 2022 Northrop Grumman began producing engine components for the NGI programme. Manufacturing these specific components involves a specialised fibre weaving capability, depicted here.

their project headquarters in Huntsville, Alabama, home of the Missile Defense Agency, although key development, construction and testing activities will still be performed at various established facilities throughout the United States.

Northrop Grumman has teamed with Raytheon Missiles and Defense as its primary partner. The firms plan to capitalise on recent development work performed on other weapon systems, such as the future LGM-35A Sentinel (formerly known as the Ground Based Strategic Deterrent) ICBM being designed by Northrop Grumman, or the SM-3 Block IIA interceptor missile produced by Raytheon. Both weapon systems are notable for advanced capabilities in such areas as sensor-based target discrimination and targeting precision, as well as high operational range. The SM-3 Block IIA is particularly interesting for its advanced targeting capability. Originally designed to combat the IRBM threat, the weapon system successfully destroyed an ICBM-class target in November 2020.

Individual technologies from these high-performance, cutting-edge systems can be adapted for the NGI or serve as a basis for new component designs, said Raytheon's deputy programme manager for NGI, Melissa Morrison Ellis. "MDA told industry [to bring in] 'technology-proven capability that you can integrate and bring to bear,'" said Terry Feehan, Northrop Grumman's NGI programme director. In this context Raytheon, for one, will be refining its interceptor sensors further to enhance the ability to isolate multiple targets in cluttered environments (decoys and debris) and properly categorise objects as priority targets or harmless. Raytheon, which produces the currently deployed EKV, will also be charged with developing the new generation of kill vehicles for the NGI.

Lockheed Martin is working in conjunction with Aerojet Rocketdyne, which will supply the propulsion solutions; Rocketdyne's current development and production portfolio includes various space boosters as well as propulsion systems for Delta IV and Atlas V rockets. Lockheed Martin themselves stated that they are leveraging previous investments in multi-object kill vehicle technology, hit-to-kill experience on the Terminal High Altitude Air Defense system (THAAD) as well as decades of work on the US Navy Trident missile programme. The firm also promises improved maintainability and reliability when compared to the GBI.

Early Progress

Both teams are relying on digital engineering and model-based engineering tools for the preliminary design phase, including running virtual performance testing on the individual design options to verify that they can defeat the threat parameters supplied by the Pentagon. The MDA will have full access to the firms' digital environments, ensuring transparency and providing the government the opportunity to comment or intervene at any stage. The MDA approved both teams' System Requirements Reviews (SRR) in late 2021, ahead of schedule. This early programme milestone certifies that the vendor is ready to proceed with the initial system design. In this context, both contractors were required to demonstrate that their respective critical technologies achieved Technology Readiness Level (TRL) 5 or higher. TRL 5 affirms that technology has been tested in a laboratory or relevant environment, but the hardware is not necessarily of the form and fit that would be integrated into the final product. Passing the SRR cleared both teams to proceed into the initial system design phase. Both contractors are currently focussed on maturing technologies, testing parts for survivability, defining requirements at the subsystem level, and developing interceptor software.

Northrop Grumman

Northrop Grumman promises to leverage advancing manufacturing techniques and a digital collaboration environment "to design, produce and test with speed and agility." To this end Northrop and Raytheon have developed a joint "digital software factory" for the NGI programme. According to Northrop Grumman, the design centre is equipped with a set of tools, process workflows, scripts and environments configured to streamline and coordinate code development

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Credit: Lockheed Martin

Close-up concept of a salvo of NGI interceptors.

and integration with minimal human intervention, thereby accelerating critical decision making. The facility was approved by the government in December 2021.

The firm has stated its intent to pursue prototyping and small-scale manufacturing of the riskiest elements of the system first, in order to mitigate the most likely risks early and smooth the way for full-scale production. Additive manufacturing (also known as 3D printing) is being used when possible for rapid prototyping of components, to speed testing and comparison of various possible component and sub-component designs. By early 2023 Northrop Grumman reported having manufactured and tested prototypes of several key NGI components ahead of schedule. This includes elements of the propulsion system, such as the integral throat entrances for the NGI solid rocket motors first manufactured in June 2022. In December 2022 the firm reported completing the first full-scale mix of the solid rocket motor propellant, which will be needed for ground testing Northrop's NGI rocket engine prototypes. An early engineering test of the thruster valve and nozzle on the liquid propellant divert and attitude control system (DACS) designed for the new kill vehicle was completed by Raytheon in December 2021, with the actual design created by Aerojet Rocketdyne acting as a subcontractor.

Lockheed Martin

Lockheed Martin is building a 2,400 m2 Missile System Integration Lab in Huntsville exclusively for the development of NGI. The USD 16.5 M integration laboratory will be co-located with the company's engineering team. The facility is scheduled to open in late 2023. According to the firm, it will serve for early development and integration work, testing of the AUR and communications systems as well as ground testing, enabling the firm to thoroughly vet the concept before physical flight testing.

Lockheed Martin states that it plans to leverage data as a strategic asset to support the operational system. A so-called Digital Twin of each individual interceptor will be maintained. The goal is to maintain critical data unique to each round, helping the firm to model performance and assess readiness. In this context Lockheed also relies on a "digital factory," although the term here refers to a framework consisting of software development tools, scripts and process workflows. This process is designed to maximise reliability through continuous automated software testing. Utilising these processes, the firm presented the first NGI flight software package in October 2022, one month ahead of schedule.

In August 2022 the firm also demonstrated the NGI communications radio technology prototype. The communications system, developed in collaboration with the Texas-based firm X-Microwave, provides bi-directional high-speed in-flight data exchange with ground control units, enabling the interceptor to respond quickly to changes in the operational environment. The early prototype test validated the ability of the communications suite to function in so-called harsh and adversarial environments encountered during intercept missions.

Critical Design Review and Beyond

Preliminary Design Reviews (PDR) are scheduled for late FY 2023. In order to reduce risk within the development programme and to promote design stability, MDA will require both contractors to demonstrate all critical technologies at a TRL 6 or higher to pass this milestone.

The Critical Design Review (CDR) is currently set for 2025. While both firms are voicing optimism that the trend of completing programme milestones early could continue into the CDR, the precise timing of the review will depend on the state of progress. Following the CDR, each vendor will submit a proposal for production of test missiles and 20 operational missiles. Flight tests are to be conducted in the 2025-2026 timeframe.

Regarding flight testing, MDA 2023 budget documents foresee each vendor proffering one test interceptor. However, Admiral Hill has consistently advocated for a minimum of two intercept tests per design before making a production decision, a policy he calls "fly before you buy."

The current testing plan provides for attempting an intercept using a single NGI prototype, followed at a later date by a salvo of two interceptors fired simultaneously, Hill expressly said during a May 2022 Centre for Strategic and International Studies (CSIS) forum in Washington; no changes to this policy have been publicly announced since then.

Beyond the flight tests, there remains considerable flexibility – and uncertainty

Credit: Northrop Grumman

Notional BGI system graphic.

Credit: Northrop Grumman

Notional cutaway representation of silo-based NGI interceptors.

– regarding how the programme will proceed with respect to downselecting to a single vendor. Formal funding for two NGI industry teams is guaranteed only through the Critical Design Review. However, Pentagon leadership has consistently maintained that they wish to retain maximum flexibility with regard to when – or even if – the government commits to a single vendor. While an ultimate downselect remains the likely outcome, delaying the decision as much as possible provides the MDA with greater flexibility and enhances the outlook for achieving the highest-performance system.

At the CSIS forum, Admiral Hill stressed that dual-production lines as well as retention of a secondary optional production line are not uncommon. "So the options that we have now, carrying two really qualified contractors, is [that] you could have a dual production line. [...] So, if one of the performers doesn't perform or we see issues, we can drop down and we still have the one to carry through and go to production," he said. The ultimate decision regarding downselect or a dual-vendor strategy will be "real world threat driven" and will be influenced by input from the combatant commanders, the MDA director stated. One factor which could push the Pentagon to offer production contracts to both firms would be a perceived need to speed production of the new weapon system in order to meet a rapidly escalating threat environment.

Production and Fielding

A 2021 estimate by the Pentagon's independent Cost Assessment and Programme Evaluation (CAPE) office predicted that the total cost of the NGI development programme would come to USD 13.1 Bn, including the production of 10 test missiles. Procuring the first 21 operational interceptors was estimated at an additional USD 2.3 Bn. Operation and maintenance of those 21 units over their service lifetime would likely come to another USD 2.2 Bn, according to CAPE. Factoring out the development cost, this would come to a unit price of circa USD 110 M per interceptor.

Fielding the first operational units was originally slated for 2028, following a mid-decade testing period. Given the current pace of development, the Pentagon believes that the operational introduction of NGI could potentially be moved forward by one year. "Right now, both are performing so well that they are anticipating, and our team believes, that we're tracking towards 2027," Adm. Hill testified before Congress in May 2022. "That means flight testing earlier. That means ground testing earlier. That means we have a better sense of where we are as we move forward to upgrade the numbers of interceptors and the capability that we'll bring forward." The MDA concedes that this aspiration is ambitious, and has clearly stated that it will ensure operational maturity before committing to any procurement decisions.

The first units are to be deployed at a new missile field which was completed at Fort Greely in 2022. Designated as Missile Field 4, this area has 20 launch silos and is currently being equipped with support and control infrastructure. Missile Field 4 will enable expansion of the GMD capacity to 64 interceptors, an end-state approved by Congress in 2017. For the first few years NGI and GBI will serve side by side. Whether the Pentagon ultimately phases out the GBI completely, replacing the current inventory with additional NGIs, or retains the GBI force as long as possible, remains to be determined. While Congress formally required the Department of Defense to present a funding plan for acquiring a minimum of 64 NGI in order to optimise future GMD operational capability, the Biden administration has so far opposed this mandate, citing cost concerns and denying the strategic necessity for the larger NGI inventory. ■

Heavy-Lift Helicopter Programmes

Ian Frain

In this article, Ian Frain examines some of the heavy-lift helicopter programmes from the recent past and present.

Currently, there are only four heavy-lift platforms in the world. The twin-engine, eight-blade Russian Helicopters Mil Mi-26, NATO reporting name Halo, is the largest helicopter currently in service, since the late 1980s. Then there is the three-engine, six-blade Sikorsky (a division of Lockheed Martin) CH-53K King Stallion and the slightly smaller CH-53E Super Stallion, and in service in Germany, the smaller tandem-engine CH-53G/GS/GA. Finally, there is the iconic twin-engine, twin-rotor Boeing CH-47F Chinook and the older CH-47D.

From the late 1950s, Sikorsky led the way with heavy-lift helicopters such as the CH-37 Mojave, in service with the United States Army and United States Marine Corps (USMC), which had the unusual clamshell front opening cargo doors. There was also the S-64 /CH-54 Tarhe flying crane. The CH-54 Tarhe was simply a front cabin for two pilots and crew chief, with a conventional main rotor head and high tail rotor, and an empty space from the cockpit onwards. The purpose of this was so it could lift and carry modules, such as a medical evacuation surgical pod, aRiverine Patrol Boat (RPB), or artillery howitzer, as well as damaged aircraft and much more. During the Vietnam War, the Tarhe performed these essential tasks, and additionally it also dropped the 'Daisy Cutter' 6,800 kg (15,000 lb) bomb to flatten the jungle trees in order to create landing zones for the helicopters.

In the early 1960s, Sud Aviation, which became Aerospatiale and then Airbus Helicopters today, developed the SA321 Super Frelon, which served for around four decades with the French Navy aviation (Aéronavale) in the anti-submarine warfare (ASW), and SAR roles until 2010. In China, it still serves, albeit in smaller numbers, as the licenced built Z-8KH. The Super Frelon was also exported as a heavy cargo helicopter to the Middle East, including to Israel, Iraq, and Libya.

The Russians designed and built a few heavy transport cargo rotorcraft from the Mil Design Bureau (now Russian Helicopters JSC), from the late 1950s. The five-bladed Mi-6 Hook was powered by a pair of Soloviev D-25V turboshaft engines, and was followed by the Mi-10 Harke

Credit: Ian Frain

VMX-1 CH-53K King Stallion at ILA Berlin 2022

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produced in either the regular Mi-10K short leg, or Mi-10R long leg able to carry large vehicles, such as tanks, artillery or coaches, on a platform between the legs. There was also the monstrous Mil V-12 Homer, which was the largest rotorcraft ever built and had transverse /side-by-side main large rotors, and was intended to transport the Soviet Intercontinental Ballistic Missile (ICBM), but the programme was short lived, and after a decade of development with only two prototypes produced, it was cancelled in 1974.

How Heavy is your Halo?

After the Mil V-12 came the Mi-26T Halo, the largest helicopter in the world to this day, with its first flight in 1977 and entering service in 1985.

The compartment, which is 12 m long, 3.3 m wide and 3.2 m high, can hold two combat vehicles of approximately 1,000 kg each. Two electric winches on the overhead rails are used to move loads into the cabin. It also boasts a closed-circuit television camera to monitor the positioning of an underslung load. It has a fixed, tricycle-type, landing gear, with two steerable nose wheels. A hydraulic crane allows for loading cargo from different surfaces through rear doors (tail fuselage), using ladders and sub ladders. The take-off weight is displayed on a device fitted on the main gear's shelf on the rear side of the flight engineer seat.

The Mi-26 boasts many advances in safety devices, such as electrically de-iced main and tail rotor blades, infrared jammers, infrared suppressors, infrared decoy dispensers, and a colour-coded identification flare system to protect the helicopter from ballistic missiles. Infrared jammers block any infrared signal transmission to protect the helicopter from infrared missiles.

The King of the Corps

The development of the CH-53K dates back to April 2006, when the Naval Air Systems Command (NAVAIR) signed the System Design & Development contract for the heavy-lift replacement helicopter with Sikorsky, which had been maturing its 'CH-53X' design for several years. The last of the CH-53D Sea Stallions was retired in 2012, but the CH-53E Super Stallions are expected to continue through the 2020s.

The first CH-53K was rolled out in May 2014 and named the King Stallion by the Marines. The aircraft made its first flight in October 2015. Since then, the four engineering development model (EDM) King Stallions have accumulated more than 850 flight test hours, plus nearly 800 hours of ground testing on the Ground Test Vehicle (GTV). With these aircraft, the programme completed its first operational testing phase (OT-B1) in 2016. In March 2017, the CH-53K passed its Milestone C review, which provided authorisation to buy up to 26 low-rate initial production (LRIP) King Stallions in four lots over the fiscal years 2017 to 2020.

The aircraft has demonstrated that it can fly with an external lift load of 36,000 lb (16,300 kg). One unique external load test involved lifting the new Joint Light Tactical Vehicle (JLTV) in January 2018. The JLTV has a curb weight of 6,400 kg (14,000 lb) and will replace the venerable High Mobility Multipurpose Wheeled Vehicle (HMMWV). The helicopter has also undergone 60° bank turns, flying at 5,600 m (18,500 ft) mean sea level (MSL), and weapons firings, among other tests.

The King Stallion is a three-engine helicopter, powered by three General Electric T408-GE-400 engines. Compared to the T64 engines on the CH-53E, the

Credit: Ian Frain

Troop seats in VMX-1 CH-53K King Stallion at ILA Berlin 2022

King Stallion's 5,600 kW (7,500 shp) engines have 57% more power, 18% less fuel consumption, and 63% fewer parts. The engines are also equipped with dual channel Full Authority Digital Engine Control (FADEC). Overall, the T408 engines greatly contribute to King Stallion performance in general, and especially in 'hot and high' conditions. In addition to its incredible lifting capabilities, the King Stallion has demonstrated level flight above 333 km/h (180 kn) and over 370 km/h (200 kn) in a dive.

A Knighthawk in Shining Armour

A real life mission occurred by chance during the first week of September 2021, when the King Stallion hoisted a smaller twin-engine Sikorsky MH-60S Knighthawk belonging to Naval Air Station

Credit: Ian Frain

The Royal Air Force Chinook Display Team Boeing Chinook HC6 performing at Royal International Air Tattoo 2022 at RAF Fairford

Fallon in Nevada, 'Longhorn' base SAR unit, from difficult terrain, near Mount Hogue, in the White Mountains at 3,658 m (12,000 ft) MSL. The MH-60S had made a hard landing several weeks earlier in July, while assisting civilian authorities in searching for a missing hiker on the California/Nevada border, when the mishap occurred. The crew of the Knighthawk were not injured and were subsequently rescued the next day, but it was up to the King Stallion to rescue their craft.

During the same month, a pair of King Stallions were undergoing the Initial Operational Test and Evaluation with the Marine Corps Air Station (MCAS), Yuma based Marine Operational Test and Evaluation Squadron One (VMX-1), at Marine Corps Air Ground Combat Center (MAGCC) located at Twentynine Palms in California, when they were tasked by the Navy Safety Centre to recover the MH-60S from the mountain. The MH-60S weighs 6,895 kg (15,200 lbs), and as the lifting capability of the King Stallion is almost double that, at 27,000 lbs, it was the only helicopter capable of carrying out the mission.

The Philadelphia Twin

The iconic Boeing CH-47 Chinook has seen action with the United States Army from the early days of the Vietnam War, to Grenada and Panama and the first Gulf War, and in the last two decades, it has played a vital role in the global war on terror, including in Afghanistan and Iraq. The Chinook has also seen action with the UK Royal Air Force (RAF) from the 1982 Falklands War, to Sierra Leone at the turn of the century, and operations in Afghanistan and Iraq. Outside of its military duties, the Chinook has also participated in humanitarian operations both at home and abroad.

The CH-47F is the latest model, and entered service with the United States Army in 2010, but the concept and development date back to the 1990s, with the proposed Aerial Cargo Transport, which had four blades, but this was cancelled. The actual CH-47F programme came about as a Service Life Extension Program (SLEP), which would fill a twenty-year gap until the Joint Future Transport Helicopter would come into service.

At the end of 2010, the new Foxtrot also reached the European theatre when the 12th Combat Aviation Brigade in Germany received their airframes, replacing the Delta models. In 2014, the 300th CH-47F was delivered to the United States Army.

Currently in Europe, the British RAF is the largest operator, followed by the Italian Army Air Cavalry (ALE), Spanish Army Aviation (FAMET), the Royal Netherlands Air Force (KLu), and Hellenic Army Aviation. The Turkish Land Forces Army Aviation is the newest member of the Chinook club with the CH-47F. The Italian ALE operates the ICH-47F (manufactured under licence by Leonardo), while the Spanish and Dutch have upgraded to the Foxtrot. The Greeks on the other hand are still operating the earlier CH-47C models.

Block II is a modernisation of the CH-47F Block I; this allows roughly around an 8% increase in gross weight from the Block I. Some of the system improvements started with reduction in weight with features such as the reduced weight ballistic protection and lightweight fuel system (LFS). The result of this is the ability to add an additional 378.5 litres (100 US gallons) of fuel.

The easing of pilot workload and handling qualities includes a redesigned flight control system; digital automatic flight control system (DAFCS), and an updated common avionics architecture system (CAAS). Regarding the engine and powerplant, there is an upgraded drive train system and Improved Drive Train (IDT). The main rotor head was projected to have a new rotor blade design called the Advance Chinook Rotor Blade (ACRB), however, as of 2022, the Army decided the ACRB would be removed altogether with the Block II entering production.

A Heavy-Handed Future

In 1970, the United States Department of Defense (DoD) drafted a proposal for a large heavy-lift helicopter (HLH). In 1971, Boeing Vertol was issued the contract to build the XCH-62 tandem rotor, four blades, as opposed to the usual three-blade Chinook, flying crane but due to a number of technical difficulties, especially with some of the major components in testing, the Army subsequently cancelled the programme.

The United States Army is conducting studies into a new heavy-lift platform post-Chinook with its future plans, including the Future Long Range Assault Aircraft (FLRAA). The Bell V-280 Valor tilt rotor has already been selected for the Future Vertical Lift (FVL) programme

Erickson, which took over the manufacturing of the legacy S-64 (CH-54) from Sikorsky, purchased the licencing rights from Sikorsky in the 1990s. In 2021, Erickson Inc. was pitching the US military on an autonomous variant of its heavy-lift Air Crane helicopter, the S-64F+. Erickson announced in 2020 that it had partnered with Sikorsky to give the S-64 autonomous flight capabilities. The helicopter's mechanical flight controls will be removed and replaced with fly-by-wire controls, and Sikorsky's Matrix autonomous flight control technology. Sikorsky's Matrix-controlled helicopters, such as a retrofitted UH-60A Black Hawk, have relied on sensors, such as Lidar and cameras, as well as digital terrain obstacle databases, to guide their autonomous flights.

As for the future, at the 2019 Russian International Aviation and Space Salon (MAKS) in Zhukovsky, near Moscow, the Russian Minister for Trade and Industry, Denis Manturov, and China's Minister of Industry and Information Technology, Miao Wei, announced a collaboration on a heavy helicopter development programme. This was something that had been rumoured for several years, but was now coming to fruition: "For the next step, the Chinese government will accelerate the progress for project approval and finish it as soon as possible, so the project can officially start," Miao Wei said.

The initial information on the project was exciting, with the 'Advanced Heavy-Lift' expected to be in the 40 tonne class, with a weight-lift capability of 15 tonnes, a range of 630 km, and a top speed of 300 km/h. However, nothing has been heard of the project since 2021, and with the current situation in Ukraine, it would seem unlikely to progress. ■

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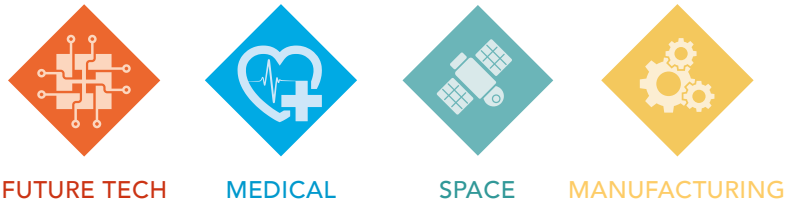

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Escorting you to Safety

Thomas Withington

The escort jamming mission is a staple of airborne electronic warfare, but it will grow in complexity as new tactics and levels of connectivity come to the fore.

At first blush, escort jamming seems a relatively simple task. It involves the transmission of jamming signals into red force ground-based air surveillance and Fire Control/Ground-Controlled Interception (FC/GCI) radars. This helps protect blue force aircraft as they perform their missions in contested airspace. Red force radars will be the eyes of an Integrated Air Defence System (IADS) protecting all, or a large part, of a nation's airspace. They may protect red force airspace at operational and tactical levels during land operations. These radars will be networked with deployed Surface-to-Air Missile (SAM) and Anti-Aircraft Artillery (AAA) systems. The key tenet of ground-based air defence is to provide layered hard kill at ever-expanding ranges and altitudes. FC/GCI radars provide target location information to red force fighters and are linked to GCI centres. These centres receive imagery from the assorted radars protecting red force airspace. These disparate radar pictures are merged into a recognised air picture of the airspace under the centre's control. That way, threats can be detected, identified, tracked and then engaged with either SAMs, AAA or fighters.

Blinding red force radar is paramount and is achieved through kinetic attack against the radars using ordnance or through electronic attack. The latter can take the form of conventional jamming. Radars are inundated with electromagnetic noise significantly degrading their performance. An analogy of this is when a car goes under a high-tension power line and the driver hears static noise on their radio. This noise may drown out the programme they were listening to.

Alternatively, red force radar signals may be sampled, subtly altered and retransmitted back to the radar, a tactic known as deception jamming. For example, the incoming radar signal maybe manipulated to fool the radar into thinking there are more aircraft are in the sky than there really are. This ruse will cause confusion at the GCI centres as the radars will be sharing authentic-looking, but false, information.

Jamming signals may also transmit malicious computer code into the radar. Most contemporary radars are digital systems using software to generate and interpret their signals and control their operation. Malicious code can be transmitted into communications antennas or potentially even the radar antenna to infect the radar. Alternatively, as the radars are likely to be networked, the code may spread across the communications links connecting the radars to the GCI. The code may also infect networked SAM batteries and AAA systems. Command and control software the IADs relies on to facilitate operations may be similarly affected. Like deception jamming, it may not be immediately obvious to red force air defenders that their systems have been infected.

Today's and tomorrow's escort jammers may perform a combination of these tactics while protecting other friendly aircraft. Escort jamming is so-called because it accompanies packages of aircraft while they perform their missions in contested airspace. This is distinct from aircraft self-protection which will use jamming techniques chiefly to protect an individual platform. Escort jam-

Credit: Ukraine Weapons Tracker, via Twitter

Image shows a damaged Russian Army 48Ya6-K1 Podlet-K1 ground-based air surveillance radar. The offensive counter-air battle involves suppression/destruction of enemy air defence attacks against hostile radar. As well as using kinetic effects, these threats can be attacked electronically and cybernetically.

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ming requires specialist equipment usually in the form of a jamming pod. The pod needs to house electrical equipment generating significant levels of jamming power to protect blue force aircraft over a large area. Aircraft self-protection jammers do not need to generate equivalent power levels because they have a far smaller area around the plane to defend. Some escort jamming pods use a ram air turbine, a small propeller positioned at the front of the pod. The turbine rotates at speed as the aircraft flies, thereby generating the requisite power levels. This avoids having to use the aircraft's own engines to generate this power which risks depriving the aircraft's other electrical systems.

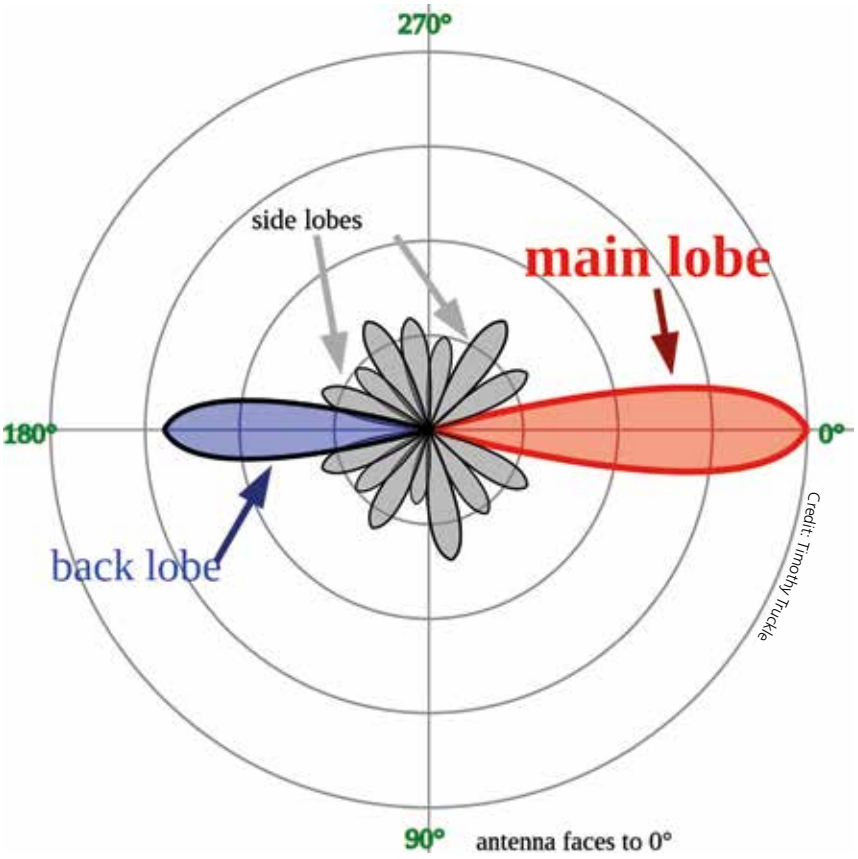
Tactics

Escort jammers typically provide jamming support beyond the detection range of the red force's radars. Hopefully, this will avoid the aircraft carrying the jammer being detected by hostile radar. Protecting escort jamming aircraft is paramount as once these are destroyed, the blue force loses escort jamming coverage.

To understand how the escort jammer's task works, we need to talk about radar signals which have main lobes and sidelobes. As figure 1 shows, these look like petals of a flower fanning out either side above and below of the main lobe. The main lobe is the most powerful part of the signal and is in effect the boresight where the radar points its signal to detect and track targets. Circa 80% of a radar's transmitted power is contained in the main lobe. As this is where the most of the radar's power is going, a jammer needs significant power to jam this signal.

The strength of the jammer's signal must eclipse that of the radar's by the time the jamming signal reaches the radar's antenna. Signal strength is measured in decibels (dB). Let us consider this hypothetical, and highly unlikely, scenario. The red force has an antiquated FuMG-62D Würzburg FC/GCI radar. The FuMG-62D was widely used by the Luftwaffe (German Air Force) during the Second World War. The blue force plans to jam this radar using an ITT/L3 Harris ALQ-99 airborne jamming pod carried by one of its fighters. The FuMG-62D and ALQ-99 both have details regarding their signal strengths available in the public domain. As one can imagine, such details can be closely guarded secrets. However, the FuMG-62D is now beyond obsolete and the ALQ-99 is in its twilight years.

Let us suppose the radar is transmitting on a frequency of 560 MHz and, for the purpose of this discussion, that the ALQ-99 can detect and attack such transmissions.



This illustration demonstrates how sidelobes fan out either side, and above, below and behind a radar's main lobe. Sidelobes can be exploited to inject jamming or hostile code via a jamming signal into a radar.

The aircraft carrying the pod is 30 km (16.2 NM) from the radar and in its main lobe. The radar is transmitting a 7 kW signal while the AN/ALQ-99 transmits a 6.8 kW jamming signal. The efficacy of the jammer is not merely a function of how powerful the jamming signal it transmits into the radar is. A host of other factors come into play, such as the gain of the radar and the jammer. In essence, gain is the level of signal concentration the radar or jammer can direct onto its target. The power levels of the outgoing radar and jamming signals also make a difference, alongside other factors like the weather and electromagnetic activity in the atmosphere. We want to reduce the range at which the red force radar detects the blue force aircraft with the jammer, and we are in luck. In this case, the jammer's signal strength reduces the radar's signal strength to the extent that it cannot detect targets beyond a 14 km (7.6 NM) range.

Ideally, we want to keep our aircraft carrying the jammer beyond the 30 km (16.2 NM) maximum range of the FuMG-62D while ensuring the FuMG-62D cannot detect other blue force aircraft flying nearer to the radar. Let us suppose we have our jamming pod aircraft at a range of 60 km (32.4 NM) from the FuMG-62D. We want to protect other blue force aircraft that must fly within 10.8nm (20km) of the offending radar. The jammer is notably further away in this example, but thanks to its signal strength, it still reduces the radar's detection range to 14.5 km (7.8 NM). Blue force aircraft can fly within the radar's detection range, but to remain undetected thanks to the jamming. An even safer option for the jammer aircraft is to attack the radar by transmitting the jamming signal into its sidelobes. Sidelobes reduce in strength as they fan out from the main beam and cannot detect targets at the same range, because they are not strong enough.

Dedicated Platforms

A few nations maintain fleets of combat aircraft dedicated to detecting, identifying and jamming radars. The first such aircraft appeared during the Second World War. The Royal Air Force's Bomber Command maintained a dedicated electronic warfare unit called 100 Group. As the Command waged its war against Axis strategic targets in the European

Credit: US Navy

A US Navy E/A-18G Growler electronic warfare aircraft is seen here in the foreground of this picture carrying an AN/ALQ-99 jamming pod on one of its under-wing hardpoints behind an AGM-88 missile. The AN/ALQ-99 will eventually be replaced by the NGJ variants.

theatre of operations, 100 Group gave invaluable support. It used specially adapted light, medium and heavy bombers. These were tricked up with Electronic Support Measures (ESMs) and Electronic Countermeasures (ECMs). The ESMs would seek out Luftwaffe airborne and ground-based radars, surface-to-air/air-to-surface radio communications and radio navigation systems. These emitters would then be blasted with torrents of electromagnetic noise using onboard ECMs. Powerful ground-based ECMs in the United Kingdom gave similar support hundreds of nautical miles into occupied Europe.

The concept of dedicated EW aircraft supporting strike packages of combat aircraft was further refined in the Cold War, notably during the United States' involvement in the Vietnam War between 1965 and 1975. The US Navy began its 'Iron Hand' missions in 1965. Iron Hand used navy aircraft equipped with AGM-45 Shrike variant anti-radar missiles. Shrike was developed by the US Navy's Naval Weapons Centre. Packages of Iron Hand aircraft included Douglas A-4 Skyhawk and A-3 Skywarrior series combat aircraft. These planes were escorted by Vought F-8 Crusader variant fighters. The missions were dedicated to finding and destroying radar-guided SAM and AAA batteries the Soviet Union had supplied to its North Vietnamese allies. Radar Warning Receivers (RWRs) would advise A-3 and A-4 pilots that a hostile radar was nearby and active. AGM-45s would then be launched and home in on the hostile radar signal, destroying the antenna. A variant of the mission, known as 'Wild Weasel', was adopted by the US Air Force (USAF), commencing the same year as Iron Hand.

The Wild Weasel mission continues in the USAF today. Dedicated General Dynamics/Lockheed Martin F-16CJ Viper Weasel combat aircraft are armed with Texas Instruments/Raytheon AGM-88 HARM (High Speed Anti-Radiation Missile) variant weapons and Raytheon's AN/ASQ-213 HARM Targeting System (HTS). The latter hunts for hostile radar signals. When discovered, the aircraft launches the HARM which, like the AGM-45, uses these signals to home in on the hostile radar, destroying it.

The US Navy has continued to refine its Iron Hand capabilities. In 1971, the force introduced the Northrop Grumman EA-6B Prowler, equipped with AN/ALQ-99 jammers and deploying the AGM-88. The Prowler had a long career until its eventual replacement from 2009 by Boeing's E/A-18G Growler. For now, the Growler deploys the AN/ALQ-99. The AN/ALQ-99 is being progressively replaced by the US Navy's low-, mid- and mid-band extended Next Generation Jammer (NGJ). The first of these, Raytheon's AN/ALQ-249, has already entered service and detects and jams radar threats across frequencies of 2-6 GHz. The low-band NGJ will cover wavebands of 500 MHz to 2 GHz and is awaiting contract award. Reports in May said the navy is looking to extend the AN/ALQ-249 to cover higher frequencies, circa 18 GHz. The force had originally planned to procure a separate high-band jammer, but this now appears to have been abandoned. Extending the AN/ALQ-249's capabilities would be arguably more cost-effective than procuring a third NGJ variant.

The US' European North Atlantic Treaty Organisation (NATO) partners are receiving new escort jamming capabilities in the form of the Luftwaffe's Eurofighter Typhoon-EW electronic warfare jet. The Typhoon-EW replaces the Luftwaffe's legacy Panavia Tornado-ECR suppression/destruction of enemy air defence aircraft. During the 2023 Association of Old Crows' (AOC) Electronic Warfare conference in Bonn, western Germany held on 15-16 May, officials close to the programme told the author that the type of

Credit: Airbus

The Luftwaffe is procuring new Typhoon-EW jets to replace its erstwhile Tornado-ECR air defence suppression aircraft. These new jets will be equipped with escort jamming pods.

escort jammers these aircraft will carry are yet to be determined. Nonetheless, the Typhoon-EW will be spoiled for choice. Escort jammers are available from Elettronica (EDGE), Hensoldt (Kalætron), Indra (ALQ-500P), Israel Aerospace Industries (EL/L-8222SB Scorpius), Leonardo (Common Jamming Pod), Northrop Grumman (AN/ALQ-131), Rafael Advanced Defence Systems (SkyShield) and Saab (Arexis).

Meanwhile, the European Union is advancing its Airborne Electronic Attack (AEA) initiative, one of the European Defence Agency's Permanent Structured Cooperation (PESCO) programmes. It would not be surprising if the German government selects a podded version of the jamming technology developed via the AEA programme. This would underscore Germany's ongoing commitment to the European defence industry writ large. It would also avoid the country procuring escort jammers for the Typhoon-EW from the US. Lawmakers in Washington DC may be prepared to supply technology like the AN/ALQ-249 to Germany, much like it has to Australia. Nonetheless, this could come with caveats covering access to advanced signal processing and jamming technology used by the US Navy in their pods. Others could include restrictions on when and where the pods are used operationally. As Hensoldt is already involved in the AEA initiative, any procurement of the technology yielded under AEA would benefit Germany.

While Germany is buying a dedicated jamming aircraft in the guise of the Typhoon-EW, escort jamming pods represent a cost-effective way that air forces can deploy powerful EW tools without needing dedicated platforms. Several pods can be purchased and moved between aircraft as and when required. The author's records note that the average price for an escort pod can be around USD 1.5 M. Such price tags are notably less expensive than the circa USD 125 M publicly available unit price for an E/A-18G.

Mission Creep

One of the biggest evolutions expected in the coming years is the addition of cyber effects as part of the jammer's tactics as discussed above, but other developments are afoot. The doctrine of Multi-Domain Operations (MDO) is being embraced across NATO. MDO strives for the intra- and inter-force connectivity of every warfighter, sensor, weapon, platform and capability at all levels of war to allow synchronous operations across all domains. The goal is to harness and share information to improve the quality and pace of decision making in wartime. High quality, rapid decision-making is seen as vital by NATO if it is to prevail over adversaries in future conflicts.

Hensoldt's Kalætron airborne electronic attack pod is one potential system which could equip the Typhoon-EW. Germany could also opt to procure technology developed under the auspices of the European Union's Airborne Electronic Attack programme for the aircraft.

Professor Steve Roberts, president of the United Kingdom Chapter of the AOC, expects to see a deeper level of connectivity between EW systems in the air domain in the future allowing escort jamming functions to be achieved in new ways. What this could mean in practice is that jammers and Electronic Support Measures (ESMs) on multiple platforms share detailed signal data in real-time allowing geolocation and threat assessment. Networking these assets could facilitate a more rapid and accurate response to hostile radar threats as and when they appear, with information on hostile emitters moving between blue force airborne EW capabilities at the speed of light.

One example of the potential for future capabilities envisaged by Prof. Roberts is the detection and defeat of a hostile air defence system by CEMA (Cyber and Electromagnetic Activities). The process starts with the detection of RF (Radio Frequency) activity by ESM systems on one or more combat aircraft. The information is immediately shared with other blue force assets supporting an air campaign via secure cloud computing. An escort jammer, many kilometres away from the threatened aircraft acting as a 'force protection control hub', receives and integrates this information. Artificial intelligence software recognises the radar activity and intent based on similar waveforms that have been detected in the past. The same software also notes that, based upon past experience, a combination of jamming and insertion of malicious code is likely to be the most effective way to engage this air defence system. The escort jammer shares the appropriate instructions and code with the combat aircraft via the cloud. The EW systems on the threatened aircraft then transmit the appropriate jamming signal. This use of distributed sensors and effectors creates the desired result of forcing the threat to become inoperative or ineffective.

Such capabilities maybe closer than we think. NATO has introduced the Cooperative Electronic Support Measure (CESMO) communications protocol. CESMO lets participating aircraft and naval vessels share radar threat information with each other across existing communications networks. This helps evolve the airborne electronic warfare mission from one which protects individual, or small groups, of aircraft into an overarching, continuous and contiguous mission performed synchronously with other air operations. It is emblematic of the MDO trajectory of electronic warfare and air operations in general.

Escort jamming technology is developing rapidly. The mission is set to be enhanced significantly in the coming years with the advent of cyber effects and deeper connectivity. Customers have an enviable array of products to choose from multiple vendors. What may seem a relatively simple mission is destined to get more complex. ■

UAV Programmes: a Focus on the EU

Giulia Tilenni

Unmanned Aerial Vehicles (UAVs) have become a crucial asset on the battlefield in the last decades. Initially a niche product that only a few of the best funded armies in the world could afford, these systems are now broadly used by state and non-state actors, and the war in Ukraine has clearly proved their importance in conventional conflicts as well. Are EU countries ready to take up the challenge, as users and as producers?

In recent decades, UAVs have mainly helped regular armed forces carry out intelligence, surveillance and reconnaissance (ISR) missions in non-contested airspace. Unmanned systems were mostly redeployed for persistent information gathering in asymmetric conflicts opposing a regular armed force and/or a non-state actor. With the systems evolving to mount weapons, their use was then expanded to ad-hoc strike missions, mainly to clear the battlefield before the arrival of ground troops. During the 2000s, these two roles made up the most frequent unmanned aerial missions in Iraq and Afghanistan. About a decade later, the same kind of missions were carried out during the war in Libya.

As the use of these systems has proven to be increasingly effective, a growing number of companies and countries are now developing this kind of technology. The miniaturisation has gradually allowed non-state actors acquire small UAVs and redeploy them in strike missions, such as the Houthi's attacks against Saudi Arabia's critical infrastructure demonstrate.

Credit: Bayhaluk, via Wikimedia Commons

The Bayraktar TB2 UAV has served with success in a number of recent conflicts, most notably the 2020 Nagorno-Karakbakh War.

The 2020 Nagorno-Karabakh conflict represents a game changer in the deployment of unmanned systems on the battlefield, marking the first large-scale use of unmanned aerial technology in a conventional state-on-state conflict. In fact, UAVs, and in particular loitering munitions (LMs), had already been used in an earlier phase of the conflict in 2016. However, in September-November 2020 Azerbaijan's UAVs first destroyed Armenia's substantial array of ground-based air defence (GBAD) systems, followed by Yerevan's land forces materiel, including tanks, artillery, and supply trucks. For the first time, unmanned vehicles were replacing manned systems for air attack and close air support (CAS) missions in a regular conflict.

More recently, the war in Ukraine has reaffirmed the importance of UAVs on the battlefield. The first regular conflict on European soil in decades sees a significant use of regular weapon systems, such as tanks and artillery, but also the massive use of UAVs by both sides. As neither Russia nor Ukraine have been able to achieve air superiority, the two parties have been deploying tactical UAVs to reduce risks when carrying out strike missions. Moreover, intelligence provided by small UAVs has been a game changer in different battles. In March 2022, the Ukrainian Aerorozvidka air reconnaissance unit, consisting of 30 special forces troops and UAV operators, detected a 65-km-long Russian mechanised column tasked with mounting an attack in the north of the country, most likely with Kyiv as its ultimate objective. After several days halted on the route, the Russian operation failed due to Aerorozvidka's nightly ambushes, mainly based on attacks by UAVs.

Since then, Ukraine has considered unmanned aerial assets as a cost-effective tool in countering Russian attacks. In February 2023, the Ukrainian Deputy Prime Minister and Minister for Digital Transformation Mykhailo Fedorov, said that Kyiv had purchased 1,765 UAVs for USD 3.4 Bn and trained about 3,500 soldiers in their use. Last June, President Zelenskyy launched the "Army of Drones" crowdfunding campaign and called on hobbyists and commercial drone pilots to donate their machines to regular Ukrainian troops.

Kyiv's inventory comprises several models, their pre-war fleet of around 20 Turkish-made Baykar Bayraktar TB2 was supplemented by a further 50 according to Ukrainian Defence Minister Oleksii Reznikov. Added to these, Ukraine has received roughly 850 Prox Dynamics Black Hornet micro-UAVs, and weaponised commercial

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off-the-shelf UAVs to drop explosives, not dissimilar to ISIS' techniques. As part of the significant military aid pledged to the country, the US approved the delivery of several UAV models in February 2023. These systems include the Area-I ALTIUS-600 LM (which has a swarming capability, and was tested as an electronic warfare (EW) platform). Also delivered was the AeroVironment Jump 20 UAV with vertical take-off and landing (VTOL) capability, as well as a 14-hour endurance and a range of 185 km; and the AeroVironment Switchblade 600 LM, which can carry a 14 kg payload for 40 minutes within a 40 km range.

In the meantime, Ukraine is significantly investing in the development of locally-produced UAVs. In an interview with Reuters in March 2023, Defence Minister Reznikov said that the Government was working with about 80 Ukraine-based producers, adding that Ukraine required hundreds of thousands of UAVs. Kyiv, which has set up drone assault units within its armed forces, plans to invest USD 550 M on these systems in 2023 alone, with a focus on loitering munitions. Coupled with foreign supplies of tanks, missiles and artillery assets, the development of domestic UAVs, which are substantially cheaper compared to traditional weapon systems, might help in reducing the capability gap with Russia. During the first year of war, the deployment of UAVs on the battlefield has maximised Ukrainian reconnaissance capabilities. The country is now seeking the use of assets that can travel longer and carry larger payloads.

Baykar Technologies is emerging as one of the big winners in the conflict. Now that the place of Medium-Altitude Long Endurance (MALE) strike UAVs on the modern battlefield has been well-established, Baykar is expected to further increase its global market share and is starting to sell its UAVs to EU members. Although EU defence companies possess all the know-how required to develop UAVs, their development is quite complex, and armed forces have strong capability gaps in this domain. Let's try to understand why.

Programmes within the EU: a fragmented landscape

The EU military mission in Libya in 2011 confirmed the importance of UAV-carried ISR missions, suggesting to European countries that unmanned technology would have been the best solution to fill the long-lasting capability gap in this domain, which first emerged during operations in the Balkans in the early 1990s. Since then, some EU members have acquired US or Israeli off-the-shelf MALE UAVs, and/or launched national programmes to develop tactical systems, while trying to develop a common MALE system to gain strategic independence. In the meantime, France, Germany, Italy and Spain are all involved in programmes to develop next-generation fighters – the first three within the Future Combat Air System (FCAS) programme, the latter within the Global Combat Air Programme (GCAP) with the UK and Japan. Both efforts take a system-of-systems approach integrating different types of unmanned systems. Several major EU countries have launched several development projects simultaneously, hoping to relaunch their national defence industries. However, their ambitions have been at odds with the slow recovery from decades of underinvestment in defence, and the need to focus on the replacement of all sorts of ageing equipment and weapon systems at once.

Eurodrone – The Quest for a European MALE UAV

France, Germany, Italy and Spain launched the medium-altitude long-endurance remotely piloted aircraft system (MALE RPAS) programme, also known as MALE 2020 (and later: Eurodrone), in August 2016, within the framework of the Organisation for Joint Armament Co-operation (OCCAR). The idea to jointly fill the already mentioned gap in ISR capabilities with ITAR-free technology, to gain independence from the US and the other non-EU producers, dates back to 2013. When the programme was launched, the four countries all had some experience with MALE systems. Italy was among the users of the General Atomics MQ-9 Reaper and MQ-1 Predator, which had already been deployed in the Middle East and just received Congress's authorisation to mount Lockheed Martin AGM-114 Hellfire missiles. France already had the General Atomics MQ-9 Reaper in its inventory for a couple of years, and Spain had just ordered a batch of them. Germany had several years of experience with the Israel Aerospace Industries (IAI) Heron TP, in use in Afghanistan under a lease agreement.

After a definition study that lasted two years and ended with the 2018 System Requirement Review (SRR) and a System Preliminary Design Review (SPDR), two additional years were devoted to the elaboration of the offer and the negotiation of the global contract. Prime contractor Airbus Defence and Space GmbH and major sub-contractors Airbus Defence and Space S.A.U, Leonardo and Dassault Aviation, finally signed a contract on 24 February 2022, agreeing on the development of 20 systems (seven for Berlin, five for Rome, four for Paris and Madrid), each one consisting of three flight units and two ground control stations.

According to the initial schedule, the first flights of a prototype were expected in early 2023, and the delivery of the final system in 2025. However, the programme is behind schedule due to fundamental divergences in core technical features, namely propulsion and armament, and on the final costs. Germany, which wants the system to be used above its national territory, pushed for the twin-turboprops in a pusher configuration. This is a solution that increases safety during flight

Credit: Giulia Tilenni

The full-size mock-up of the European MALE UAV, also known as 'Eurodrone', presented for the first time at the ILA 2018 exhibition. This ambitious joint development programme demonstrates the limits of defence collaboration in Europe.

in non-segregated airspaces, but brings the weight of the system to 11 tonnes, compared to the Reaper at 4.5 tonnes. In a document released in June 2019, the French Senate pointed out the systems' 'obesity', barely compatible with the country's need to redeploy it in operational theatres, mainly in Africa. After long discussions, Berlin finally agreed on a system with strike capabilities.

Able to carry out intelligence, surveillance, target acquisition and reconnaissance (ISTAR) missions, each UAV will have an endurance of 30 hours, a 13.7 km service ceiling, and a 500 km/h maximum speed. With a length of 17 m and wingspan of 30 m, it will be 1.5× larger than the MQ-9 Reaper. Its maximum payload is estimated at 2,300 kg.

According to the latest information available, the production of the first prototype is now scheduled in 2024 and the beginning of flight tests in 2027, with first deliveries likely at the end of the decade.

As was the case for the A400M, the Eurodrone programme highlights the limits of pan-European defence cooperation. As participating nations have different operational needs, the definition of the systems' features took a long time, and finally ended in sub-optimal specifications. Moreover, delays in production forced the parties to purchase off-the-shelf systems again, and might further delay the Future Combat Air System (FCAS) programme, a system-of-systems supposed to integrate the Eurodrone. The possible failure of the Eurodrone, among the first programmes to receive a grant under the European Defence Fund kicked off in 2021, might discredit EU efforts towards a stronger defence base, undermining an EU independence deemed necessary but far from being a reality.

Credit: Rheinmetall

A Luna NG UAV on its launch rail.

A Plethora of Tactical Unmanned Systems

EU countries with the most advanced armed forces have all reaffirmed the importance of fielding tactical UAVs in their strategic documents. Despite the similar operational requirements, most decided to go for national solutions, resulting in the multiplication of programmes. This choice is likely driven by political-industrial considerations, namely, the possibility of helping national defence companies develop and produce new systems at relatively limited costs. According to results obtained so far, this vision is short-sighted, with several programmes delayed due to COVID-19, thus increasing armed forces' capability gaps, as well as R&D and acquisition costs, which had been expected to be limited for this type of asset.

In April 2022, Rheinmetall announced the development of the LUNA NG, an advanced version of the EMT Luftgestützte Unbemannte Nahaufklärungs Ausstattung (LUNA) UAV, which has been in service with the German Armed Forces since the early 2000s. The new system has an endurance of 12 hours, a range of 100 km, a service ceiling of 5,000 m, in addition to a 40 kg take-off weight and a 30 kg maximum payload. Compared to its predecessor, the LUNA NG can have a reconnaissance or combat configuration, being able to mount the Hero-R rotary-wing loitering munition recently developed by Rheinmetall in collaboration with the Israeli company UVision. If this collaboration allows for having state-of-the-art combat capabilities, it is worth noting that the contract for the development of three unmanned systems with five UAVs each was awarded in July 2017, with deliveries initially expected in 2020. However, the Bundeswehr has still not received any of these UAVs.

Looking at France, the latest military programming law (Loi de Programmation Militaire, LPM) allocates EUR 5 Bn in unmanned aerial technology between 2024 and 2030. Paris stressed its willingness to maintain investment in naval UAVs, to increase the number of tactical UAVs in use with the Army, and to develop French-made loitering munitions. This batch of investments is supposed to fuel the efforts begun under the 2019-2025 document, but some of the systems are not operational yet, or have been recently delivered to their end-users. The Patroller UAV was developed by Safran and intended to replace the ageing fleet of Sagem Sperwer UAV. In 2016, Paris signed a EUR 330 M contract for 14 Patrollers, later revised upwards to 25 units with the 2019-2025 LPM. Due to enter service in 2019, the system only received certification for operational use in February 2023, and deliveries are due to take place out to 2030.

Final Remarks

Since their role on the battlefield began to grow with the Wars in Afghanistan and Iraq in the 2000s, UAVs have gradually become a key aerial asset on the battlefield, both for symmetric and asymmetric conflicts. The importance of these systems has launched a global race not only for their acquisition, but also for their development. Unable to access the Western market, dominated for a long time by the General Atomics MQ-9 Reaper and MQ-1 Predator and the Israeli Aerospace Industry Heron, China and Turkey have developed a broad range of competing systems. Cheaper than Western systems and exported without strings attached, they have conquered African and Asian markets in recent years.

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By focusing on building the best possible MALE UAVs, despite different operational requirements, EU countries are lagging behind in terms of production, and will likely be unable to find a place in the global UAV market. Worse still, their efforts to build a common system are preventing them from filling a capability gap identified two decades ago. As other EU defence cooperative programmes have shown in the past, developing an ambitious multinational programme can end in late deliveries of expensive systems that have average technical features resulting from a compromise among all the relevant operational requirements.

Unfortunately, the Eurodrone case seems to follow this logic: the countries involved are investing a lot of time and money in a technological solution that will barely be useful for its end-users. Miniaturisation has allowed for high-performing tactical UAVs with interesting payloads, able to perform strike missions in support of ground forces. This is a trend that has spread over the last decade, but one that EU countries do not seem able (or willing) to identify. Overly-focused on trying to find a compromise solution on the Eurodrone, most EU countries underestimated the urgency to boost the range and number of tactical UAVs in their respective inventories. Considering the know-how present in different European defence companies and the similar operational requirements across Europe, going for just one or a couple of EU solutions to develop tactical UAVs might have been a more efficient decision. Conversely, the biggest defence spenders focused on the development of national tactical UAVs, or off-the-shelf purchases, thus deepening market fragmentation and the dependence on non-EU producers.

On the one hand, the launch of new programmes seems to be purely driven by political objectives, such as increasing the production of national companies to maintain employment levels or create new jobs, rather than military ones. As an example, the Spanish Ministry of Finance recently authorised a EUR 500 M investment in the development of the Sistema Remotamente Tripulado de Altas Prestaciones (SIRTAP) tactical UAV, to be divided into eight annual payments between 2023 and 2031. Co-funded by Spain and Colombia, expected to purchase 27 and 18 units respectively, the system will be developed by Airbus. The vehicle will have an endurance of 20 hours, a service ceiling of 6,000 km, a 750 kg maximum take-off weight, and a 150 kg payload. These are almost the same characteristics as the Leonardo FALCO EVO, reportedly in use in several Middle Eastern countries, but not in the inventories of any European customer.

On the other hand, national preferences force countries with limited budgets or urgent operational requirements to procure non-EU, off-the-shelf products. This is the case for Poland, which ordered four Bayraktar TB2 UAVs in May 2021, thereby becoming the first EU user. Poland also concluded a lease agreement with General Atomics for several MQ-9A Reapers to prepare an eventual purchase. In April 2023, Romania became another EU customer for the Bayraktar TB2, ordering 18 UAVs for EUR 280 M.

Credit: Giulia Tilenni

The Hellenic Aerospace Industry's Archytas tactical UAV. An important step in the domestic development of Greek drones might have a positive impact on EU defence cooperation – if European stakeholders want to take up this opportunity.

'Hope Springs Eternal'

If accompanied by strong and long-lasting political will, two trends might still help the EU recover, and enter this race again. First, trying to push ahead with meaningful cooperative programmes. In 2021, Spain, Germany, Portugal, Romania and Slovenia decided to launch the Next Generation Small RPAS (NGSR) project within the Permanent Structured Cooperation (PESCO) framework. This Spanish-led project is intended to develop a multi-role, next-generation tactical UAV, with a range of approximately 200 km and an endurance of 5 to 10 hours. The system should be rapidly deployable to support military operations in the land, air and maritime domains, but also be used for law enforcement, disaster management and other civilian missions. The first prototype should be ready in 2026, and tests should be completed by 2027, with a development that runs in parallel with the Euromale. This system might be an interesting test bed for the impact of EU funding on procurement, as the European Defence Fund is supposed to support the joint procurement of the system once operational.

Second is the little-discussed case of Greek know-how. Greece is not at the heart of cooperative programmes despite its strong and long-lasting experience with locally made UAVs. The Hellenic Aerospace Industry (HAI) Pegasus, whose development started in 1979, was delivered to the Greek Air Force in the early 2000s with the upgraded version, Pegasus II, introduced in 2005. Considering Turkish assertiveness and relevant know-how in UAVs, Greece has decided to build up its capacities to boost its national production while continuing to procure abroad – mainly in Israel. In September 2022, HAI and the Aristotle, Thessaly and Democritus universities presented Archytas, a multipurpose, dual-use, VTOL UAV, with significant surveillance and reconnaissance capabilities. In January 2023, Athens announced that the consortium would also develop the Grypas combat UAV. With a more modular structure and a larger payload than its predecessor, a first prototype is expected in 2025. Greece will officially be the first customer, but other countries willing to buy European might follow. ■

Australian Helicopter Programmes Update

Sidney E. Dean

As part of its ongoing modernisation, the Australian military is pursuing several helicopter procurement programmes to benefit all three service arms.

UH-60M Black Hawk

In January 2023 the Australian Department of Defence (DoD) formally announced its decision to purchase 40 Sikorsky UH-60M Black Hawk helicopters. The procurement package is valued at AUD 2.8 Bn (approximately USD 2 Bn). The new aircraft will replace the 41 MH90 Taipan multi-mission helicopters currently operated by the Australian Army, which have been plagued by readiness and maintenance issues. The Black Hawks' mission spectrum will include assault carrier, special operations support, general utility and transport, as well as support of humanitarian operations. The first UH-60M is expected to be delivered in the second quarter of 2023. The new aircraft are to operate from bases at Oakey, Queensland and Holsworthy, New South Wales.

The decision the replace the MH90 with the UH-60M has bipartisan support, and goes back to a proposal made by the previous government in 2022. The current government has explained the choice of the UH-60M utility helicopter with reference to the aircraft's proven record and well-established supply chain as well as with the fact that it is operated by numerous security partners, first and foremost the United States. From that perspective, the Black Hawk is expected to enhance interoperability and the capability to cross-support one-another's helicopters while on deployment. "The Black Hawk capability will be a crucial element for us to protect Australia's sovereignty, and deliver foreign policy objectives, including providing humanitarian assistance and disaster relief," said Major General Jeremy King, Head of Land Capability, in January 2023. "The Black Hawk will support the deployment of our troops and their equipment where they are needed in times of crisis. The Black Hawk is a reliable, proven and mature platform supported by a robust global supply chain. This acquisition will mean we can continue to defend Australia and respond in times of need in a safe and effective way for years to come."

Credit: US Army

Australian Defence Force military personnel and US Army 160th Special Operations Aviation Regiment (Airborne) service members conduct bilateral fast rope training from a US Army MH-60 during Exercise Talisman Sabre 21, at Royal Australian Air Force Base Tindal, Australia, July 17, 2021.

Credit: RAN

MH-60R helicopters provide RAN frigates with an advanced ASW capability.

MH-60R Seahawk

The Royal Australian Navy (RAN) is also planning to retire its six MRH-90 Taipans by 2027. They will be replaced by 12 Sikorsky MH-60R Seahawk helicopters under a contract issued on 30 August 2022. The aircraft are being procured through the US Navy under a Foreign Military Sales agreement. The acquisition is being pursued under the Australian MoD's Project Sea 9100 Phase 1 (Embarked Logistics Support Helicopter Capability). The helicopters and associated subsystems have a value of AUD 730 M (USD 503 M at time of contract signing). An additional AUD 316 M are projected for expanded infrastructure at HMAS Albatross, the Fleet Air Arm's main base.

Credit: Australian DoD

An Australian Army CH-47 Chinook from the 5th Aviation Regiment conducts a refuel for the 2nd Cavalry Regiments M1 Abrams Main Battle Tank while on Exercise Eagle Walk at Townsville Field Training Area, Queensland.

The new MH-60Rs are to be delivered beginning in 2025, and they will join 23 Seahawks which entered RAN service in 2013-2016. Canberra cited several advantages to utilising a homogenous aircraft fleet, including greater operational efficiency as well as streamlined maintenance, training and sustainment. Procuring a dozen new Seahawks also parallels the Navy's expansion of its surface fleet and ensures sufficient aircraft are available to outfit deploying warships.

The aircraft are assigned to the RAN's 816 Squadron (operations) and 725 Squadron (training). One to two MH-60R multi-mission helicopters are deployed aboard RAN frigates and Hobart class destroyers. They provide over-the-horizon reconnaissance, targeting-support and damage assessment, conduct direct anti-surface warfare missions by launching 70 mm laser-guided rockets and AGM-114 Hellfire missiles, and enhance the ships' anti-submarine warfare (ASW) capabilities by deploying sonar and Mk-54 ASW torpedoes. Secondary missions include search and rescue (SAR), logistics support, personnel transport and medical evacuation.

CH-47F Chinook

The Australian Army has operated the Boeing CH-47 Chinook since 1995. In 2015-2016 the Army upgraded its fleet by divesting older models and acquiring 10 units of the newest variant, the CH-47F, through a Foreign Military Sales agreement with Washington. In 2021-2022 the Army, facing a vertical lift shortfall, received four additional aircraft for a new end strength of 14 heavy lift helicopters at a total cost of AUD 595 M. The 14 helicopters are assigned to C Company, 5th Aviation Regiment. The mission spectrum extends from battlefield heavy lift and special operations support to disaster relief and other humanitarian operations. The aircraft's long-range and air-refuelling capability enhance their utility for missions in the archipelagos surrounding Australia, while their high payload capacity and robust performance make them well-suited for deployment to almost any operational theatre. Lt. Col. Christopher McDougall, commanding officer of the 5th Aviation Regiment, welcomed the two final aircraft in June 2022 with the words: "The additional helicopters will provide Defence with additional lift capacity and strengthen Army's ability to support operations globally."

AH-64E Guardian

In January 2021 the government of then-Prime Minister Scott Morrison announced the selection of the AH-64E Apache Guardian attack helicopter to replace the 22 currently operated Eurocopter Tiger aircraft in the Armed Reconnaissance Helicopter role. The AH-64E prevailed over two competitors. The Apache's proven track record, established production line and advanced suite of mission systems were major factors in the decision. The then-Defence Minister, Linda Reynolds, described the AH-64E as "the most lethal, most survivable and lowest-risk option, meeting all of Defence's capability, through-life support, security and certification requirements."

The procurement order, conducted under the Land 4503 programme, was finalised in May of 2022. In a 9 May 2022 statement, Prime Minister Morrison said the investment was key to the Government's plan for a safe secure Australia in the face of regional and global uncertainty. "Australia and our region is now in the midst of the most consequential and challenging strategic realignment since the Second World War," he said. The procurement package, including mission systems, is valued at AUD 5.5 Bn (approximately USD 3.83 Bn at the time of signing). An additional AUD 500 M will be invested in facilities upgrades to support operations and maintenance. Boeing Defence Australia has promised to include Australian suppliers and subcontractors for both the construction phase and subsequently for the in-service support system.

The Australian Army will acquire a total of 29 Apaches, with deliveries slated to begin in 2025. Five of the aircraft will be devoted to training; the remaining 24 units will equip two co-located operational squadrons, presumably with the 1st Aviation Regiment based in Darwin. Initial operational capability (IOC) of the first 12 aircraft is expected in 2026, with full operational capability of both squadrons by 2028.

AW139

The DoD has contracted the private firm CHC Helicopters Australia to conduct Search and Rescue (S&R) missions for the military since 1989. Between 2017 and 2019 the firm introduced ten Leonardo/Agusta-Westland AW139 helicopters (in a red and white paint scheme) to serve the RAN and the Royal Australian Air Force (RAAF) in this role. The aircraft are operated by CHC personnel.

In 2021, three AW139 leased from Toll Helicopters entered service with the Australian Army under the Army Interim Helicopter Capability programme, also known as 'Plan Corella.' Two more AW139 will be added in the second half of 2023. These aircraft retain civilian registration and a white paint scheme, but bear the 'ARMY' designator and the military's Kangaroo emblem, and are flown by military personnel of the 5th and 1st Aviation Regiments. They are used for pilot and aircrew training, logistic support, disaster relief and crash response. Leasing the AW139 for the Army was deemed necessary to compensate for a capability shortfall caused by the MH90s' low availability rate.

Light SOF Helicopter

On 1 March 2023 Major General Stephen Jobson, commander of the Australian Army's Aviation Command, announced the cancellation of the Army's planned acquisition of 16 commercially-based light helicopters to support special operations forces. The procurement project, primar-

ily aimed at supporting the counterterrorism mission, had been designated Land 2097 Phase 4. Three firms had replied to the Request for Tenders issued in 2020. Addressing journalists during the Avalon 2023 airshow, MG Jobson explained that the other helicopter programmes were providing sufficient overlapping capabilities to make Land 2097 Phase 4 redundant. He specifically cited the UH-60M as "an aircraft system that will provide dedicated support to Australia's special forces," while also referencing the AH-64E, the CH-47, and the pending acquisition of the rail-launched Insitu Integrator UAV.

Credit: Leonardo

Leased AW139 helicopters support all three branches of the Australian armed forces.

Impact of the Defence Strategic Review

One major element of uncertainty remains. On 14 February 2023 the final version of the 2022 Defence Strategic Review (DSR) was presented to the government of Prime Minister Anthony Albanese, who assumed office on 23 May 2022. The independent Review was led by former Minister of Defence Stephen Smith and former Chief of the Defence Force Sir Angus Houston. Details of the DSR were expected to be released to the public sometime in April 2023. Given the planned investment in expensive advanced technology (nuclear powered attack submarines, hypersonic weapons, unmanned aircraft), many Australian defence experts have speculated that the DSR would recommend cuts to acquisition of conventional systems – including helicopters – to rebalance the budget. These observers expect the Army to be particularly hard hit in this regard given the new emphasis on speed and long-range strike capabilities. With publication of the Review's findings imminent, there should soon be clarity regarding the future of helicopter procurement, one way or the other.

Ukraine – Tactical Missiles on the Battlefield

Tim Guest

While tactical ballistic missiles have been used on battlefields in previous conflicts, the war in Ukraine has seen some of the most intense usage of such systems in any modern conflict.

With some historical introductory anecdotes, this article looks at tactical missile use against Ukraine through the eyes of Ukrainian intelligence. It addresses developments in and around the Ukrainian theatre of operations, as well as mentioning one of the country's own tactical missile systems, and a US system Ukraine would sorely like to have, but will likely remain at arms' length, for now, at least.

Historic Irony

The Russians have been launching a variety of tactical battlefield missiles with conventional warheads and cluster munitions against mainly civilian infrastructure in Ukraine since last year's invasion. The threat to replace conventional warheads with tactical nuclear warheads on some of those missiles has also been made from the very start and continues to hang over the battlefield, particularly with the recent agreement between the Kremlin and Minsk to deploy tactical nuclear weapons to Belarus. For the Ukrainians, their limited number of home-grown tactical missiles have been no match for the large, though dwindling numbers, of Russian weapons and they remain hopeful – despite the arrival of air-launched Storm Shadow cruise missiles from the UK, with their operational range up to 550km – for a weapon system from the West's ground-launched arsenal of longer range, tactical missile systems.

That such missiles might potentially face off against each other, depending on decisions taken later on, it might be interesting to take a brief, ironic look back to the end of WWII, when the Nazi Germany's advanced science and rocket technology ended up in the hands of both the Americans and Western forces, as well as their Soviet allies. That technology had achieved its metaphorical apogee at the time through the creation of the V-2 (also known as 'A-4'), the world's first tactical ballistic missile (and indeed the first ballistic missile), prototyped in the summer of 1944 and first launched against British and Belgian cities from September of the same year with devastating effect. So dangerous was the system, with its 320 km range, that allied forces prioritised the capture of V-2 launch sites and production facilities. By the end of the war, US forces had secured much of Nazi Germany's scientific brainpower in the form of Wernher von Braun and some 100 fellow rocket scientists, together with rocket assemblies sufficient to construct some 80 missiles, all of which – scientists and hardware alike – were shipped to the US. Meanwhile, Soviet forces secured V-2 manufacturing facilities and subsequently removed these from German soil to the Soviet Union, where they resumed production of the weapon system after the war.

Fast forward from those ironic, post-WWII, technological starting points/boosts for both sides' tactical missile developments to today's bloodied battlefields and urban

Credit: US DoD

An ATACMS missile under factory assembly.

Credit: DIU

Tactical missile strikes by the likes of Iskander-M missiles on Ukrainian critical infrastructure and civilian targets have been devastating, but have also seriously depleted Russian tactical missile stocks.

centres of Ukraine. Russian tactical missiles and drones of one sort or another, such as Iskander-Ms, rain down on Ukrainian towns and cities, while Ukrainian forces respond in limited fashion with the likes of home-grown Grom-2s, though await further discussions/protracted decisions from their allies about other long-range tactical missiles from western arsenals, such as the Army Tactical Missile System (ATACMS), which, despite latest political hesitations, must surely come, in long, 'over-due' course.

Real-World Use and Dwindling Stocks

Russia has used its various tactical and cruise missiles during its attacks on Ukraine with great intensity, but according to Ukrainian intelligence sources, until recently, there were increasingly longer periods between missile-heavy attacks, with a greater diversity of airborne weaponry used in more recent strikes, such as drones. This is a possible indicator that Russia's tactical ballistic missile inventories are feeling the strain.

In mid-March 2023, Andrii Yusov, a representative of Defence Intelligence of Ukraine (DIU), the main directorate of intelligence of the country's Ministry of Defence, stated that since the invasion began, tactical missiles such as Iskander-Ms, (amongst other missiles such as Kalibr and Kinzhal cruise systems), have been used in great numbers, but these are weapons Russia cannot afford, cost-wise and quantity-wise, to keep using. As a result, they have for some time been using their stocks of outdated, less accurate missiles, alongside these. One such example is their S-300P systems, which, are being employed as surface-to-surface tactical systems, as well as being used in their intended surface-to-air role. Indeed, the S-300P has several versions with different technical capabilities and ranges, the maximum aerial engagement range of the 48N6P-01 missile being 200 km (though its maximum range against land targets would be higher), carrying a warhead weighing 143 kg.

The DIU's Yusov said that accuracy was something the Russians did not particularly 'strive for' with their missile strikes, making any less-accurate legacy stock well-suited to questionable tactics and indiscriminate targeting. In many cases, he said that missing targets by as much as a kilometre appeared to be an acceptable norm for the Russians, hence the reason why not just intended energy infrastructure was being struck, but also civilian facilities such as residential high-rise buildings, schools, maternity homes and hospitals. With large stocks of S-300P family missiles, it is a likely this series of missiles will continue to be used as surrogate surface-to-surface missiles for the long-term. That said, where a previous 'missile terror tactic' strike 'periodicity' of about a week, i.e. the amount of time needed to prepare for the next missile strike, had been observed by the DIU, (possibly the result of depleted stockpiles of precision tactical missiles and wait times for new missiles), the large inventory of S-300P family missiles and the use of other systems alongside, may see the frequency of missile strikes increase once more.

Tactical Overreach… or Oversight?

In March 2023, with DIU statements trying their best to keep pace with latest missile attacks, and the fluid and changing operational conditions on the battlefield, DIU's Yusov said that tactical missile strikes at that time had been undertaken using missiles that Russian industry had been able to manufacture during the month immediately prior to strikes against Ukraine's power infrastructure on 9 March 2023. He said a deficit of high-precision missiles now existed in Russian stocks and some tactical system numbers were 'critically low', resulting in the growing time gap between such attacks at that time as the Russians failed to replenish stockpiles in sufficient quantities quickly enough.

While not dealing with cruise missiles per se, Yusov cited, as a known example, the Kalibr family of cruise missiles, which possess a maximum range of 1,500 km to around 2,600 km depending on variant. According to Yusov, the Russians had only 7% of the Kalibr cruise missiles they had at the beginning of the full-scale aggression remaining at that time and that even new missile production would be unable to make up such losses in the circumstances. In November 2022, the DIU estimated there to be only 120 Iskander-Ms left in Russia's tactical missile arsenal and that it was monitoring Kremlin plans to acquire the approximately 700 km operational range, Fateh-110/Zolfaghar tactical ballistic missile from Iran. The DIU said at the time that arrangements had already been made for these plans to be undertaken, and expected them to be shipped by air to Crimea, or by sea to Russian ports on the Caspian Sea. Yusov also noted that Russia was trying to use all approaches to circumvent sanctions, particularly by smuggling, or using 'grey' schemes, to secure the necessary components for missile and weapon production (more of which, below).

In the meantime, Russia appears to have modified its approach in the use of tactical missiles, certainly with a necessary, less-frequent expenditure of their most expensive tactical systems. Making slower progress in the overall fight, the Russians seem to have realised they were using up their tactical missile inventory unsustainably quickly, though not before having reached a point of running very low, not only of high-precision systems such as Iskanders, but long-range strike missiles in general. While Russia still has thousands of missiles, such as the S-300P series, in its inventory, many more of them have been used than have been produced. The DIU estimates that

Credit: DIU

Based on Defence Intelligence of Ukraine estimates, fewer than 120 Iskander-M systems – seen here undergoing assembly – are left in Russia's current inventory.

'no more than 30–40 missiles' can be produced a month by the Russians, and that the older, legacy missiles in service either do not reach their targets due to malfunction, or have limited effectiveness due to "poor destruction radius".

Tactical Nukes and Sanction Dimensions

Staying with the DIU, at the start of the year, another of the department's representatives, Vadym Skibitskyi, spoke of the nuclear threat posed by Russia's tactical, (and strategic), nuclear missile arsenal. With Ukraine's military intelligence resources constantly monitoring the movements of these assets, he said Ukraine's intelligence services "know all the storage locations" as well as "the number and deployment of nuclear weapons carriers" at the tactical level. He added that movements of all launch vehicles were constantly monitored, together with the activities of the 12th Chief Directorate of the Russian Defence Ministry. Also known as the Nuclear Technical Service Directorate, this is Russia's department responsible, amongst other things, for preparation and delivery of nuclear warheads to deployed assets from their secure storage locations. Skibitskyi said that the whole process was not a simple one, but that the DIU has experience monitoring and gathering intelligence about tactical and strategic nuclear forces from military exercises conducted since 2014 and earlier, 'so it knows all the procedural issues involved' in the deployment of Russian tactical nuclear missiles and other materiel.

Skibitskyi also commented at that time about sanctions, touched on earlier, and Russia's changing missile tactics and capabilities, commenting that the impacts of economic sanctions on the Russian Federation were visible and their resulting efforts to circumvent sanctions and import components for missiles and other weaponry were monitored by the DIU. Information collected was shared with Ukraine's partners, and 'other measures' were taken to prevent missile and weapon production by Russia from increasing. Skibitskyi said today's Russian tactical missile deficit related particularly to Iskander tactical ballistic missiles, as well as air and sea-launched cruise missile systems, but that while the number of high-precision missile strikes and their density and intensity had lessened in recent months and weeks, it had to be recognised that the production of tactical missiles in Russia continued. "Unfortunately, production does not stop," he said. "Their volume is not that big, but they are produced. We now find debris from missiles made in the fourth quarter of 2022. Therefore, they are produced and immediately given to the troops for the shelling of our facilities."

Skibitskyi recalled that with dwindling missile stocks and this almost 'just-in-time' supply of new missiles, "the enemy began to combine and change tactics". As alluded to earlier, this is apparent through the different weapon compositions of a strike, such as the inclusion of Iranian-made UAVs and Loitering Munitions (LMs), legacy tactical missiles, high-precision tactical ballistic missiles and modified S-300 SAM missiles employed in a surface-to-surface, tactical missile role, for their strikes, rather than just one missile system. DIU's Yusov commented at that time that while Russia's stockpile of certain high-precision missiles, like the Iskander-Ms, "has fallen to a critically low level" they still have a "sufficient number" of S-300 missiles, which they use to strike frontline cities and towns, such as Kharkiv, Kherson, Mykolaiv, Sumy and Zaporizhzhia.

UK MoD's Long Range Strike

As tactical missiles and drones fly in Ukrainian skies, predominantly in one direction, the UK MoD, as part of its International Fund for Ukraine (IFU), has recently tendered for a 'Long Range Strike' capability. Expressions of interest (EOI) were requested for land, sea or air-launched missile or rocket systems with a range between 100–300 km, and a payload of between 20–490 kg. The tender, which closed on 4 May, posted 'desirable requirements' for the system to include:

- Low Probability of Intercept (LPI);
- A mission planning capability;
- Assured navigation (with hardened Global Navigation Satellite System capability) in the face of advanced countermeasures and EM spectrum denial;
- Air defence penetration methods to increase probability of successful strike;
- Technical Readiness Level of at least 8.

The IFU is a funding mechanism that uses funding from international partners to procure priority military assistance for Ukraine and is intended to ensure the continued supply of military support – lethal and non-lethal – through 2023 and beyond. The fund is administered by the UK MoD on behalf of an executive panel, comprising the UK, Norway, the Netherlands, Denmark and Sweden. These partners, along with Iceland and Lithuania, have contributed a collective total of more than GBP 520 M to the fund to date. Supplier EOIs for Long Range Strike are currently being assessed at time of writing and suppliers of interest are set to be contacted from 5 June 2023.

Ukraine's Own and ATACMS Question

With Iskander-Ms having been used extensively, though now in short supply, Ukraine has been able to mount a limited response with its own home-grown Grom-2/HRIM system, which Russia claims to have had some success in shooting down. At the same time, Ukraine still hankers after the US ATACMS. These three systems are all tactical short-range ballistic missiles (SRBMs) with effective ranges out to approximately 500 km (300 miles). However, rather than giving further space to the Iskander-M, the focus here is on Ukraine's own homegrown Grom-2/HRIM system, the US ATACMS. At the time of writing the US continues to hold the position that it has insufficient stockpiles of ATACMS to be able to supply this weapon system to Ukraine; whether that will change has yet to be seen. With this conflict's history of delayed decisions in the supply of weapon systems…probably best to 'never say never'.

Credit: VoidWanderer, via Wikimedia Commons

GROM-2 Ukrainian tactical missile system, also known as Hrim-2, or OTRK Sapsan, during a rehearsal for the Independence Day military parade in Kyiv, 2018.

Ukraine's home-grown short-range ballistic missile system developed by the Pivdenne Design Office and AM Makarov Southern Machine-Building Plant is referred to by various names, including the Operational-Tactical Missile System Hrim-2, also OTRK Sapsan, and, as referred to earlier, Grom-2. Similar in role and capabilities to the Iskander, Grom-2 was intended to replace Ukraine's stock of 120 km range Tochka-U SRBMs, its predominant tactical missile of recent years. The single-stage Grom-2, is controlled using inertial navigation system (INS) and global navigation satellite system (GNSS) guidance and has been reported to possess a terminal homing capability, perhaps indicating the presence of a radar seeker. The export variant has been stated to have a range of 280 km to comply with the Missile Technology Control Regime (MTCR), but the domestic variant is report-

edly capable of reaching out to around 500 km. The missile is armed with carrying a 480 kg warhead, comprising either a high explosive fragmentation (HE-FRAG) or penetrating HE-FRAG unitary warhead, or HE-FRAG submunition natures. Grom-2's approximate area of effect with the unitary HE-FRAG warhead exceeds 10,000 m2, while the submunition warhead covers 30,000 m2. Two missiles can be carried on the Ukrainian-made, 10×10 wheeled transporter erector launcher (TEL) vehicle, which must elevate the missiles to a vertical firing position prior to launch.

The Grom-2 was reportedly used against the Saky Air Base in occupied Crimea in August 2022, with several explosions having occurred, although this remains unconfirmed by the Ukrainians. In May 2023, Russian media outlets and officials claimed that two Grom-2 tactical ballistic missiles had been shot down by air defences over Crimea, although, once again, this incident has not been verified by Ukraine.

Ukraine's Missile Wish-List

Concurrently with the UK's IFU tender, the UK has sent air-launched Storm Shadow long-range cruise missiles to Ukraine, which have, reportedly, already been in use. This may give the Americans some comfort in their decision to hold onto their ATACMS stock, claiming the US arsenal has insufficient numbers of these missiles to make such a move wise. So, while, for now, any temptation to supply Ukraine with Lockheed Martin's ATACMS has been resisted, the missile, nevertheless, remains on Ukraine's wish-list.

Credit: US Army

ATACMS remains on Ukraine's tactical missile wish-list despite US reservations.

Credit: US Army

ATACMS fired from M270 and M142 launchers.

As for the ATACMS, the family is already long in the tooth, with the earliest missile variant first seeing use in Operation Desert Storm in 1991. During that conflict, according to US Government records, some 30 of these road-mobile, solid-propellant fuelled, surface-to-surface systems were used to strike Iraq's medium-range ballistic missile launchers and surface-to-air missile sites at ranges of up to 160 km.

The MGM-140 ATACMS had effectively taken over from the MGM-52 nuclear-capable, Lance missile system in the 1980s and now has a successor lined up in the form of the Precision Strike Missile, or PrSM, which should enter service in 2023/2024. Whether growing stockpiles of the newer system make a difference to the ATACMS decision is a guessing game, but with no end to the war in Ukraine in sight, if the Ukrainians do eventually get their ATACMS wish, the capabilities it will afford them are many. According to manufacturer, Lockheed Martin, the guided missile is a conventional long-range, precision-strike, surface-to-surface artillery weapon system packaged in MLRS look-alike launch pods and launched from the MLRS family of launchers (the MLRS M270 and M270A1 platforms), as well as being M142 High Mobility Artillery Rocket System (HIMARS) compatible. Two missile pods can be carried by the MLRS vehicles and a single pod on HIMARS, with each pod containing one ATACMS missile. The system incorporates an improved guidance package with INS/GNSS, carries a unitary WDU-23/B, 227 kg (500 lb) blast fragmentation warhead, and has a maximum range of 300 km. FY20 contracts for MGM-140B ATACMS production totalled USD 426 M with over 400 missiles made during that period. As of 2020, eight nations have procured and fielded the system.

Beyond ATACMS…

As for its PrSM successor, this missile again is designed to be launched from the M270A2 MLRS vehicle and the M142 HIMARS. The baseline missile, 'Increment 1', will be developed and fielded to engage a wide variety of point and imprecisely located targets at ranges greater than 400 km. The PrSM will give field artillery units a long-range, deep-strike capability, at the same time supporting brigade, division, corps, army, theatre, joint/coalition forces, and marine air-ground task forces. In replacing ATACMS, it will double the volume of fire with two missiles per launch pod and will maintain and improve accuracy in partial GPS-degraded environments; the missile is slated for M-Code GPS integration to improve resistance to jamming.

Lockheed Martin successfully completed three prototype flight tests in late 2020 and is set to field its first production missiles by the end of 2023 under the terms of its Urgent Materiel Release (UMR) contract awarded by the US DoD at the end of 2021. While an initial competitor to Lockheed Martin in the programme, Raytheon withdrew from the Long-Range Manoeuvrable Fires programme in 2020 after difficulty with prototype flight tests, but has recently re-entered the fray following the award of a USD 97.7 M contract from the US Army. This is for design advancement for PrSM Increment 4, which aims at a system with considerably increased range, possibly out to 1,000 km. Raytheon is partnering with Northrop Grumman in this effort. ■

Broken ARRW? Mixed Signals on Air-Launched Hypersonic Missile Project

Sidney E. Dean

Following a failed flight test in March of 2023, the US Air Force announced it would cancel plans to procure the AGM-183A hypersonic missile. A month later the service seemingly reversed course, announcing it would decide at a later date whether or not to acquire the weapon.

The Air-launched Rapid Response Weapon (ARRW; pronounced: 'Arrow') program aims to develop an air-launched hypersonic glide vehicle (HGV) prototype capable of sustained flight speeds between Mach 6.5 and Mach 8, and with an operational range of circa 1,600 km. The United States Air Force (USAF) has designated the objective Air-to-Ground Missile weapon system as the AGM-183A. The weapon is intended to be launched at high altitude by B-52 and B-1 bombers and be deployed against highly defended targets. The B-52 could carry a total of four missiles externally, while the B-1 could accommodate 31 missiles through combined internal and underwing carriage. A possible launch via F-15EX fighters has also been proposed, although the weapon's size would probably preclude such deployment.

The complete AGM-183 consists of an all-up-round (AUR) integrating the HGV with a booster rocket. Like all HGVs, the ARRW does not have a conventional propulsion system. Instead, the booster rocket ignites after the weapon system is released by the bomber, and accelerates the AGM-183A to hypersonic speeds. After the booster burns out, the protective nose cone separates to release the inert wedge-shaped HGV which continues to glide toward its target at hypersonic speed. According to some sources the HGV could reach speeds up to Mach 20, and would destroy the target through the kinetic energy released by the high-speed impact.

Credit: Lockheed Martin

The protective nose cone separates from the ARRW to reveal the warhead in this concept image.

Credit: USAF

Airmen ready an AGM-183A for a 2020 captive carry test beneath the wing of a B-52 bomber.

Testing Programme

ARRW was initiated as a rapid prototyping project aimed at fielding an operational capability as quickly as possible in response to an urgent need – in this case Russian and Chinese advances in hypersonic weaponry which need to be balanced quickly. USAF awarded Lockheed Martin an initial USD 480 M ARRW design contract in May 2018. This was followed in December 2019 by a USD 989 M contract modification for the ARRW critical design review, test and production readiness support. Successful airborne captive carry tests of the HGV beneath the wing of a B-52 bomber were conducted in 2019 and 2020.

Launch- and flight-testing of the ARRW booster rocket began in April 2021. All three flight tests attempted in that year failed, each time for a different reason, leading Congress to cut the 2022 program budget in half. The final two booster tests, conducted in 2022, were successful. This opened the door for flight tests of the full operational prototype, consisting of the complete All Up Round

Credit: USAF

A B-52 readies for a captive carry test of the AGM-183A ARRW in August 2020.

including both the hypersonic glide vehicle and the booster rocket. The first of four planned AUR flight tests took place on 9 December 2022. Following release from the B-52, the missile accelerated to hypersonic speeds, completed the planned flight path, and struck the offshore target area, thereby meeting all test objectives. However, the second operational prototype test, conducted on 13 March 2023, was declared a failure. The comprehensive test was designed to evaluate the AGM-183A's 'end-to-end performance' from captive carry through launch, booster ignition, shroud separation, and hypersonic body glide to impact. Citing operational security, USAF declined to provide details of the failure. Instead, the service announced that – although several test objectives had been met – the test was unsuccessful overall because vital data was either not collected or lost.

Wrapping Up...

On 29 March 2023 – 16 days after the last failed test – USAF seemed to announce the impending cancellation of the AGM-183 program. Andrew Hunter, the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics, informed Congress that USAF "does not currently intend to pursue follow-on procurement of ARRW once the prototyping program concludes." He added

Credit: Lockheed Martin

Lockheed Martin concept of an ARRW missile being launched from a B-52.

that USAF did wish to complete the two remaining planned AUR flight tests in order to collect data which could flow into future hypersonic development programs. To support the final tests and evaluation, USAF is requesting USD 150 M in funding for Fiscal Year (FY) 2024. According to concurrent USAF statements, remaining program elements planned in 2024 include "complete contract closeout, finalise documentation and analysis, and activities to support the leave-behind capability." The "leave-behind capability" refers to an unspecified number of production-representative weapons which could be used for further research or, hypothetically, even be deployed in combat.

...Or Not?

Then, on 28 April 2023, Air Force Secretary Frank Kendall seemed to contradict Hunter. In testimony before Congress, Kendall stated that a final decision regarding AGM-183A procurement had not been made. Rather, the service would await the conclusion of the complete AUR testing cycle and conduct a comprehensive evaluation of the results before committing to either procurement or termination. "We haven't stopped on ARRW. We still have funds to complete the test program. And we'll reserve judgment until we see how that does and we'll look at our priorities going forward," Kendall told the House Armed Services Committee. He added that, if the final test flights are successful, "we'll revisit it … as we build the [2025] budget and see what will be done in the future."

A USAF spokesperson later confirmed the position expressed by Kendall, stating that Hunter had merely been referencing the fact that the Pentagon was not requesting procurement funding for FY 2024. The spokesperson added that – if the testing and system production readiness review demonstrate the AGM-183A's operational utility – "the AF will [then] need to look at our weapons mix and see if ARRW falls within the requirements."

However, closer inspection of the various official's statements shows that there is no great contradiction between their respective positions. Kendall himself has frequently voiced dissatisfaction with the pace of the program. As recently as 28 March 2023 – one day before Andrew Hunter's testimony – Kendall openly stated that USAF was more committed to its second air-launched hypersonic weapon program, the Hypersonic Attack Cruise Missile (HACM). The Air Force Secretary reiterated that sentiment in late April, stating "HACM, we think, offers the most potential to us at this point." Kendall stated that HACM has demonstrated a "reasonably successful" development schedule to date and promises a "greater combat capability overall." This statement of preference is in and of itself telling, as HACM is not expected to achieve operational utility before 2027, and purportedly will have only half the objective range of the AGM-183A. Kendall's evaluation most likely reflects a conviction that ARRW is technologically too immature. The one major advantage of HACM is the fact that it could be carried by a greater variety of aircraft including US and allied tactical fighters, providing greater flexibility and deployment options.

Decision Time

Given the pattern of negative evaluations made by senior civilian USAF leadership in recent years, it would seem logical that the latest deferment of judgement regarding a procurement decision is primarily aimed at securing the funding to conclude the planned ARRW testing cycle, in order to flow the results into other research projects. Given past congressional cuts to programs which fail to perform in testing, the Pentagon must anticipate that funding for a scrapped program would be terminated. Congressman Ken Calvert, Chairman of the House Appropriations Committee defense subcommittee, hinted at this in a 28 March 2023 exchange with Kendall. "I don't like to call it [research and development] welfare, but it seems to go on forever," Calvert said. In a speech delivered on 9 May 2023, Deputy Defense Secretary Kathleen Hicks gave the most recent indicator that the ARRW will not continue past the current testing cycle. Specifically referencing ARRW, Hicks underscored the need to be vocal about learning from potentially unsuccessful experiments. "Some tests worked. Some tests didn't. But even then, we still learned a lot of useful things from ARRW — which we're applying to the many other hypersonic missiles we're developing and procuring across DoD. [...] We have to embrace the fact that being truly innovative requires a willingness to fail, and learn from failure, and try again." ■

NATO BMD and Upper-Tier Developments

Tim Guest

In a worsening missile threat environment, the need for comprehensive and technologically superior ballistic missile defence (BMD) is more important for western allies now, than at any other time in world history.

The US and its NATO allies have a great responsibility to protect their respective populations in what are, probably, the most dangerous geopolitical era of our lives. Missiles abound and are a means to project power both regionally and strategically. With burgeoning ballistic missile inventories, many state actors now have the ability to reach out across any distance, short or long, to target almost any nation they deem the enemy, with conventional, as well as nuclear weapons. Not only are ballistic missiles increasing in number, but also in range, sophistication and complexity by incorporating such tech as countermeasures to BMD systems. As a result, they've become more survivable, reliable and accurate, thereby threatening to reducing military options for allied commanders in the field, and potentially decreasing the survivability of their regional military land and sea assets.

It's imperative, therefore, to defend against these clear and present dangers, and that requires collective strategy, forward planning, co-operation, interoperability, great resolve and, most importantly, technologically superior, multi-layered/tiered ballistic missile defences using the very latest technological advances to ensure success in their defensive aims against some of the most advanced weapons of their kind ever pointed in our collective directions. This article takes a look at the current alliance BMD framework and thinking, and then at latest upper-tier developments.

Credit: IAI/MDA

Arrow 3 during a test launch in 2019. Germany's discussions with Israel about acquiring Arrow 3 to create a new multi-layered, BMD shield alongside the German IRIS-T-SLM and the US PATRIOT systems, reach an advanced stage towards the end of April 2023.

NATO's Current and Evolving BMD

For NATO, the proliferation of ballistic missiles is an increasing threat to member populations, territories and forces, particularly with the proximity of several countries to alliance states that either have ballistic missiles or are attempting to develop and/or acquire them. As such, one of the alliance's permanent missions is that of NATO Ballistic Missile Defence (NATO BMD), which forms a wholly defensive, deterrent component of the alliance's Integrated Air and Missile Defence (IAMD) framework. As part of a strategic mix of conventional, space, cyber and nuclear forces, BMD plays a key role in protecting the alliance's European populations, territories and forces as ballistic missile threats increase, particularly along the alliance's southeast borders.

More than a decade ago, an expanded BMD capability was agreed as a core element of NATO's defensive and deterrent raison d'être, and just over six years ago the Initial Operational Capability of NATO BMD was reached. Ongoing commitments by leaders of NATO member states were made at the 2022 Madrid Summit to continue implementing NATO BMD fully, requiring commonly funded assets, as well as voluntary contributions provided by several allies. The US European Phased Adaptive Approach (EPAA), for example, covers the US contribution designed to protect Europe against short, medium, and intermediate-range ballistic missiles launched from Iran, though without compromising protection from Russian threats. Indeed, prior to the invasion of Ukraine, NATO BMD was purportedly intended to largely counter the increasing threat posed by ballistic missile proliferation on the south-eastern borders of the alliance. This was in response to increasing concerns about Iran's increasing numbers of missile tests, as well as the range and precision of its ballistic missiles.

While those aims of NATO BMD remain, the changing level of threat means its framework needs to adapt accordingly. In general, the alliance sees effective BMD

as able to complicate hostile planning by potential aggressors, as well as providing valuable decision-making time for both military and civil command in response to imminent/ongoing missile attacks; BMD even contributes as a partial deterrent to nuclear missile threats, complementing, though not replacing, allied nuclear capabilities, in that regard.

Interestingly, alliance posture on BMD prior to 24 February 2022, stated that: "NATO BMD is intended to defend against potential threats emanating from outside the Euro-Atlantic area" and that: "NATO BMD is not directed against Russia and will not undermine Russia's strategic deterrence." This posture is, of course, now urgently being reviewed as of the Madrid event; it's worth noting that at the Madrid Summit, allied leaders adopted the NATO 2022 Strategic Concept policy document that guides all alliance activities, including BMD, and which encompasses and considers the rapidly evolving strategic environment, which notes: "…authoritarian actors challenge our interests, values and democratic way of life. They are investing in sophisticated conventional, nuclear and missile capabilities, with little transparency or regard for international norms and commitments". In response to these authoritarian challenges the concept document states that: "NATO's deterrence and defence posture is based on an appropriate mix of nuclear, conventional and missile defence capabilities, complemented by space and cyber capabilities. It is defensive, proportionate and fully in line with our international commitments".

EPAA Moves

As for the EPAA, mentioned above, implementing this is core to the alliance's IAMD and follows four-phased deployments, including that in which the US will provide upper-tier ballistic missile defence of Europe. Two of the four phases of EPAA are operational today, with an increasing number of allies already having provided assets, or having set development or acquisitions in motion for additional BMD assets, including upgraded ships with BMD-capable radars, ground-based air and missile defence systems, or advanced detection capabilities.

Ukraine notwithstanding, NATO BMD is based on voluntary national contributions, including nationally funded interceptors and sensors and hosting arrangements. It is also based on the command and control systems backbone delivered through the NATO BMD programme, which is commonly funded by all allies. In a nutshell at this time, Germany hosts the NATO BMD command centre at Ramstein Air Base, the US contributes through its EPAA, Turkey hosts a US BMD radar at Kürecik, Romania hosts a US Aegis Ashore site at Deveselu Air Base and Poland also now hosts an Aegis Ashore site, the construction of which was completed in October 2022 at the Redzikowo Military Base, with the US Missile Defense Agency (MDA) expected to confirm the site safe and technically capable later in 2023, at which point it will be taken under US Navy control before some operational control is expected to be transferred to alliance partners. In addition, Spain hosts four multi-mission, BMD-capable Aegis vessels at its naval base in Rota, as part of the EPAA and for use as part of NATO BMD, if required. Aegis is a capable system when it comes to BMD – in late 2020, the US Navy demonstrated the successful interception of an ICBM in mid-course flight, using an SM-3 Block IIA missile launched from the USS John Finn.

The above is by no means an exhaustive list, as several allies also offer additional integrated air and missile defence systems, such as PATRIOT or SAMP/T, or suitably capable naval ships, while others are developing and/or acquiring assets, which may, eventually, be suited for integration with NATO BMD.

Ukraine and BMD Rethink

As the IAMD framework was put together without a crystal ball to hand, it was aimed, as stated above, at countering ballistic missile threats emanating from outside the Euro-Atlantic area and not designed to defend against massive strategic retaliation from Russia. Therefore, as a direct result of the invasion of Ukraine, the core US EPAA document is under scrutiny to include BMD capabilities against such a Russian threat. It's clear to see why; looking back to the start of the war waged against Ukraine, in the first month alone, around 1,000 ballistic and cruise missiles were launched from Russia, Belarus, and the Black Sea at critical infrastructure and civilian targets inside the country. Of those missiles, the 3M14 Kalibr, the 9M728 Iskander-K cruise missiles, and other Iskander-M and Tochka short-range ballistic missiles (SRBMs) were fired from Russian land and air-based platforms, with the Ukrainians having some limited air defence capabilities to stop them at that time. On its borders, US and NATO Allied PATRIOT missile batteries were then deployed/re-deployed into NATO member countries, US PATRIOTs to Poland and German and Dutch PATRIOTs to Slovakia. While massive missile strikes on Ukraine have, of course, continued throughout the war and been well documented, at time of writing, the dynamics have totally changed from those early days and the Ukrainians now have effective air defence assets in the form of approximately two PATRIOT batteries (both estimated to be under-strength), given the green light by the US in October 2022, and seemingly even proving effective against Russia's Kh-47M2 Kinzhal air-launched ballistic missiles. Furthermore, according to Ukrainian defence intelligence sources, Russian theatre ballistic missile stocks are running critically low.

Credit: Lockheed Martin

PAC-3 MSE shown during a test-launch at WSMR. THAAD's continued incremental capability improvements have led to its integration with the PAC-3 MSE.

BMD as Part of IAMD

To round off this brief look at current NATO BMD thinking, this crucial missile defence capability is a key component of the alliance's overall IAMD framework to protect against air or missile threat or attack. This is a vital element of NATO's deterrence, defence and ability to provide a strategic response to any event, so the alliance maintains a desired level of control in the skies, so as full a range of alliance missions can be carried out on the ground and at sea.

IAMD is designed to provide 360° cover enabling it to detect, identify and engage any threat from any direction. While in peacetime, NATO BMD remains one of the two major ongoing IAMD activities alongside air policing, following Russia's invasion of Ukraine, NATO IAMD is adapting to address all air and missile threats, including Russia's hypersonic weapon and drone threats. Measures taken by the allies to enhance NATO IAMD in response to the invasion of Ukraine, for instance through the movement of the Patriot batteries mentioned earlier, are a demonstration of how allied cooperation under IAMD works.

It is also worth noting that in May 2023, it's worth noting that a PAC-3 MSE interceptor was successfully test launched from a German-modified M903 Patriot launcher at White Sands, under simulated tactical/operational test conditions conducted by the German Air Force against a virtual tactical ballistic missile target to prove compatibility between PAC-3 MSE and the German-modified Patriot M903 launching station. MBDA Deutschland partnered with Lockheed Martin to perform the necessary modifications of the launcher to enable the integration of the PAC-3 MSE missile, with the test being a critical final step before delivery of the first PAC-3 MSE shipment to Germany and follows the 2019 agreement between US and German Governments for German PAC-3 MSE procurement.

Credit: Lockheed Martin

THAAD launch. THAAD is the only US system designed to intercept targets in the high atmosphere, and just outside the atmosphere.

Upper-Tier Interception Developments

Moving away from alliance thinking to some recent BMD system developments, (though just a couple of the many that could be discussed), let's now look at some recent upper-tier/mid-course interception developments with the US Terminal High Altitude Area Defence (THAAD) from Lockheed Martin and the joint US/Israeli IAI Arrow 3.

Scene setting: mid-course is the phase of flight between the boost phase after a ballistic missile is launched and the terminal phase of its flight, once it has re-entered the Earth's atmosphere. The mid-course phase in space can last from a few/several minutes for shorter and medium-range missiles, to as long as 20 minutes for an intercontinental ballistic missile (ICBM), which offers the longest potential timeframe in which a defensive system can be used against an incoming missile, giving the defender time for both decision-making and an interception. This also means that an anti-ballistic missile (ABM) rising to meet the threat has a large exo-atmospheric area in which to conduct its interception. That said, these factors, in turn, require such an ABM to be large and supported by powerful ground-based radar systems, space-based sensors, and capable of evading space-based decoys.

THAAD Moves

Built to defend against short, medium and intermediate-range ballistic missiles, THAAD is the only US system designed to intercept targets at upper-endoatmospheric to lower-exoatmospheric altitudes. The system uses a hit-to-kill defeat mechanism to destroy threats with kinetic energy from a direct impact, which is also intended to neutralise lethal payloads before they reach the ground. THAAD continues incremental capability improvements within the weapon system to continually improve performance against current and emerging threats. The first THAAD battery was activated in May 2008 and the seventh in December 2016.

According to the manufacturer, THAAD's continued incremental capability improvements within the weapon system have led to its integration with the Patriot Advanced Capability (PAC)-3 Missile Segment Enhancement (MSE), demonstrated in March 2022 when the US Missile Defence Agency (MDA) in partnership with the US Army Programme Executive Office Missiles and Space, US Army Space and Missile Defence Command, and Ballistic Missile Defence System Operational Test Agency (BMDS OTA), tested the integration of THAAD with the Patriot missile defence system. The test, designated Flight Test THAAD Weapon System (FTT)-21, was conducted at the White Sands Missile Range, New Mexico and achieved its objective, with the THAAD weapon system launching two PAC-3 MSE interceptors, which successfully took out a Black Dagger target. MDA Director Vice Admiral Jon Hill said that the test marked a milestone for the integration of the two weapon systems, enabling commanders on the ground the ability to "use the right missile for the right threat at the right time".

FTT-21 was the first live intercept flight test of software upgrades that now provide THAAD with the capability to compute PAC-3 MSE firing solutions, communicate with an M903 Patriot Launching Station, and simultaneously control multiple PAC-3 MSE interceptors in flight. The integration of the PAC-3 MSE interceptor into THAAD allows it to be launched earlier, enabling a longer fly-out time, which, in turn, potentially increasing the defended area, and offers an integrated layered defence. A month after the FTT-21, the MDA awarded Lockheed Martin a USD74-million contract to produce an eighth THAAD battery for delivery to the US Army in 2025. VP of Upper Tier Integrated Air and Missile Defence at Lockheed Martin Missiles and Fire Control, Don Nimblett, said at the time that continued confidence in the THAAD system and its "unique endo- and exo-atmospheric defence capability" were behind the award, adding that, "With 16 of 16 successful flight test intercepts and recent combat success clearly documenting the effectiveness of THAAD, adding an eighth battery will further enhance readiness against existing and evolving ballistic missile threats."

In October 2022, the company delivered the 700th THAAD interceptor to the MDA as part of a USD 1.4 Bn award in March 2022 for additional interceptors, for both the US Army and the Kingdom of Saudi Arabia. This milestone was met just 14 months after Lockheed Martin delivered the 600th THAAD interceptor to the US in August of 2021. Despite March 2022, contract, the MDA also exercised a USD 304.9 M option for further interceptors in April 2022.

AWS and Arrow 3

Another upper tier/mid-course BMD system gaining traction at the moment is the Arrow 3 interceptor, which is part of the Arrow Weapon System (AWS), jointly devel-

oped by Israel Missile Defence Organisation (IMDO) and the MDA. It forms a central part of Israel's multi-layered defence array based on four layers: Iron Dome, PATRIOT, David's Sling, and the Arrow-2 and Arrow-3 systems. Whereas the Arrow 2 interceptors are designed for endo and exo-atmospheric interception capabilities, the Arrow 3 interceptors are upper tier, mid-course, exo-atmospheric interceptors for longer-range threat engagement. The missiles are two-stage, solid propellant designs, comprising booster and sustainer sections as well as a hit-to-kill defeat kinetic kill vehicle. The Arrow system (also known as the Arrow Weapon System; AWS) provides radar detection, tracking, intercept data to both Arrow 2 and 3 interceptors on any incoming TBMs over a large footprint, thereby protecting strategic assets and population centres with a multi-layered system. For its part, Arrow 3 is designed to intercept and destroy the latest, longer-range threats, especially those, including ICBMs, carrying weapons of mass destruction; a fire-control system guides the interceptor to its target, but Arrow 3's kill vehicle is equipped with advanced, high-resolution optoelectronic sensors imparting long-range acquisition capabilities, enabling it to home in precisely on its prey over a very large defended area. Even though its overall manoeuvre envelope is large, its time-of-flight is short, thereby enabling a large number of interception opportunities within the mid-course environ. By integrating into the overall Arrow system and complementing current and future blocks of Arrow 2 interceptors, Arrow 3 completes the upper-tier engagement capability of this now multi-tier BMD system.

Credit: Lockheed Martin

An eighth THAAD battery will further enhance readiness against existing and evolving ballistic missile threats.

In January 2022, the IMDO of the Directorate of the Defence Research and Development (DDR&D) at Israel's Ministry of Defence, together with the US MDA and participating Israeli Defence Forces, conducted a successful flight test of the AWS and the Arrow 3 interceptor at a test site in central Israel. AWS radars detected the target and transferred data to the battle management control (BMC) system, which analysed the information and established a defence plan, resulting in the launch of two Arrow 3 interceptors toward the target for a successful mission completion. Once again commenting for the MDA, Vice Admiral Jon Hill said that the test had been designed to challenge every element of the AWS and that data from the whole event would help guide future system development, adding, "MDA remains committed to assisting the Government of Israel in upgrading its missile defence capability against current and emerging threats."

IMDO director, Mr Moshe Patel, said at the time that since a successful series of tests in Alaska in 2019, the Arrow system's capabilities had been significantly extended and that this latest successful test had been a 'complicated flight' involving the complete AWS and the Arrow 3 interceptor and would help the Israeli Ministry of Defence to continue in its efforts to enhance and upgrade Israeli multi-tier missile defence capabilities to meet any and all emerging threats in the region. The IMDO, MDA and the US Government have collaborated on Israel's current missile defence developments for more than 30 years.

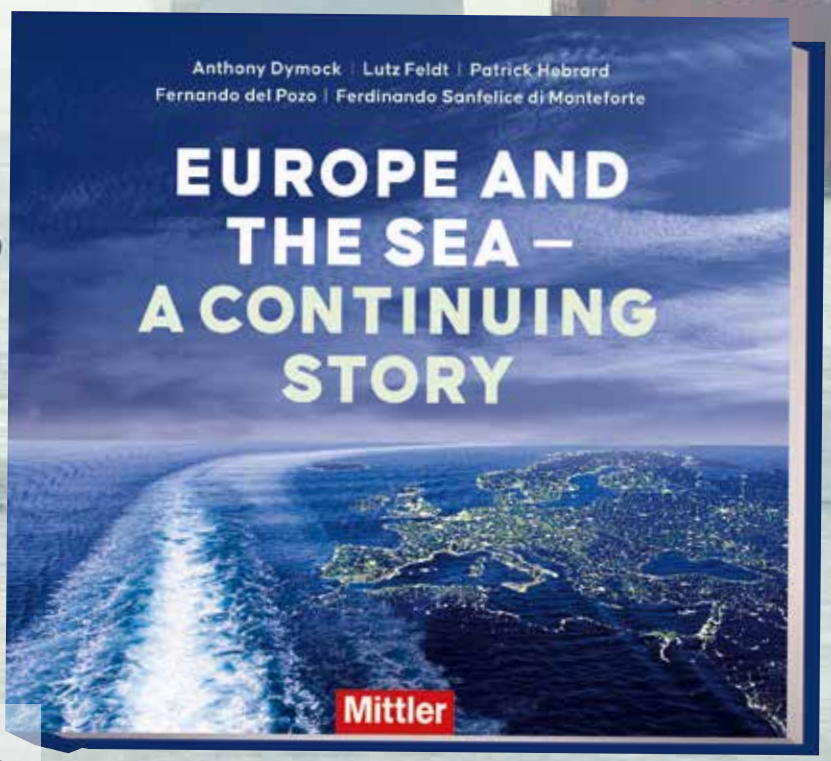
For some months now, Germany has been in discussions with Israel about acquiring Arrow 3 to strengthen its air defence capabilities, effectively creating a new multi-layered, BMD shield that would also include and be integrated with the German IRIS-T and the US Patriot system. Towards the end of April, it was reported that these talks had reached an advanced stage. This major development is part of Germany's new approach to defence and military spending, as a direct result of the war in Ukraine. The purchase was reported to have been approved in principle by US President Biden in March 2023.

Credit: IAI/MDA

Arrow 3 during a test launch in 2019. Arrow 3 interceptors are upper tier, mid-course, exo-atmospheric interceptors for longer-range threat engagement.

EUROPE AND THE SEA

A CONTINUING STORY



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Hypersonic Multitasker: USAF Project Mayhem Takes Shape

Sidney E. Dean

'Project Mayhem' aims to provide the US Air Force with an unmanned hypersonic aircraft capable of both reconnaissance and strike missions.

The project's official designation is Expendable Hypersonic Multi-Mission Intelligence, Surveillance, Reconnaissance and Strike. As the name states, the unmanned aircraft will be tasked with both reconnaissance and combat missions. As a hypersonic aerial vehicle it will be considerably more survivable than other manned or unmanned ISR systems, and will be able to provide situational awareness or targeting data much faster than conventionally-powered aircraft. As a strike platform, the aircraft will have a larger payload capacity than the hypersonic cruise missile concepts currently being developed by the US Air Force (USAF). In either mission mode 'Mayhem' is expected to enhance short-term response to fluid and developing tactical situations. Despite the inclusion of 'Expendable' in the weapon system's name, the highly capable plane is not designated as a one-mission suicide drone. Rather, the term reflects the reality that the military will more readily send an unmanned aerial vehicle (UAV) on some high-risk missions, accepting the potential loss of the plane when the operational reward is high.

The existence of the program was first revealed publicly in August 2020, through an initial Request for Information (RFI) to industry. At the time it was designated the 'Expendable Hypersonic Multi-Mission Air-Breathing Vehicle,' with no specific mention of a mission profile. The current designation and the revelation of the dual mission configuration was announced in December 2021. Announcement of the program was followed by several additional RFIs, and a solicitation for offers was issued in March 2022. The latter ultimately led to the December 2022 award of the contract for design and systems development to Leidos Inc. as the prime contractor.

As stated in the April 2022 updated solicitation to industry: "The Mayhem Program is focused on delivering a larger class air-breathing hypersonic system capable of executing multiple missions with a standardised payload interface, providing a significant technological advancement and future capability. The standardised payload interface would create multiple opportunities for various payload integration within the same hypersonic system."

Credit: ARFL/Leidos

Concept of an air-breathing hypersonic aircraft.

Hypersonics 2.0

While the state of technological development is only now making operational hypersonic systems viable, the concept – and the aspiration – are not new. The USAF experimented with manned hypersonic aircraft as early as the 1960s. The current world speed record for manned powered flight was set on 3 October 1967 by then-Major William Knight in the X-15A-2, reaching 7,274 km/h or Mach 6.7. The North American X-15 was a rocket powered aircraft which was carried underwing by a B-52 bomber and launched at an altitude of circa 13,000-14,000 m. The rocket engine fired for a maximum of 120 seconds, propelling the aircraft to very high speeds, after which the pilot continued to conduct high-speed glide manoeuvres before landing via the retractable gear. Despite the impressive propulsion results, the experimental program was terminated in 1968 because of persistent technical and safety issues.

Interest in hypersonics continued. NASA built and tested three X-43 unmanned hypersonic aircraft in the 2001 to 2004 timeframe. The 3.7 m long aircraft were launched via B-52, and propelled to hypersonic speeds via a booster rocket. Following separation of the booster, an experimental scramjet engine ignited for circa 10 seconds. The third and final X-43 achieved Mach 9.68 on 16 November 2004. The X-43 was designed as a one-flight aircraft; all demonstrators were deliberately crashed into the Pacific Ocean following test flights.

The X-43's primary purpose was to serve as a testbed for scramjet technology. The program was succeeded by the unmanned X-51 Waverider, which was also launched from a B-52 and brought to speed with the aid of a booster before firing the experimental scramjet engine. Four powered flight tests were conducted from 2010 to 2013, each ending a planned crash. Only the final test was considered a full success, achiev-

ing 210 seconds of propulsion from the scramjet engine, and reaching Mach 5.1 in the process. While progress was slow and limited, these preceding decades of experimentation did ultimately pave the way to today's hypersonic programs.

Tactical Advantage

With all three major military powers – and several secondary powers – developing or at least researching hypersonic military systems, fielding this technology is taking on new urgency. To date Russia and China have been focussed on developing hypersonic glide vehicles as well as hypersonic cruise missiles. The United States armed forces are following suit, but are also interested in acquiring hypersonic aircraft. Project Mayhem seeks to develop technology in support of the latter goal.

From an operational standpoint, a hypersonic ISR/Strike aircraft will provide commanders the ability to quickly update situational awareness, including locating high-value mobile targets and destroying them before they can relocate. A reusable hypersonic strike aircraft could effectively turn conventional air-to-ground bombs and missiles into hypersonic weapons by carrying them past enemy air defence networks and deploying them at ranges close to the target. The aircraft will also be able to react more flexibly if a programmed target has moved. Additionally, a hypersonic aircraft will be much better-suited than conventional supersonic aircraft to evade enemy air defence missiles. Hypersonic aircraft would also have several advantages vis hypersonic missiles (including cruise missiles). The greatest advantage is the fact that they will, under most circumstances, return to base after a mission. Commanders will retain the asset more-or-less indefinitely (minus battlefield attrition), permitting multiple sorties per unit. In addition to improved readiness, a reusable aircraft would be considerably more cost-efficient than single-use hypersonic missiles. A 2021 Pentagon study found that the hypersonic missiles being developed for the Navy and Army could cost between USD 89.6 M and USD 106 M each, as much or more than an F-35 fighter aircraft; a 2023 report by the Congressional Budget Office assumes a unit cost of only USD 41 M, still a significant figure. This cost factor will limit availability. For example, the US Navy and Army together are planning to acquire only 300 hypersonic glide vehicle (HGV) weapons under their respective Conventional Prompt Strike and Long Range Hypersonic Weapon programs (even at USD 41 M per unit, this 300 missile tranche would cost as much as a Ford class aircraft carrier – which is capable of launching 300 sorties per day).

Credit: Sidney E. Dean (created with Bing Image Creator)

AI generated concept of a hypersonic strike aircraft launching a missile.

Credit: Lockheed Martin

Concept image of the SR-72, another hypersonic unmanned strike aircraft project being pursued by the US Air Force. Dimensions are expected to approximate those of the manned SR-71.

Capabilities Profile

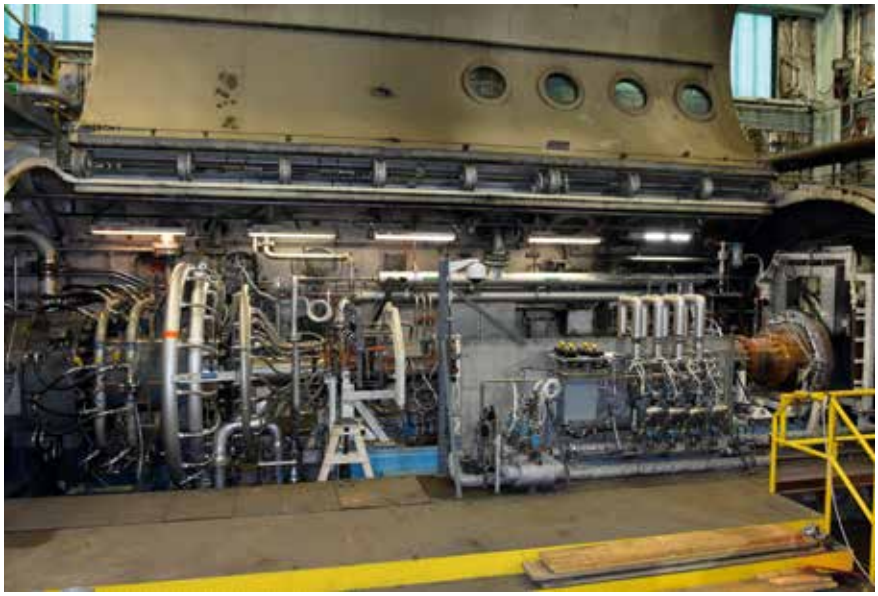
Many details of the Mayhem program remain classified. The new system will be a large-class version that surpasses current developmental hypersonic systems in range and payload capacity. Mayhem's technology will increase USAF's ability to attack more distant or highly defended tactical targets, especially when they are time critical. The Air Force has also clearly stated that the objective aircraft will be unmanned, and (as a hypersonic system) be capable of a minimum Mach 5 airspeed. Some unofficial sources estimate airspeeds up to Mach 10.

A request for information (RFI) published by the Air Force on 14 December 2021 publicly revealed details which would indicate the objective capabilities pro-

Credit: Hermeus

The Chimera TBCC demonstrated transition from turbojet to ramjet propulsion mode in November 2022 in a testbed simulating high-Mach temperatures and pressures.

Credit: USAF



The Aerodynamic and Propulsion Test Unit at Arnold Air Force Base supports AFRL testing of scramjet technology necessary for developing airbreathing hypersonic systems.

file and concept of operations. Previous RFI's had already mentioned the need for a modular payload bay capable of accommodating a trio of payloads. The 14 December 2021 notice specified three distinct payload types needed to accomplish "three key mission goals": an "area effect payload," a "large unitary payload" and a "responsive" ISR payload. "The system goal is to carry payloads five times the mass and double the range of current technology capability systems," the RFI stated. Although this data was specifically designated as "Controlled Unclassified Information," a new RFI was published only three days later – on 17 December 2021 – omitting these details.

Propulsion Challenge

In order to achieve the anticipated speed and range objectives, Mayhem will most likely need to employ a scramjet engine as the primary propulsion system. Unlike conventional jet engines, which use internal fan blades to compress inflowing air before mixing it with fuel and igniting it, scramjets utilise the natural compression which occurs when air enters the engine at very high speeds, typically Mach 3 or higher. This enables them to achieve sustained hypersonic flight at significant range. Since the scramjet engine will normally not function properly at airspeeds below Mach 3, the aircraft is likely to require a combined-cycle propulsion system. This would combine a conventional high-performance jet or ramjet engine and a scramjet engine. In such a scenario, the conventional engine would be used to take off and to accelerate to supersonic speeds. When the plane meets the Mach 3 or higher range, the scramjet engine would fire up and accelerate to hypersonic speeds. The conventional engine would come into play again for controlled landing at the end of a mission.

Such technology is currently being pursued by the Department of Defense (DoD) as well as the aerospace industry. Creating a combined-cycle engine is considered a significant technological challenge. Even pure scramjets have yet to be fully developed. A successful free flight test of a US scramjet engine took place in 2021 as part of the DoD's Hypersonic Attack Weapon Concept (HAWC) cruise missile program. Mayhem is expected to directly benefit from the hypersonic cruise missile research, but integrating conventional and scramjet engines faces the difficulty of not blocking airflow to the scramjet engine and also keeping weight within acceptable parameters. Lockheed Martin is known to have been researching this technology as part of the SR-72 program, which predates Project Mayhem, and also aspires to developing a hypersonic strike aircraft concept. However, to date no firm or agency has publicly acknowledged success in devising a combined-cycle engine.

Although the focus remains on scramjet technology, there may be an alternative based on more mature technology. While it has not been publicly mentioned in connection with Project Mayhem, the firm Hermeus is developing a non-scramjet propulsion system capable of achieving hypersonic speed. Chimera is a turbine-based combined cycle engine (TBCC) which has been described as a hybrid between a turbojet and a ramjet. The transition to ramjet propulsion occurs between Mach 2 and Mach 3. Hermeus hopes to achieve sustained speeds of Mach 5 with the Chimera engine, and apply the technology to both civilian and military aircraft. The firm plans to utilise the TBCC on the Darkhorse unmanned aircraft demonstrator which it hopes to fly in 2025. The Darkhorse, which Hermeus is specifically designing for military and intelligence applications, is expected to achieve Mach 5.

Contract Status

The contracting and lead development agency for the government is the Air Force Research Laboratory (AFRL). The competition for the system's development contract was launched in March 2022 with publication of a broad agency announcement soliciting industry offers; given the sensitive nature of the project, the statement of objectives and the proposal requirements were only provided to industry on request. As defined by the Air Force, the development program is focussed on delivering a "larger class air-breathing hypersonic system capable of executing multiple missions with a standardised payload interface, providing a significant technological advancement and future capability."

The government received six industry offers. On 16 December 2022, AFRL awarded Leidos Inc. an indefinite-delivery/indefinite-quantity, cost-plus-fixed-fee development contract for the Mayhem program. The award has a USD 334 M ceiling, and encompasses a 51 month period of performance, including a 45 month ordering period. The 51 month period of performance is divided into several phases. According to Leidos, the initial task order is valued at USD 24 M to conduct the System Requirements Review (SRR) and Conceptual Design Review (CoDR) in a Digital Engineering (DE) environment. This section of the project has a 15 month period of performance, divided into 12 months for technical effort and three months for completing the final reports.

Leidos has in fact stated that it will apply digital engineering (DE) and model-based systems engineering (MSBE) throughout the design and development program, including the initial concept testing phase. This fits the recent trend in digital design and testing which is increasingly favoured by the Pentagon, as it can significantly shorten development timelines while reducing cost when compared to traditional design and development methods. The three firms, together with Leidos, will form the System Design Agent (SDA). The SDA will be responsible for design efforts, prototyping and testing under the current contract, with the ultimate goal of producing and delivering a technical data package for high-performance hypersonic weapon systems. According to the AFRL's series of RFIs as well as the corporate press releases, this package will encompass the entire integrated and functional vehicle system, to include an airframe, propulsion system, booster, avionics and vehicle subsystems. Work is to be performed at Wright-Patterson Air Force Base, Ohio, and other potential testing sites to be determined by the government. Work under the December 2022 contract is expected to be completed by 15 October 2028. ■

DEW in the Air

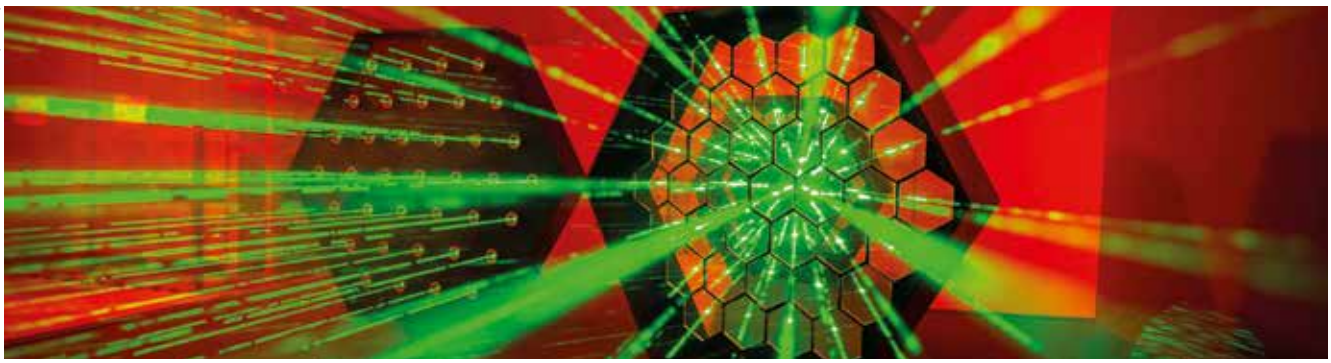
Tim Guest

Once the stuff of science fiction, directed energy weapons (DEWs) are now becoming a reality, as research, development, trials and funding advance their progress towards maturation for fielding on land, at sea and in the air.

A type of electromagnetic (EM), or particle technology, which uses energy, as opposed to a solid projectile, to strike a target, DEWs have been under development for many decades. Defence establishments and government agencies around the globe have been considering the potential for these systems to transform strategic and tactical approaches on the field of battle and how they might offer new options to counter emerging threats. However, despite early enthusiasm and research around the technology, progress has faced many technical and operational challenges. Nevertheless, the increasing electrification of the battlespace and tech advances are just some of the factors giving greater impetus to DEW efforts, although current approaches to military systems power specification, generation and delivery still need radical change, otherwise these systems may continue to be held back. That said, being able to disrupt, degrade, or damage a target by emitting highly focused EM energy, either in the form of a beam laser light, concentrated radio frequency (RF), microwaves, or using other directed energy, means such systems could have multiple applications on the battlefield, from airborne platform protection to ground-based air defence, including, just as one critical example, to defeat swarming attack drones.

For the defence industry, several leading defence companies such as Lockheed Martin, Raytheon, MBDA, Rheinmetall, Thales, QinetiQ, to name just a few alongside many others, have been working in the field of directed energy systems and weapons for decades and have been working closely with partners and national defence establishments. Systems have been trialled, and projects have come and gone. Rather than looking back, however, this article takes a look at some of the current thought, research and operational thinking around DEWs, as well as at recent developments for their application in the airborne environment.

Credit: QinetiQ



Directed energy weapons have been under development for many decades and have the potential to transform strategic and tactical approaches on the field of battle.

Technology Scene Setting

A catch-all term that encompasses several different complex tech under one umbrella, directed energy weapon technologies are at different levels of maturity, each with its own important distinctions from the others. Fundamentally, three main systems fall under the DEW term. The first, High Energy Laser (HEL)-based systems, includes different types of lasers, with chemical, solid-state and free-electron lasers the most relevant. While invented back in the 1960s, the main obstacle to the development and uptake of laser weapons has been the energy required to power them, which is where the greater electrification of the battlespace may play its part in changing this. Of the different laser types, chemical lasers are the most mature, but suffer from a number of impracticalities, not least of which is their use of hazardous substances. Safer in this regard, the laser weapon systems starting to be fielded are solid-state, or fibre lasers (being advanced by AFRL, see below), while the third kind, free-electron lasers, are the most recent discovery, and the least-developed for weapon use as a result.

The second kind of technology falling under the DEW term is based on the use of focused radio frequency (RF) waves, including high-powered microwaves (HPM). Widely used in high-powered mobile and telecommunications networks, this technology is more mature than laser-based systems and is already operational.

Lastly, particle beam systems – the least mature tech of the three – unlike the others, fire atomic and sub-atomic particles at a target, either as charged or neutral particles. The latter holds particular interest for space-based systems as they can be used outside the atmosphere.

Applying the Tech

As for which technology to apply to which defence application, that's based not only on technological challenges, but also on the different effects each has on a target and whether a lethal or non-lethal effect is required. HELs and particle beam systems, for example, can disrupt and destroy equipment, whereas the effects of low-power lasers on equipment such as optoelectronic

sensors, including those on satellites, as well as pilot vision is simply to dazzle the target and to achieve a desired result in that non-lethal fashion. High-power microwaves can also degrade and damage electronics, command post computer and communications systems and have also been effective against UAV platforms. As for millimetre waves, these have been tested as anti-personnel area denial weapons, where they create burning, though non-lethal, sensations on the skin.

Given their low operational cost per shot, (each of which travels much faster than rounds from conventional weapon systems

Credit: US AFRL

The AFRL is working on high-power microwave weapons which enable a variety of low-collateral-damage military applications.

and remains unaffected by gravity 'during flight'), as well as their ability to launch silent and invisible (to the naked eye) attacks, DEWs are an increasingly attractive prospect for military inventories. Trying to locate the source from which a DEW attack has come, such as an RF attack using high-powered microwaves, for example, can be difficult without specialised equipment. Such RF tech may be that behind 'Havana syndrome' – tied to relatively recent documented 'events' at overseas US diplomatic missions, when numerous diplomats and staff became ill with lasting neurological and audiological symptoms, due likely to an unidentified directed energy weapon system.

Yet, DEWs are not without their operational limitations. The effect of a high-power laser on a target, for example, is not an immediate one, as would be the case using a conventional weapon; a laser effect is cumulative, its energy on target requiring several seconds before damage and/or destruction occurs. And while a conventional artillery round, for instance, will be affected to some degree by weather conditions, they can still fire and hit a target under such conditions, whereas the impact of rain, cloud or fog on a laser will be to attenuate the beam to the point where it cannot be used. The system needs line of sight and if the target is obscured a laser will be unable to see its target. RF systems, too, can be affected by weather conditions. Powering such systems remains a challenge. Power constraints mean that the highest-power DEWs are most suited for mounting on ships, and their employment of land vehicles typically involves some level of compromise. For effective deployment of such weapon systems, regardless of size, a revolution in the way energy is stored and delivered is needed; compact, ultra-high-power batteries are just one of the needs that will help ensure the right amount of power is delivered to a laser, for example, where and when it's needed.

Air Force Research Lab

At this time, whereas particle-beam weapons are merely a distant, future prospect, it is the low-powered lasers and radio frequency-based systems, which are much more frequently used in the field. HELs have now reaching the levels of technological maturity they need for operational use on land, sea or air platforms, including for airborne applications. Indeed, the US Air Force Research Laboratory (AFRL) underscores how laser weapons, in general, already offer operatives unique opportunities for quick and precise target engagement, highlighting such laser capabilities such as speed-of-light delivery, multiple target engagements and rapid retargeting, deep 'magazines', their exceptional accuracy and adjustability, lower logistical support requirements and low incremental cost per shot, as some of their outstanding properties. For its part, the AFRL is one of those establishments alluded to above that is working with the USAF and other DoD partners and industry to bring high energy laser weapons to the field. The lab is rapidly maturing fibre-laser-beam combining capabilities, where larger numbers of fibre laser amplifiers are combined into a single beam; it has made significant progress in this regard, increasing the output power of individual fibre laser amplifiers. Through beam combining, single amplifier improvements result in enormous power scaling and AFRL is actively transitioning this and other key technology elements to strategic DoD entities and prime contractors for use in advanced technology demonstrations, including for airborne DEW/laser weapon system (LWS) applications.

The AFRL is also working on high-power microwaves which it sees as offering the military innovative technologies that enable a variety of low-collateral-damage military applications, including enabling

Credit: Lockheed Martin

The drone threat is challenging and rapidly evolving - defensive systems must evolve even faster to combat this threat. Lockheed Martin has worked with multiple services to rapidly develop and prove a key Counter-Unmanned Aerial System capability: MORFI-US, which is a reusable, multi-engagement, loitering, tube-launched interceptor equipped with an onboard seeker and a compact, high-power microwave effector to execute non-kinetic defeat of drones, including complex swarms.

users to achieve counter-electronic effects, to counter improvised explosive devices, and also to counter weapons of mass destruction. The AFRL believes that in the not-too-distant future, focused beams of microwave energy will be used defensively to protect planes and ships against incoming missiles, and offensively to attack militarily important electronic targets, including from the air aboard UAVs and other airborne platforms. These beams will emanate from sophisticated compact devices that convert a modest quantity of stored electrical energy into high-power bursts that have the capacity to penetrate structures and disrupt delicate electronic devices that reside within. This vision of modern directed energy warfare is enabled by revolutionary high-power electromagnet (HPEM) advances made in the recent past and by additional, anticipated advances.

Industry Snapshot

While many leading players, as mentioned above, are active in this space, one industry player we'll look at briefly here with airborne projects underway, is Lockheed Martin, which is currently undertaking its Tactical Airborne Laser Weapon System (TALWS) programme. This is aimed at developing mature and producible tactical airborne laser weapon solutions, which complement kinetic defences to protect land, sea, and aerial assets. With over 40 years of R&D experience in this field, including with beam-control tech, its cur-

Credit: Lockheed Martin

At Lockheed Martin, work is underway on a tactical airborne laser pod that supports a rapid transition to production and deployment.

rent developments 'under contract' today can defeat small rockets, UAVs, small attack boats, and lightweight ground vehicles. Yet it's with the US Government that the company is a core member of the industry team for the USAF's Self-Protect High Energy Laser Demonstrator (SHiELD) system, developing critical components of an airborne laser pod, including the high-energy laser and other sub-systems that will be demonstrated ahead of a programme of record in the mid-2020s. This is alongside its land and sea-based programmes.

As part of the company's research for both SHiELD and other projects, it's working with partners, DoD and government establishments to develop producible, low-cost, tactical beam directors -- the optical system that puts high-energy light on-target and keeps it there with high precision to ensure the desired target effect is achieved and the threat defeated. The DoD's investment in acquisition and tracking technologies over the years is contributing here to the development of LWS-specific algorithms that enable the beam director to detect, identify, track and defeat threats. While it will be adapted for both airborne and maritime applications, the current stage of beam director development, comprising a gimballed beam director assembly and an acquisition and tracking system, will first be demonstrated in a ground application for the US Army. Maturation of these beam director lab developments for use in the field is something Lockheed Martin is striving to achieve so full-rate production can take place as soon as possible.

In the meantime, development work is underway on an airborne laser pod solution that supports a rapid transition to production and deployment—and ultimately, a transition to embedded systems. Some critical components, for example, such as optics that can handle high-energy laser beams, have only been built in very small quantities for prototypes and so capital investment in expansions to produce such components for the airborne pods at full production rates and at lower cost, are underway, to ensure the USAF receives its tactical airborne laser pods when required.

In another project, in October of 2021, the company delivered its Airborne High Energy Laser (AHEL) to the USAF for flight testing on an AC-130J aircraft. This followed successful completion of factory acceptance testing for the AHEL in preparation for US military ground and flight testing of the system and follows on from the January 2019 contract award to the company for integration, test and demonstration of the laser weapon system aboard the AC-130J. The programme is now on a rapid schedule to continue testing this capability. VP Lockheed Martin Advanced Product Solutions, Rick Cordaro, said at the time that the company's partnership with the USAF was rapidly achieving important advances in laser weapon system development, demonstrated by the field-test-ready system at that time. The company is also now halfway through a cost-plus-fixed fee, indefinite-delivery, five-year contract award, (awarded mid-July 2021), for technical services, integration, test, and demonstration for the AHEL system for the USN's Naval Surface Warfare Centre, Dahlgren Division.

DoD Airborne Laser Interest for BMD

In the area of ballistic missile defence (BMD) the US DoD's latest Missile Defence Review (MDR) noted the importance and potential for laser weapon systems to play a part in BMD.

The review noted that the interception of offensive missiles in their boost phase, (i.e. before the re-entry vehicle separates from the booster), using kinetic interceptors and/or directed energy would increase the likelihood of successfully countering a threat by reducing the number of mid-course or terminal active defence interceptors needed to destroy an adversary's remaining offensive missiles. It would also help complicate an aggressor's attack calculus by reducing its confidence in its missile attack planning and likelihood of success.

The DoD's MDR also stated that developing scalable, efficient, and compact HEL technology and integrating it onto an airborne platform holds the potential to provide a future, cost-effective capability to destroy boosting missiles even in the early part of their trajectory, which is the most difficult phase of flight (due to both distance and the short time window for reaction), in which to take down a ballistic missile. Doing so would leverage technological advances made previously in the DoD's Airborne Laser Programme, including, for example, advances in beam propagation and beam control. The Missile Defence Agency (MDA) is developing a low-power laser demonstrator to evaluate the technologies necessary for mounting a laser on an unmanned airborne platform to track and destroy missiles in their boost-phase. The DoD has a strategic roadmap for the development and fielding of directed energy weapons and key enabling capabilities aimed at informing high-energy laser investments in the future. ■

Aerial Refuelling Options in North America and Europe

Sidney E. Dean

Armed forces in North America and Europe are seeking to upgrade their aerial refuelling capacity. Currently two options dominate the market.

Aerial refuelling is essential for long-range combat missions and for long distance transport flights, especially when there is limited capacity for intermediate landing. This has long been a major priority for the US armed forces, given their global commitments and the vast distances their aircraft need to cover in peacetime and in war. European nations have increasingly discovered the value of aerial refuelling as they have accepted out-of-area commitments and recognised the need for greater power-projection capabilities. Even operations in peripheral regions require this capacity, especially when tactical strike aircraft are involved, as they discovered during the 2011 air campaign over Libya.

Roughly a dozen different types of refuelling aircraft are in service in the various European nations, with another four dedicated refuelling types active with the US armed forces. In addition to dedicated refuellers, numerous large and medium transport aircraft models and even combat aircraft can be outfitted with tanker modules enabling them to serve as ad hoc refuellers on demand. However, currently only two large, dedicated refuelling aircraft models are in production, one each in Europe and the United States.

Credit: Singapore MoD

Transferring fuel between two Royal Singapore Air Force A330 MRTT aircraft.

Airbus A330 MRTT

Figures published in March 2023 by the Center for Strategic & International Studies (CSIS) in Washington show that, while the European NATO partners currently own circa 160 aircraft capable of aerial refuelling operations, only a quarter of these are dedicated refuelling aircraft. The long-range refuelling capability of the European NATO partners is steadily improving through ongoing procurement of the A330 MRTT (Multi-Role Tanker Transport); 30 aircraft are currently operational in Europe, with another 10 on order. In addition to national armed forces, operators include the NATO Multinational Multirole Unit (MMU) which is actively supported by six European members of the alliance. Additional units serve with the armed forces of several Middle Eastern and Asia-Pacific nations. The Royal Australian Air Force was the first service to introduce the A300 MRTT (under the designation KC-130A) in 2011, followed by the British RAF (as the Voyager) in 2012.

The twin-engine A330 MRTT is based on the commercial Airbus A330-200. The MRTT designator reflects the fact that the wide-body plane – like other major tanker aircraft – retains the capacity to transport cargo and/or passengers, including medical evacuation (medevac) personnel across intercontinental distances. The total payload capacity is 45 tonnes, including the passenger deck and the lower (cargo) deck. The 120 m3 cargo deck itself can accommodate up to 37 tonnes, including either 27 LD3 containers or eight military pallets, as well as bulk cargo. For personnel transport, the A330MRTT can seat – depending on configuration – up to 300 passengers. In the medevac configuration the plane can accommodate 40 stretchers and 100 seated passengers (plus 20 medical staff) or up to 130 stretchers in bunk-bed configuration; alternately, the passenger deck can be outfitted with six intensive care stations while accommodating 47 seated patients and another 16 on litters.

The A330 MRTT can refuel all classes of fighter, transport, and surveillance aircraft in NATO service. For this mission, the A330 MRTT has a fuel capacity of 111,000 kg, the highest capacity of all operational tanker models. According to Airbus the plane can offload 50,000 kg of fuel to a broad range of aircraft during a four-hour loitering mission at over 1,000 NM (1,852 km) from its take-off point. In addition to operational refuelling missions the tanker can support four fighter aircraft on a 2,800 NM (5,185.6 km) ferry flight to a distant operating zone – approximately the distance from Athens to Kabul or Rome to Addis Ababa.

Refuelling operations are controlled via the onboard refuelling console which is located in the cockpit. Stationing the boom operator here enhances safety by allowing the flight crew to react immediately to unexpected developments. The digital high-definition 2D/3D Enhanced Vision System which feeds into the boom operator's console supports both day and night refuelling and provides high resolution video recording of the refuelling operation.

Credit: Airbus Defence and Space/Martin Agüera

The A330 MRTT in the Medevac configuration.

The aircraft can deploy either a tail-boom system or a wing mounted probe and drogue system, depending on the aircraft to be serviced. Airbus Military's Aerial Refuelling Boom System (ARBS) supplies receptacle equipped aircraft, including most US-designed fighters; the fuel transfer rate via the ARBS is 3,600 kg per minute. The ARBS can also be used to transfer excess fuel to another A330 MRTT via a Universal Aerial Refuelling Receptacle Slipway Installation (UARRSI) mounted atop the receiving aircraft. Cobham 905E pods can be attached under each wing for drogue and probe refuelling, which accommodates most European designed fighters as well as the F/A-18. The fuel transfer rate is 1,300 kg per minute per fuel pod. Additionally, a removable Cobham 805E Fuselage Refuelling Unit (FRU) can be mounted centreline beneath the stern to permit drogue and probe refuelling of transport aircraft such as the A400M or C295, which require a different fuel than the fighter aircraft. The FRU's transfer rate is 1,800 kg per minute.

Since the A330 MRTT's introduction Airbus has continued to upgrade the technology and the design to ensure state-of-the-art status. In 2020 Airbus teamed with the Republic of Singapore Air Force (RSAF) to develop the A330 SMART MRTT. According to Airbus, the new design will be the world's first to integrate a fully Automatic Air-to-Air Refuelling (A3R) capability. It will also provide an enhanced vision system for night-time covert operations. Prototype testing is ongoing in Singapore.

Boeing KC-46A

The United States Air Force (USAF) is currently replacing its legacy tanker aircraft through a three-phase cycle initiated in 2006. Since the program's inception the three phases have been designated KC-X, KC-Y and KC-Z. The KC-X phase was to represent extant technology and provide a readily available solution to replacing the oldest active tankers. KC-Y was conceived as a "bridge tanker" with some advanced technologies, paving the way for a revolutionary next generation KC-Z. In 2008 USAF selected the KC-45A (a derivative of the Airbus A330 MRTT, which was jointly offered by then EADS (now Airbus) and Northrop Grumman) as the winner of the KC-X competition. Following Boeing's protest the competition was repeated. In 2011, Boeing won the contract to supply up to 179 KC-46A Pegasus aircraft.

The twin-engine KC-46A is derived from Boeing's civilian 767 airframe. In the transport role, the plane has a maximum payload capacity of 29.5 tonnes (including up to 18× 463L pallets) or up to 114 passengers. In the medevac configuration the Pegasus accommodates 30 ambulatory and 24 litter patients, plus up to six intensive care stations. The aircraft can be converted between the three transport missions – cargo, personnel or medevac – within two hours. In addition to the tanker and transport missions, the KC-46A is designed to serve as a communications node, using the integrated data links and Advanced Battle Management System to provide tactical situational awareness to combat aircraft.

The KC-46A has a fuel payload capacity of 97,000 kg to serve US, allied and coalition forces. The aircraft is equipped with a refuelling boom for receptacle equipped aircraft; the boom is a modernised variant of the system used on the KC-10 tanker. The Pegasus also has a permanent centreline drogue system for probe-equipped fighters. Additionally, two Wing Aerial Refuelling Pods or WARPs can be carried to permit drogue refuelling, servicing two fighter aircraft at the same time. Transfer rate is 4,500 kg per minute via the tail boom and 1,500 kg per minute via either drogue system.

Unlike on earlier USAF tankers, the KC-26A's boom operators are not seated aft; instead, the two-seat Aerial Refueler Operating Station (AROS) is located at the front of the aircraft. The refuelling process is conducted via fly-by-wire controls, guided by imagery and flight data provided via three displays on the AROS console. The imagery is provided via the Collins Aerospace high resolution Remote Vision System (RVS) which operates a number of externally

Credit: Boeing

A KC-46A deploying the hose and drogue basket from one underwing refuelling pod.

Credit: USAF

Personnel at the Aerial Refueler Operating Station (AROS) need special stereoscopic glasses to view the 3D images on their displays.

cameras and sensors designed to provide a 185° stereoscopic view of the airspace below and aft of the plane.

Delayed Evolution

Unfortunately the RVS, in its original configuration, was seriously flawed. It reacted poorly to lighting changes, and tended to relay distorted images which misrepresented distances. The USAF deemed this as a category 1 deficiency. A revised RVS design was finally accepted in mid-2022. This RSV 2.0 system has two pairs of 4K ultra-high definition 3D colour day cameras and two improved infrared cameras, as well as redesigned image processors and panoramic sensors. However, supply chain issues are expected to delay serial production until October 2025.

RVS was not the KC-46A's only issue. Technical problems surrounding the plane's design and major subsystems delayed delivery of the first units to USAF by over a year, to early 2019. As recently as March 2023, Boeing announced that ongoing deliveries were being delayed over a supplier quality control issue related to the plane's centreline fuel tank. To date delays, refitting and re-design measures have cost Boeing a cumulative USD 7 Bn; the firm is locked into a fixed-price development contract and therefore responsible for all expenses above the original award's USD 4.9 bn cost ceiling.

Overall, however, Boeing and the Air Force agree that the new plane has weathered the worst of its problems. The 68 airframes currently in service with USAF conduct an average of 400 missions monthly. In 2022 the KC-46A made first deployments to the Indo-Pacific and Middle Eastern regions. The first 'real-world' operation was recorded in August 2022 with the refuelling of F-15Es on patrol in the US Central Command (CENTCOM) area of responsibility. The Pegasus is now officially authorised to conduct worldwide refuelling of every US military fixed-wing aircraft except the A-10; seven international aircraft types have also been cleared for refuelling. However, the KC-46A is not expected to achieve formal initial operational capability (IOC) until installation of the RVS begins in 2025. Deliveries under the KC-X contract are expected to be completed in 2029.

Credit: Boeing

For the NGAS program, USAF is open to a blended wing design. Advantages over conventional airframes include: better aerodynamics; reduced radar signature; greater fuel efficiency; much larger internal fuel payload capacity.

Moving Forward – Next Generation Air-Refuelling System (NGAS)

This notwithstanding, USAF is currently planning the next two acquisition phases. With the Pegasus approaching maturity, USAF is leaning toward skipping the recompete for the KC-Y procurement phase, stated USAF acquisition chief Andrew Hunter on 7 March 2023. Recent Pentagon analyses predict that neither Boeing nor Lockheed Martin could develop an advanced-capability derivative of an existing airframe before the 2032-2034 timeframe, leaving a multi-year procurement gap between KC-X and KC-Y. USAF plans to decide in mid-2023 whether or not to compete the KC-Y contract, Hunter said. Many observers now expect the Pentagon to award Boeing a non-competitive contract for another 75 Pegasus tankers.

Looking forward, the Pentagon has changed the third tanker production phase's designation from KC-Z to NGAS (Next Generation Air-refueling System). The Air force launched initial capabilities studies in January 2023, including a Request for Information (RFI) posted online on 31 January. The analysis of alternatives is set to begin in October 2023, based on the proposals received from industry. According to Andrew Hunter, the USAF is planning a full and open competition for a clean-sheet high performance tanker capable of operating in a contested environment. Hunter cited the goal of acquiring an initial increment in the mid-2030s, several years earlier than the 2040 timeframe mentioned in the RFI. Both Boeing and Lockheed Martin (working in partnership with Airbus) have announced plans to compete. In this context Lockheed Martin has already proposed to base its NGAS design on the LMXT, a further derivative of the A330 MRTT. Larry Gallogly, Lockheed's LMXT campaign director, stated in early March 2023 that his team could potentially deliver NGAS capabilities by 2031, by working from the LMXT design. Whether this would be sufficiently innovative remains to be seen. Air Force Secretary Frank Kendall stated in January 2023 that the increased long-range threats to aircraft being devised by potential opponents could preclude a design based on a commercial airframe. "They're not designed with a high set of requirements for survivability, for resilience. The threat's taking that freedom away from us," stated Kendall. ■

Provided below is a table summarising current aerial tanker procurements in progress:

Current Long-Range Aerial Tanker Procurement Programs (As of 31 March 2023)

Operator	Aircraft	Goal	Delivered
USA	KC-46A	179 (+ 75?)	68
Japan	KC-46A	6	2
Israel	KC-46A	4	0
France	A330 MRTT	13	9
Spain	A330 MRTT	3	0
UK	A330 MRTT	14	14
NATO MMU	A330 MRTT	10	7
Saudi Arabia	A330 MRTT	6	6
UAE	A330 MRTT	5	3
Australia	A330 MRTT	7	7
Singapore	A330 MRTT	6	6
South Korea	A330 MRTT	4	4

Sources: Airbus, Boeing

LGM-35A Sentinel: Aiming for 2030 Debut

Sidney E. Dean

The US Air Force (USAF) is developing the LGM-35A Sentinel ICBM (formerly known as Ground-Based Strategic Deterrent) to replace its Minuteman III arsenal and retain a viable ground-based nuclear deterrent into the mid and late 21st century.

The US armed forces have maintained a nuclear triad – consisting of land-, sea- and air-launched weapons, since the 1960s. In recent years some politicians and strategists have advocated eliminating the land-based component. These critics argue that silo-based Inter-Continental Ballistic Missiles (ICBM) are too vulnerable to pre-emptive strikes, and too predictable in their flight path when compared to strategic missile submarines or strategic bombers. However, the Obama Administration's 2010 Nuclear Posture Review (NPR) reaffirmed the value of the triad concept to ensure a survivable nuclear strike capability and to hedge against adversaries developing defences against any individual strategic weapon system. Subsequent administrations have agreed regarding the need to retain a three-legged nuclear deterrent. The Biden administration's 2022 NPR concluded that reducing or eliminating the ICBM arsenal would increase risk.

The current US land-based nuclear force consists of 400 deployed Minuteman III ICBMs. Each missile carries a single nuclear warhead. The weapons are operated by the USAF and are dispersed across three bases in the western United States. The Minuteman III was introduced in 1970 and is approaching the end of its service life. Several upgrade programs have extended the system's viability through 2030, but a replacement is due soon.

Credit: Northrop Grumman

Artist rendering of Sentinel missile

Credit: Northrop Grumman

Artist rendering of future Sentinel Launch Facility (above ground view).

GBSD Programme

The Ground Based Strategic Deterrent (GBSD) programme (now more commonly known as 'Sentinel') will replace the entire Minuteman III inventory with a new missile design, as well as updating or replacing the existing launch silos and ground infrastructure, including the ground launch control facilities. The new missile system was officially designated the LGM-35A Sentinel in April 2022. The designator breaks down into "L" for silo-Launched, "G" for surface (or Ground) attack, and "M" for Missile.

The USD 96 Bn GBSD program was initiated in 2016 with a Request for Proposals issued by the Air Force Nuclear Weapons Center. Boeing and Northrop Grumman entered bids, and both received three-year preliminary design/technology maturation and risk reduction contracts in 2017. However, Boeing withdrew from the competition in 2019.

The contract for the GBSD's engineering and manufacturing development (EMD) phase was awarded to Northrop Grumman in September 2020, following a successful Preliminary Design Review (PDR) in April of that year. The firm opened a USD 1.4 Bn facility in Colorado Springs to pursue this and other strategic development programs. The prime contractor is working with approximately a dozen partners including: Aerojet Rocketdyne (solid rocket motor, stage 3

and post-boost propulsion system); Bechtel Corporation (launch system infrastructure); Collins Aerospace (command and control and training systems); General Dynamics (command and control systems, digital engineering environment, aerospace vehicle equipment); Honeywell (guidance and control instruments, booster control); and Textron Systems (reentry system).

LGM-35A Sentinel

The LGM-35A will feature a modular design and open architecture that will simplify insertion of new technology (both hardware and software) over its service life, ensuring that the weapon system can adapt to changing threat environments as well as incorporate performance enhancing innovations. Maintenance is also expected to be streamlined. Another benefit of the open architecture approach is that the government will be able to control the intellectual property of the system, including source codes. This will enable to Air Force to bring additional vendors into the production and maintenance cycle, rather than tying the service to a single firm. Such flexibility is considered a powerful tool to control cost, while enabling the military to access the best technologies or services available at any point in time.

Like the Minuteman III, Sentinel will be a silo-based weapon system consisting of a three-stage booster rocket topped by a shrouded reentry vehicle carrying the nuclear payload. The first two stages of the booster rocket will be built by Northrop Grumman. The third stage is being supplied by Aerojet Rocketdyne.

In contrast to the Minuteman III, which uses steel casings to house the missile propellant, the LGM-35A booster segments will be built from much lighter composite materials while maintaining or improving thrust capacity. This improved thrust-to-weight ratio will increase the missile's throw weight (the payload weight which can be delivered at any given range) or payload weight capacity. The improved throw weight creates several options regarding future payload configurations or mission profiles. Among other benefits, it would permit the missile to carry countermeasures to overcome missile defence measures which adversaries may introduce in the future; this would likely include electronic countermeasures to overcome enemy electronic warfare and cyberwarfare capabilities developed to interfere with targeting.

Credit: Northrop Grumman

Artist rendering of future Sentinel Launch Facility built over a reclaimed Minuteman III facility (above and below ground). The missile silo and silo cover are presented in the centre of the picture.

Warhead

A new warhead designated the W87-1 is being developed for the GBSD program by the US Energy Department's National Nuclear Security Administration (NNSA). It is based on the 300 kiloton-yield W87-0 warhead developed in the 1980s and retrofitted onto Minuteman III missiles beginning in 2007. The precise yield of the W87-1 has not been revealed, but the basic W87 design is capable of being upgraded to 475 kilotons.

The new warhead design passed the PDR in 2020. The engineering development phase for the W87-1 commenced in 2022. It is expected to enter production in 2030. One challenge to this goal is the fact that the United States ceased manufacturing plutonium pits in 1989. These hollow spheres form the weapon's radioactive core; when compressed upon initial detonation they achieve critical mass, unleashing the destructive nuclear chain reaction. Plutonium pits deteriorate over time, and must ultimately be replaced. To ensure sufficient supply for production of the W87-1 and other developmental nuclear warheads, the NNSA is building a new uranium processing facility. The Energy Department plans to produce 80 new plutonium pits per year by 2030. However, according to Congressman Seth Moulton who sits on the House Armed Services Committee, the new NNSA facility is currently "up to two years" behind schedule. Plutonium pit production at the rate required by the Department of Defense (DoD) will not be achieved "until the mid- to late-2030s," Moulton said during a 28 March 2023 hearing, casting doubt on the ability to field the W87-1 on schedule.

Credit: Northrop Grumman

Artist rendering of future Sentinel Missile Silo (top down view).

Reentry Vehicle

The W87-1 will be mounted on the Mk21A reentry vehicle currently being developed by Lockheed Martin under a non-competitive 2019 award. The period of performance for the Technology and Risk Reduction contract runs from 2020 through 2024. The Mk21A passed the preliminary de-

Credit: Northrop Grumman

Sentinel solid rocket motor casting is a complex process of pouring rocket motor propellant into motor cases.

Credit: Northrop Grumman

Northrop Grumman performs the case wind process for the first-stage solid rocket motor, applying composite material to form the outer shell of the motor.

sign review in March 2021. However, the first of two scheduled flight tests of the new reentry vehicle failed in July 2022 when the Minotaur II booster rocket being used exploded only 11 seconds after launch. The next prototype test launch is scheduled for later in 2023, to be followed by award of the Engineering Manufacturing and Development (EMD) contract and the Production and Deployment (P&D) contract. The Air Force Nuclear Weapons Center procurement office has stated the period of performance for both contracts is expected to run through 2036. The Mk21A is expected to enter service in 2030.

The Pentagon is simultaneously planning to develop a more advanced reentry vehicle designated the Next Generation Reentry Vehicle (NGRV). The NRGV would be capable of accommodating both current and future warheads. In March 2023 the Air Force requested USD 15.5 M in funding to begin research in FY 2024; a corresponding Request for Information (RfI) to industry was published in April 2023. USAF hopes to award a development contract in FY 2026. Details of the NGRV remain classified, although the Pentagon has said the new RV must display enhanced survivability, accuracy and lethality. The 2024 budget documents also state that "future NGRV solutions… will include acquisition of complementary countermeasures." While the military declined to comment, many defence analysts speculate that the NGRV could be designed with an option to carry more than one warhead should the strategic environment and the national defence policy require it. Alternate theories include development of a new, independently manoeuvrable single warhead which could display greater accuracy than current warheads.

Progress to Date

Supply chain and workforce issues at Northrop Grumman and several subcontractors have forced delays in the original development timeline. This includes moving up the original target date for first deployment of the new missile from FY 2029 to FY 2030. At a 28 March 2023 hearing before the House Armed Services Committee Deborah Rosenblum, Assistant Secretary of Defense for Nuclear, Chemical and Biological Defense Programs, testified that the DoD and USAF were jointly working to accelerate development in order to regain the original timeline, although the outcome

of these efforts – which include giving the LGM-35A programme preference with regard to supply deliveries – remains uncertain.

Despite the supply chain handicaps, Northrop Grumman and its subcontractors have managed to manufacture physical prototypes of major components. This early assembly reduces programme risk by validating production techniques and ensuring that physical assembly matches the digital modelling.

A major focus in this regard is placed on the booster motors which constitute the major element of the actual missile. Assembling the propulsion system is a multi-stage process. The solid propellent engines are cast by pouring rocket fuel into motor casings in a highly complex procedure. Several overlapping layers of protective material are then applied over each booster stage. The central casing of each motor requires insulation as protection against the extreme heat of burning fuel. A composite material is then applied over the insulation; this so-called 'case wind' forms the outer shell of the motors. A final protective material is applied over the case wind. For this last stage Northrop Grumman has devised a new, more efficient application procedure which reduces processing time by two-thirds.

Engine production for the three stages of the booster rocket was initiated in 2022. Inert stage one and stage two rocket motors were cast by Northrop Grumman in Summer 2022 to demonstrate motor design maturity and validate manufacturing processes, advanced tooling, and facilities. Fully functional motors were subsequently manufactured late in 2022 for use in ground testing.

Credit: Northrop Grumman

Air Force and Northrop Grumman Corporation conduct first full-scale static test fire of the Sentinel stage-one solid rocket motor.

Early Testing

The first full-scale static fire test of the stage one solid rocket motor took place on 2 March 2023 at the Northrop Grumman test facility in Promontory, Utah. This was the first in a series of tests of the weapon system's hardware under real-world conditions, said Major General John Newberry, Air Force Nuclear Weapons Center commander and Air Force program executive officer for strategic systems. "This test is just one part of our comprehensive ground and flight test program designed to help us shake down the design as we approach its critical design review. By testing early, we reduce risk to the overall weapon system schedule," Newberry said.

The engine firing was preceded by a series of wind tunnel tests using scaled models of the LGM-35A. According to a 16 February 2023 Northrop Grumman press release, the experiments were performed over the course of a year at various government and corporate facilities, and consisted of seven comprehensive test campaigns. Each campaign was designed with a unique set of requirements to measure how the missile would respond to various atmospheric, load and speed conditions. The full operational gamut was simulated, from launching the missile, to stage separation and various flight manoeuvres at subsonic and hypersonic speeds. The release stated that the physical test campaign validated the program's digital modelling and simulations, and proved the design maturity of the missile. According to the release, "the team is now updating models to enable full-scale predictive environments for the development of Sentinel flight hardware" as the engineering and design maturation efforts continue prior to Critical Design Review.

Fielding

Both the Pentagon and industry express confidence regarding successful transition through the remaining major milestones and testing events. The Critical Design Review (CDR) is currently scheduled for the fourth quarter of FY 2023. According to statements by the Air Force and Northrop Grumman, the first test launch of the LGM-35A all-up-round (consisting of the booster missile with mounted reentry vehicle) is expected during the third quarter of FY 2024. It will be conducted at Vandenberg Space Force Base in California. If all goes well, the Milestone C decision to proceed with procurement is scheduled for the third quarter of FY 2026. This will lead to Low-Rate Initial Production (LRIP).

The Pentagon plans to declare LGM-35A Initial Operational Capability (IOC) in 2030 with nine missiles on alert status. The earliest units might be armed with older Mk21 reentry vehicles and W87-0 warheads pending availability of the new Mk21A and W87-1 variants.

Full Rate Production (FRP) is anticipated for 2030. The Pentagon plans to acquire 642 units of the new missile. Of these, 400 will be deployed, with the remainder to serve for testing and as a reserve. Initial LGM-35As will serve alongside legacy Minuteman III missiles in order to retain a steady arsenal of 400 ICBMs. The acquisition program is to complete in 2036, when 400 units are expected to be deployed, replacing the Minuteman III at a one-for-one basis. As the US still maintains 450 operational missile silos, the future deployed ICBM force could hypothetically be expanded to address changes to the strategic environment. The LGM-35A is expected to remain operational past 2075.

IRST Pods: Eagle Eyes for Passive Detection

Georg Mader

Passive IRST (infrared search and track) sensors – whether built-in or in podded solutions - are an essential element of modern and future combat aircraft. IRST is a form of FLIR (forward looking infrared) that tracks individual targets, generally for weapons guidance or linked recce, while FLIR alone just 'sees' infrared heat signatures. Passive automatic search, detection and tracking functions are key elements in silent operations or tactical scenarios saturated with enemy jamming, such as Ukraine.

This article focuses on podded multi-role IRST systems. At the outset, and to set the record straight, it was not the Russians who 'invented' IRST systems, since the first system was an upgrade of the USAF F-101B Voodoo, which received the sensor from the cancelled F-108 Rapier fighter (1956). The subsequent F-102 Delta Dart and F-106 Delta Dagger interceptors both had IRST systems, as did several versions of the F-4 Phantom II. It was only later that the US 'Teen Series' fighters (F-15, F-16, F-18s, as well as European aircraft), which abandoned IRST systems, since it was felt that the increasing sophistication of aircraft radar systems made IRST redundant. The sole exception was the still much-bemoaned F-14 Tomcat, fitted with an extremely sophisticated IRST, since it was expected to operate in extreme jamming environments.

That is the reason why many fighters and especially the older ones, from their conception did not have the space to fully install IRST devices, as with the PIRATE system on the Typhoon, the OLS-series on Russian fighters, or today on F-15K/SA, F-16/60, F-18E/F III, F-35, Gripen-E' or Rafale. To provide these earlier aircraft with that capability when it was later deemed urgent, the IRST equipment was housed in an external pod mounted to the fuselage or wing weapons rails. The 'only' modifications to the plane was new video-wiring to the cockpit display, as with Rafael's Litening-V targeting pod on the Austrian Tranche-1 Typhoons.

Credit: Czech Air Force

Close up of the Litening IV pod mounted on a Czech Gripen aircraft.

Abilities and limitations

IRST works by scanning the sky for an IR signature, and when it locates one or more, it locks on for weapons tracking and guidance. Modern systems are usually equipped with an autonomous inertial navigation system (INS) that automatically calculates the angle of deviation of the target from the longitudinal axis (boresight) of the carrier aircraft. Furthermore, it provides high targeting accuracy, even under high dynamic G-loads. However, IRST is not magic and cannot fully replace radar, but it can pull off some very neat tricks, including giving a passive lock for air-to-air missiles (AAMs) and not triggering the targets' radar warning receiver (RWR). Maybe the most promising trick is spotting low-observable aircraft without using radar. Yet, while modern IR sensors are becoming sensitive, no one is going to launch a Meteor missile on IRST alone at >100 km range, or even obtain a dynamic launch zone on IRST at 100 km. The performance of IRST depends on several factors, mainly clouds, humidity, time of day (which relates to atmospheric temperature), target altitude, relative bearing, throttle setting, and aircraft structural composition in respect to thermal conductivity. A higher humidity negatively effects their performance, independent of temperatures.

Another issue is their need for cooling. Cooling is good for the sensitivity of IR detectors and reduction of noise with the signals, but is operationally inconvenient. Sensors may for example be cooled by cryogenic liquid or by cryogenic liquified gas. As cryogenic liquid is an expendable consumable, and could run out during a mission, it definitely needs to be serviced before each flight. Non-cryogenic cooling for IR-detectors can also be done with Peltier semi-conductor coolers operating on electrical power, more convenient in design as well as operation.

Litening Pods

With 26 user nations and 28 aircraft, the Israeli Rafael's Litening-family no doubt became the most widespread system of

Credit: Northrop Grumman

Front View Of Northrop Grumman's Openpod.

this type, since its first versions were introduced more than 20 years ago. The system's development programme ran from 1992 until 1999, when the successor Litening II entered service, proving its worth by competing directly with the AN/AAQ-13/14 LANTIRN targeting pod with the thousandth pod sold in October 2010. The Litening V is the latest of the family, and equipped with two small and medium-wave FLIR sensors. Previous versions, including the Litening III are nevertheless still in production. These usually have a third-generation FLIR sensor (3-5 micron), medium waveform and a resolution of 640 x 512 pixels. It can provide a wide (18.4° × 24°), medium (2.8° × 2.8°) and narrow (0.77° × 0.77°) field of view (FOV). The daytime camera (CCD sensor) provides a resolution of 659 (horizontal) × 494 (vertical) pixels with a FOV of 3.5° × 3.5° degrees, while a second is available with a smaller FOV of 0.7° × 0.7°. Its American coding is AN/AAQ-28 and since 1995 Northrop Grumman (NG) is in cooperation with Rafael, carrying out production in the US and promotion to the US Armed Forces. NG delivered more than 700 pods to the USAF, USMC and Spain, Italy, Australia, the Netherlands, Portugal, Finland and Denmark.

The air-to-air mode is well documented, including for example with videos of intercepted Russian aircraft in the Baltics, filmed at BALTOPS by a Czech Gripen. The Czechs have bought four of the previous version Litening-4i (fitted with ZEISS Optronics) pods in 2018 for CZK 325 M (EUR 13 M) - and reportedly want more. They also operate it on the L-159 ALCA. This model features colour symbology, tracker improvement and enhanced zoom compared to prior versions. Czech Air Force Commander Maj.Gen. Petr Mikulenka explained last year to the author: "Although it is primarily a tool for launching accurate attacks on ground targets, it was used there to improve the ability to visually observe aircraft day and night, which means that thanks to optical technology, Czech pilots are now able to track suspicious aircraft at very long distances and predict their behaviour…" Elsewhere, 150 units of Litening-4 were ordered by the Indian Air Force, demonstrating Rafael's versatility with integrating them into platforms such as the Su-30MKI or MiG-29UPG.

The UK's RAF Typhoons used the Litening III pod, originally carried by the service's Panavia Tornado GR4s, which were retired in April 2019. With two crewmembers, the GR4s could dedicate their weapon systems officer to working the targeting pod, but this imposed a greater workload on the single pilot of a Typhoon. Now the Litening V has entered service early last year with the RAF's No 41 Test and Evaluation Squadron (TES) for around 18 months for 'minor tweaks' and to clear it for squadron service. TES staff at RIAT 2022 were convinced that the auto-tracking, accuracy, co-ordinate generation and advanced optics "will get better by an order of magnitude…"

As an evolution to Litening, Northrop Grumman has also developed the OpenPod based on the aforementioned AN/AAQ-28(V). Any Litening pod can be converted to an OpenPod and sensors are advertised as being capable of being swapped out without modifications to the aircraft or its mission computer. It was presented as a future solution providing targeting, communications, and LIDAR, with the integration of IRST technology developed in Europe for the Typhoon's PIRATE and the Gripen's SkyWard – the latter a SELEX (now Leonardo) design. The OpenPod was discussed for the Hellenic Air Force's F-16 upgrade.

Legion pod

IRST21 (also known as AN/ASG-34) is the next-generation IRST sensor by Lockheed Martin's Missiles and Fire Control segment in Orlando, FL. It builds on the lega-

Credit: USAF

Side view of Legion Pod during trials at Eglin AFB.

cy AN/AAS-42 IRST sensor system, which accumulated over 300,000 flight hours on F-14 and international F-15 platforms. As a compact design, it enables IRST21 to be integrated in a variety of ways. On the F/A-18E/F, IRST21 is mounted on the nose section of the centreline fuel tank, (hopefully never in need to be jettisoned). A 16 inch (406 mm) diameter structure podded sensor system with IRST21 is also being introduced as the Legion pod and will be transferable across a wide range of platforms.

Eglin's Integrated Test Team (from Eglin Air Force Base in Florida) conducted the first-ever multi-platform operational test to effectively locate a target using shared IRST sensor data on 7 April 2022. An F-15C and F-16D, both Legion/IRST21 equipped, were then able to share that sensor data over the pod's Advanced Data Link (ADL) to passively triangulate target position without the use of radar or other active ranging sources. The pod's common interface allows integration onto any aircraft with minimal to no impact on the aircraft's core software. This versatility opens the door for integration with minimal effort onto other fighter aircraft such as the USAF's newest 'conventional' fighter, the F-15EX. The Eglin team's eventual goal is to provide this capability to anyone carrying an ADL Legion pod, regardless of platform. To verify this, a first successful two-ship F-15 IRST ADL test occurred in April 2021 and the first successful two-ship F-16 IRST ADL in December 2021. So far, Lockheed Martin is due to produce more than 130 systems.

The other US giant is also involved. In late 2022, the US Navy's Naval Air Systems Command asked Boeing to procure 19 ASG-34A(V)1 IRST pods to enable Navy F/A-18E/F jets to detect, track, and attack enemy aircraft with a within visual range (WVR) limit of no more than 40 km, without making its presence known. The USD 43.5 M order includes the supply of 15 IRST pod spare parts, 34 fuel tank assemblies, 34 sensor assembly structures and special tooling, non-recurring engineering, sustainment support and data. Boeing will carry out the work in St. Louis and should be finished by April 2026.

Credit: Armée de l'air et de l'espace

Close up of the TALIOS pod gimballed head housing the sensor suite.

TALIOS

The Rafale F3R fighters operated by the French Air Force and Navy currently use two types of pods: Damocles, which entered service in 2010, for engaging ground targets, and the newer TArgeting Long-range Identification Optronic System (TALIOS) for various functions including IRST, since 2020. French manufacturer Thales produces both.

The French Directorate General of Armaments (DGA) announced that the TALIOS pod, which are able to capture HD video, will be integrated with the Rafale F4.2 standard and Mirage 2000D RMV. Equipped with this pod, the Rafale covers the entire spectrum of intelligence, acquisition, tracking and target designation missions, by providing images in the near-infrared and infrared domains. It also has new, more efficient fixed or moving target tracking capabilities against ground and aerial targets, an automatic detection capability for moving targets and a new man/machine interface.

A total of 67 TALIOS pods have been ordered; as of late 2022, 36 are still to be delivered, by 2025. In February 2023, the Hellenic Air Force General Staff received Thales representatives to negotiate a deal for TALIOS pods for the Hellenic Air Force's new Rafale fleet. As the F4 variant will also be operated by the United Arab Emirates (UAE) and Indonesia, the TALIOS pod could well be used by these nations too, while at the recent LIMA trade show in Malaysia, it was heard that the Malaysian Air Force (TUDM) is also discussing this option for their Su-30MKM upgrade. Malaysian Sukhois are currently using the Damocles targeting pod.

ASELPOD

Turkish defence electronics specialist ASELSAN has the new ASELPOD multi-role optronic targeting system in its portfolio. It has been tested on TuAF (THK) F-4E/2000 and F-16s, with ASELSAN having already signed contracts.

Pakistan is one customer, having signed a USD 25 M deal for eight ASELPODs to equip their Sino-Pakistani JF-17 Thunder jets. Another recent customer appears to be Iraq, which fits into a recent release by the Turkish firm mentioning a USD 31 M contract in September 2022, as well as a recent sighting of trials on an L-159T2X testbed at the Czech AERO Vodochody facility. ■

Three-quarter view of the Aselsan Aselpod.

AIR 7000: Australia's Maritime ISR Programme

Sidney E. Dean

Australia's AIR 7000 programme aims to replace the nation's current maritime patrol and response capability – which centres around the AP-3C Orion aircraft – with a combined force of manned P-8A Poseidon aircraft and the MQ-4C Triton unmanned aerial system (UAS).

The AP-3 entered service with the Royal Australian Air Force (RAAF) in 1968, and is currently being drawn down to retirement. The two new aircraft promise significantly improved range and sensor performance. The core concept of AIR7000 revolves around the teaming of the manned and unmanned assets, which will boost the maritime patrol and response effectiveness beyond the capabilities of either aircraft alone.

P-8A Poseidon

The P-8A Poseidon multi-mission maritime patrol aircraft, based on the commercial Boeing 737-800 airframe, entered service with the RAAF in 2016. Twelve aircraft are currently operated by the RAAF's No. 92 Wing stationed at RAAF Base Edinburgh, located at the southern Australian coast near Adelaide. Operational aircraft are attached to the wing's No. 11 Squadron, while the wing's No. 292 Squadron acts as the training unit for aircrew, maintenance and operations personnel. No. 11 Sqn utilises several additional operating bases located on the western, northern and eastern Australian coasts, ensuring 360° coverage of the oceans surrounding the nation.
The P-8A is officially designated as the Maritime Patrol and Response Aircraft System. Missions include: anti-submarine warfare (ASW), anti-surface warfare (ASuW), search and rescue (SAR), maritime intelligence, surveillance and reconnaissance (ISR), and overland ISR. The integrated sensor suite includes advanced radar, optical, electronic and on-board acoustic systems. Additionally the aircraft can internally carry and deploy 129 sonobuoys. AGM-84 Harpoon anti-ship missiles (ASM) and lightweight anti-submarine (ASW) torpedoes can be carried in the internal weapons bay as well as on underwing pylons. The Poseidon will also be able to deploy the Long Range Anti-ship Missile (LRASM) once it is fielded with the RAAF.

Credit: Australia MoD

An RAAF P-8A Poseidon conducts maritime SAR manoeuvres with RANS Hobart.

Depending on mission profile and payload, unrefuelled range can reach 7,500 km. According to the RAAF, the 34 tonne internal fuel capacity allows the P-8A to conduct low-level anti-submarine warfare operations more than 2,000 kilometres from base. The operational range can be expanded through aerial refuelling.

MQ-4C Triton

To date the RAAF has contracted for three units of the MQ-4C Triton UAV. Australian personnel began training on the platform in the United States in November 2022. The first aircraft was presented to the press in September 2022, but this preceded final system integration and flight testing. As confirmed by Deputy Prime Minister and Minister of Defence Richard Marles on 3 March 2023, Northrop Grumman will actually transfer the first of the aircraft to Australia in 2024. Initial Operating Capability (IOC) is slated for 2026. Full Operating Capability (FOC), defined as "the ability to conduct two orbits, in all roles, at a rate of effort in accordance with strategic and capability guidance," is expected in the 2030-2031 timeframe.
The Triton UAS is categorised as a HALE (High-Altitude/Long-Endurance) system. The UAV is remotely flown by a pilot and co-pilot seated at a ground station. The Triton has 24+ hours endurance (with an 80% effective time-on-station) and a flight ceiling of circa 15,400 m. The payload package includes a multi-mode X-band radar, optoelectronic day/thermal sight, and a signals intelligence suite. Sensors can conduct wide-area surveillance with 360 degree coverage, or focus on individual targets of interest to gain

Credit: Northrop Grumman

The first MQ-4C in Australian colours.

detailed information. In wide-area mode the aircraft can survey an area covering one mission square nautical miles during a single mission. The Air Force intends to use the Triton for maritime patrol and for additional ISR roles.

The unmanned aircraft are being based alongside the manned P-8A units stationed at RAAF Edinburgh. Operational flights will be launched from RAAF Tindal, which is located circa 300 km from the northern coast near Darwin. According to Group Captain James Parton, Director, ISR Transition Office, this will require a steady presence of 10-12 pilots plus circa 40 Northrop Grumman Australia maintenance and sustainment contractors at Tindal. As revealed on 3 March 2023 in the course of the Avalon Airshow, the Tritons will be operated by No. 9 Squadron, which is being reactivated for this purpose. A mock-up of the MQ-4C was displayed at the airshow bearing the squadron's markings.

Operational Teaming

The manned and unmanned maritime ISR assets will operate in tandem, forming a family of systems jointly replacing the AP-3 Orion. The MQ-4C is intended to complement the P-8A, acting as a force multiplier for the manned aircraft. A major benefit is the UAS' ability to survey vast stretches at a time, locating and identifying objects of interest much more quickly than manned aircraft could. By relaying high-resolution surveillance data in real time, the UAS can enable the manned aircraft to immediately pursue suspicious or hostile vessels. The MQ-4C can also provide targeting data which can be relayed to other armed aircraft and to ships. DPM Marles described the UAV's significance by praising "the persistent reconnaissance and surveillance of our northern maritime approaches which is so important in terms of the defence of our nation. It's also going to be really useful in terms of surveilling illegal fishing both in our own waters, but also the waters of our Pacific neighbours." Deploying the manned and unmanned aircraft as a family of systems, and delegating high-altitude persistent surveillance to the UAV, will allow the P-8A fleet to dedicate itself to ASW and AsuW missions, on-call SAR, and ENLINT operations. In addition to enhancing operational efficiency, this teaming reduces stress on aircrews and airframes alike.

Credit: US Navy

RAAF Flight Lt. Nathan Owen loads sonobuoys on a P-8A Poseidon during RIMPAC 2022.

AIR 7000 Programme

The AIR 7000 programme is divided into several subphases. Changes in the order in which the two systems are being procured led to Phase 2 now being at a more advanced stage than Phase 1.

Introduction of the P-8A and the various works connected to that acquisition – including upgrading and expanding operating facilities. Collectively these make up the AIR 7000 Phase 2B - Maritime Patrol Aircraft Replacement Project. The project was formally initiated with the October 2012 development collaboration agreement with the US Navy. In 2020 the Australian government approved procurement of an additional two aircraft. They will likely be delivered by 2024, bringing the total Poseidon fleet to 14 units. Major infrastructure projects associated with AIR7000 Phase 2B include hangar maintenance and conversion of an operational facility for 92 Wing at RAAF Edinburgh. These improvements include two hangars in which operational level aircraft maintenance will be undertaken, training facilities for aircrews and maintenance personnel, as well as working accommodation for the squadrons, aircrew and maintenance crews. Runways, taxiways and aprons are also be expanded to meet the requirements of the heavier aircraft. Similar work is required on a more limited scale at the various designated operating bases.

Credit: RAAF

The Australian MQ-4C Triton UAV on maritime patrol.

The MQ-4C acquisition is officially designated AIR 7000 Phase 1B. Australia's Triton is being procured through a co-operative Development, Production and Sustainment programme with the US Navy (which is acquiring 68 units of its own.) Despite longer-term Australian interest in a HALE ISR system (and collaboration with the US Navy), the cooperative programme was not formalised until 2018. The acquisition is currently running one year behind the original plan because of a two-year production pause (2021-2022) initiated by the United States. The Australian Department of Defence is also planning to construct a UAV forward operating base at RAAF Tindal. The work was initiated in 2020 but implementation was delayed due to the MQ-4C production pause. The infrastructure upgrade is expected to be completed in 2027.

Regarding the UAV acquisition target, the Australian MoD has in the past postulated a requirement for six or even seven units; six has been the official target since 2018. During his remarks at the Avalon Airshow, DPM Marles reiterated that "at this stage, we've got three that are on order, and that's the extent of our acquisition." He did, however, also cite the Australian DoD's Integrated Investment Program "which does provide for more in the future."

In aggregate, the statement made in 2020 by then Defence Minister Linda Reynolds still stands: "Together, the Poseidon and the Triton will provide Australia with one of the most advanced maritime patrol and response capabilities in the world, [enhancing] the Air Force's flexibility to support multiple operations and will play an important role in ensuring Australia's maritime region is secure for generations to come." ■

NATO's Next-Generation Rotorcraft

Ian Frain

Throughout history, the pace of the battlefield has always increased in line with technology. As in the last century, and as foreseen for the near future, progress in technology for military rotary aircraft, will focus on carrying capacity, weapons, and the capability to cover long distances.

European Legacy Craft

The battlefield utility rotorcraft platforms currently available to NATO members are predominantly of the 1960s/1970s/1980s legacy design concepts. They include the heavy-lift twin-rotor Boeing CH-47D (and more recently the F variant) Chinook, and the twin-engine Sikorsky CH-53G/GS/G Stallion, and three-engine CH-53E Super Stallion (and newer three-engine CH-53K King Stallion). In the medium-lift category, there are the twin-engine family of the Lockheed Martin owned Sikorsky UH-60A/L/M Blackhawk, the S-70i International Blackhawk, and the Bell-Boeing V-22 Osprey tilt rotor.

In European service are the Airbus Helicopters SA330 Puma, and the AS332M/532/EC725/H215M/225M Cougar/Caracal series (derived from the Super Puma), the multinational NHIndustries NH90 TTH (Tactical Transport Helicopter), and the three-engine Leonardo AW101 Merlin. In the former Warsaw Pact countries, there are also the old Russian Helicopters Mi-8 and Mi-17, (NATO codename: Hip), though the Czech Republic is in the process of replacing their Hip helicopters with the smaller Bell UH-1Y Venom or Yankee Huey, already in service with the United States Marine Corps (USMC). Bell have been targeting the Eastern Europe market over the last decade offering the Bell UH-1Y and Bell 210 Super Huey to replace legacy Russian Helicopters fleets. The Russian invasion of Ukraine has not only cooled interest in Russian Helicopters, but has drastically reduced support for the likes of the Mi-8 and Mi-17.

Author

Ian Frain is the founder and owner of Helian Aviation Ressarch based in the United Kingdom, and holds a BSc in Engineering Studies (Aero and Mechanical) from University of Hertfordshire. He has just over two decades in the aviation industry from helicopter maintenance operations to airline business research.

Credit: NGRC Programme Office

Notional schematic of what the Next-Generation Rotorcraft Medical Evacuation variant interior could look like.

In France, most of the fleet consists of the smaller Airbus Helicopters twin-engine AS565F/AS365N3 Panther, the twin-engine light AS555 Fennec, and the legacy single-engine SA341/342 Gazelle HOT anti-armour and observation helicopters. These are due to be replaced with the twin-engine H160M Guépard under the hélicoptère interarmées léger (HIL) programme over the next few years and into the next decade.

In October 2022, the Chief of Staff of the Italian Air Force (Aeronautica Militare), General Luca Goretti, stated that he was keen to partner with Sikorsky, with their X2 high-speed rotorcraft technology, for the next generation of high-speed rotorcraft platforms, which he said their military urgently needs. He also noted that the Aeronautica Militare and their Navy (Marina) were already partnering with Lockheed Martin on the F-35A conventional take-off and landing (CTOL) and the F-35B short take-off and vertical landing (STOVL) naval variant, implying the Sikorsky partnership would be a natural progression. Two months after General Goretti's announcement, the US Army selected the Bell V-280 tilt rotor for the future vertical lift (FVL) programme, over the Sikorsky-Boeing SB-1 Defiant coaxial contra-rotating push propeller design.

The SB-1 utilises the X2 high-speed technology, which has been around since 2008 with the first flight of the small two-seat X2 demonstrator. Subsequently in 2010, the X2 demonstrator broke the world speed record for rotorcraft. With the launch of the Army's Future Long-Range Assault Aircraft (FLRAA) and the Future Vertical Lift (FVL) forming part of this, the S-97 Raider demonstrator first flew in May 2015 and from there, the SB-1 was born.

High-Speed Trans-Atlantic

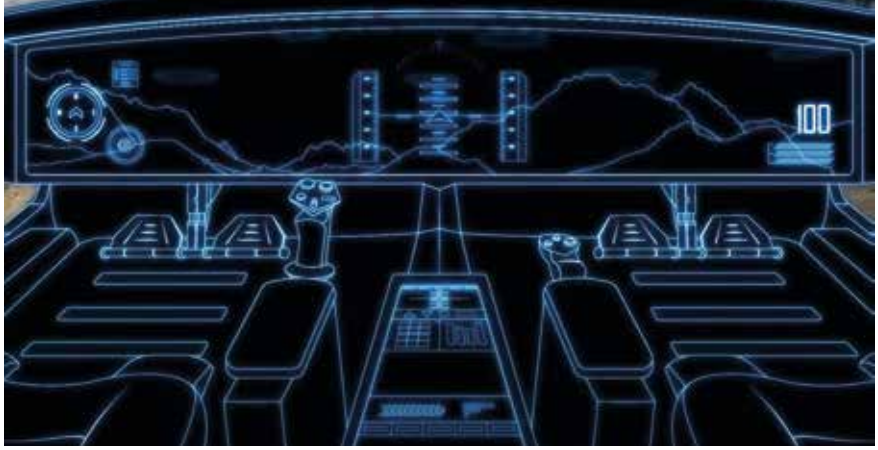
This was not the first time that Sikorsky had a similar experimental high-speed airframe. In the early 1970s, the company designed and flew a high-speed advancing blade concept XH-59A (Sikorsky S-69) demonstrator with similar blade configuration to the X2 technology demonstrator, and intended to eliminate the problem of retreating blade stall at high speeds by using two counter-rotating rotors. This was powered by a pair of Pratt & Whitney PT6T-3 Twin-Pac and externally mounted auxiliary Pratt & Whitney J60-P-3A engines on each side of the fuselage. The demonstrator achieved a speed of 444 km/h (240 kn). An interesting feature of the design was the gearbox, which was able to create differential rotor speed, which would provide yawing moments that did not reverse in autorotation.

After its successful maiden flight in June 1973, it unfortunately soon experienced a low-speed accident with the XH-59A landing, with the tail coming into contact with the ground and the fuselage rolling over.

The programme was set back by twelve months as a result, however, a second XH-59A had been constructed and flight testing resumed in November 1974. The first prototype was rebuilt and ended up as a wind tunnel test platform at the NASA Ames Research Centre on the same site as the then Naval Air Station Moffett Field (now Moffett Federal Airfield). With the continuation of the XH-59A test programme, NASA joined the US Air Force, US Army and US Navy with the programme.

In terms of tilt rotor platforms, the Bell-Boeing V-22 Osprey tilt rotor is in service with the USMC flying the MV-22B, while the USAF Special Operations Command (AFSOC) operates the CV-22B. More recently, the Navy has started to introduce the CMV-22B for the carrier on board delivery (CoD) missions, replacing the 1960s legacy twin-propeller Grumman C-2A Greyhound in that role.

The V-22 Osprey has its roots in the tilt rotor legacy of the 1950s with the Bell XV-3, which first flew in August 1957. The technology matured two decades later with the development of the two-seat, side-by-side Bell XV-15 tilt rotor demonstrator (which first flew in May 1977). Later, in the 1980s, all branches of the armed forces participated in the JVX programme, which then became the V-22 Osprey, (though the Army eventually dropped out, leaving just the USMC and USAF in the programme). The USMC was the main driving force behind the V-22, as it was intended to replace the twin-rotor Boeing CH-46E Sea Knight medium assault helicopter. The V-22 programme was temporarily halted by the then Secretary of Defence, Dick Cheney in 1989, but in 1992, under the George H.W. Bush administration, it was resumed. Nearly three decades later, with the maturity of tilt rotor technology, and a decade and a half of operations, the Bell V-280 Valor was the result of the advancement of tilt rotor design.



Credit: NGRC Programme Office

Notional schematic of what the Next-Generation Rotorcraft cockpit could look like.

NATO Looks to the Next Generation

Some NATO members are looking ahead to replace the aforementioned medium-lift legacy platforms around the 2030/2040 timeframe. The Next Generation Rotorcraft Capability (NGRC) programme is intended to have these nations cooperating in designing, developing and delivery of a medium multi-role battlefield helicopter. The aforementioned technologies are at the forefront of what the future needs of the ideal rotorcraft are expected to be.

As it is, NATO differentiates between three different classes of vertical lift: these include light, medium, and heavy capabilities. The difference lies in the payload to be carried. The NGRC concept phase will focus initially on medium multi-role capabilities.

It all started in November 2020 when the British, French, German, Greek, Italian defence ministers decided to launch the multinational NGRC initiative through the signature of a Letter of Intent (LoI). Subsequently, in June 2022, the same five nations, plus the Dutch, launched the concept stage of the project through a Memorandum of Understanding (MoU). The NGRC is currently at the concept stage, with the NATO Support and Procurement Agency (NSPA) acting as contracting authority on behalf of participating nations. It is expected that the number of participants will increase, with Canada set to join later in 2023.

In parallel with the NGRC, both the UK and the Netherlands have signed an MoU with the US Army to share information on FVL. In July 2020, the UK Minister of the Armed Forces, James Heappey, and US Secretary of the Army, Ryan McCarthy, signed a Memorandum of Agreement (MoA), on a joint modernisation of both the British and the US Army. The idea is to complement the capabilities across all arms, from 2023 to 2027, and FVL is on the list.

In the UK, the New Medium Helicopter (NMH) competition is taking place for replacing, primarily, the legacy, five-decade-old Puma HC2 medium-lift helicopter in service with the Royal Air Force (RAF). However, the NMH is also involved in replacing other assets, such as the Bell 212 Twin Iroquois, (providing the Army Air Corps support role in Brunei), and the Bell 412 Griffon (RAF Search and Rescue at RAF Akrotiri in Cyprus), and even the Army Air Corps Special Forces AS365N3 Dauphin. In the UK, all battlefield rotorcraft come under the Joint Helicopter Command (JHC), at British Army headquarters in Andover, Wiltshire. The NMH candidates are the Airbus Helicopters H175M, the Leonardo AW149, and the Sikorsky S-70i International Blackhawk.

Over a decade ago, NATO developed the Future Heavy Transport Helicopter (FHTH) programme, with the aim of replacing the two heavy-lift helicopters, the CH-47D/F and CH-53G/GS/GA, with Eurocopter (now Airbus Helicopters) being the driving force behind the FHTH. Boeing initially partnered with Eurocopter during the 2010 ILA Berlin Air Show, but shortly after, Eurocopter went it alone. Two concepts were discussed; one was a conventional main rotor and tail rotor configuration and the other was a tandem rotor heavy-lift configuration, as with the Boeing CH-47 Chinook design. The latter has triumphed but the programme has tailed off to a certain degree.

At this stage of the NGRC programme, the participating nations are 'promoting interoperability' through the Alliance, and there will be the possibility for additional NATO members to join at the next stage, namely the development stage, projected to start in 2027-2028. Throughout the concept stage, there will be several competitions, with the first tenders set to be initiated in the summer of 2023, so industry will be closely involved, almost from the outset. ■

Notional schematic of real-world view from inside the Next-Generation Rotorcraft platform

Credit: NGRC Programme Office

The Joint Force Training Centre – A Key Venue for NATO Training, Exercises & Development

NATO Joint Force Training Centre, Office of Public Affairs

As tensions continue to rise across the globe, it has never been more important for NATO member countries to ensure that their armed forces are properly trained and stand ready to defeat potential adversaries. This is NATO's Joint Force Training Centre (JFTC), located in Bydgoszcz, Poland, principle objective. JFTC's state-of-the-art facility plays a key role in preparing Joint NATO forces for the challenges they will face while operating in all domains. In this article, we will take a closer look at this training centre and the role it plays in keeping Joint NATO forces mission ready.

JFTC is the only NATO training facility responsible for conducting joint military exercises and training at the tactical level. The only other NATO training facility, Joint Warfare Centre in Stavanger, Norway, focuses on the strategic and operational level. JFTC provides a challenging and comprehensive tactical level training environment for NATO military and non-military personnel. Furthermore, JFTC also conducts military experimentation and testing which supports the NATO warfighters' effectiveness against today's threats and prepares them for future threats.

Credit: JFTC

JFTC's Headquarters in Bydgoszcz, Poland.

Background Information

The Centre's history goes back to November 2002. During the NATO Prague Summit, Heads of State and Government opened a new chapter of the Alliance's history. The Baltic States were invited to accession talks and they committed themselves to equipping NATO with new and advanced capabilities to better prepare for security threats of the 21st century.

One of the initiatives was the ambitious reorganisation of the NATO Command Structure. The overarching intent was to make it leaner, more effective and deployable, in order to ensure the full range of Alliance missions could be accomplished. Therefore, it was decided to develop two different four-star level strategic commands: one responsible for current NATO operations focused on how we fight today - Allied Command Operations (ACO) in Mons, Belgium, and the other to focus on NATO's transformation, how we will fight in the future - Allied Command Transformation (ACT) in Norfolk, Virginia. Since one of NATO's transformational objectives includes the continuous advancement of interoperable, network-enabled, combined joint forces, it was determined that investments, particularly in the area of integrated joint training, needed to be made. As a result, JFTC was established under the new Allied Command Transformation (ACT), along with Joint Warfare Centre (JWC) and Joint Analysis and Lesson Learned Centre (JALLC).

JFTC was officially formed on 31 March 2004 and conducted its Inauguration Ceremony on 25 June 2004. It was the first NATO Command Structure unit established in Central and Eastern Europe. The Centre paved the way for other NATO institutions to be established in the city of Bydgoszcz, which is now commonly referred to as "the NATO Capital of Poland".

JFTC was initially established solely for the purpose of providing tactical level training to NATO forces. Over time, and as a consequence of the evolution of global security threats and NATO enlargement, JFTC's mandate expanded to include experimentation and testing and quickly became a prominent and valuable member within the NATO network.

On 9 September 2009, JFTC moved into its new facility, equipped with modern communication and information systems. This enhanced the Centre's capabilities and offered a one of a kind training facility, ready to support NATO current operations, future

Credit: JFTC

JFTC was responsible for Exercise LOYAL LEDA 2022 that provided a venue for training, evaluation and certifying NATO Rapid Deployable Corps-Türkiye as the designated NATO Warfighting Corps for 2023.

operations, emerging requirements, and tactical level certifications. JFTC's critical contribution to the NATO training community makes it an essential player in maintaining readiness and operational effectiveness of the Alliance.

Leadership & Structure

JFTC operates in a highly coordinated and structured manner to ensure that its missions are executed effectively. The Centre's Commander is two-star General Officer. The command alternates between Germany and Poland, and currently, the position is filled by Major General Norbert Wagner of the German Armed Forces. The Commander is supported by a Deputy Commander and Chief of Staff. This position rotates between Czech Republic and Hungary, and is presently occupied by Brigadier General Petr Svoboda of the Czech Armed Forces.
The Centre consists of three divisions, each responsible for specific functions, supported by the Director of Management. The Director of Management (DOM) is responsible for managing the staff in all work requiring the attention of the Commander or Deputy Commander / Chief of Staff, coordinates administrative support, and information management. The Training and Exercise Division (TED) is responsible for the development, management, and execution all training and exercise evolutions. The Training and Exercise Enabling Division (TEED) is responsible for warfare development to include testing and experimentation. They also support preparation, execution, and assessment process of training and exercises. The Headquarters Support Division (HSD) is responsible for all logistical support for all programmes, training and exercise evolutions.
JFTC's structure is composed of approximately 170 core positions, filled by soldiers and civilians, who possess the required knowledge and expertise necessary to meet a broad range of NATO training requirements. Additionally, JFTC is responsible for the NATO liaison team at the NATO-Georgia Joint Training and Evaluation Centre (JTEC) in Tbilisi, Georgia. JFTC's team is comprised of representatives from 22 NATO nations (Belgium, Bulgaria, Canada, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, North Macedonia, Norway, Poland, Portugal, Slovakia, Spain, Türkiye, the United Kingdom, and the United States), as well as one Partnership for Peace nation (Georgia).

Missions & Tasks

JFTC has three focused mission areas which promote NATO cohesiveness, resilience, and adaptability. The first mission area is support to Current Operations through the execution of NATO pre-deployment training. The second mission area is support to Future Operations through the execution of Major Joint Exercises (MJO+). The third mission area is support to Warfare Development through experimentation, capability integration testing, and promoting interoperability. The following paragraphs will go through each mission area in more detail.

Support to Current Operations

JFTC continuously builds on its vast experience, gained from previous NATO missions, in order to provide effective training to warfighting Headquarters and special advisors deploying in support of NATO Mission Iraq (NMI). The Centre ensures that trainees gain the necessary knowledge, flexibility, and capacity necessary to provide sound advice and assistance to their counterparts, while laying the groundwork for long-term sustainability.
The pre-deployment training for NMI is conducted three times a year. It gathers future NMI staff members, advisors and subject matter experts, to include current NMI members, who facilitate the training. The training events consist of two phases. The first phase is one week and is conducted virtually. During this phase a series of briefings, individual learning modules, and

Credit: JFTC

NATO Mission Iraq (NMI) pre-deployment training.

ESD Interviews – Air Vice Marshal (retd.) Gary Waterfall

Credit: Clarion Defence and Security

Air Vice Marshal (retd.) Gary Waterfall

Ahead of DSEI in September, ESD is publishing an interview with Air Vice Marshal (retd.) Gary Waterfall, DSEI Senior Military Adviser – Aerospace

Q: What will be the highlights of the Aerospace Zone at DSEI 2023?
A: DSEI's Aerospace Zone is at capacity with major primes such as Boeing, Airbus and MBDA all booking out significant areas. Supported by the Royal Air Force, the Aerospace Zone is a key platform to see first-hand the latest developments and innovations in the aerospace domain from UK and international exhibitors.
The Aerospace Zone also has a capability area that services the entire aerospace supply chain. The Zone will have a crucial focus on the Future Combat Air System (FCAS) and the Combat Air Strategy, combining crewed and uncrewed platforms, and space capability of course within the Space Hub.

Q: Why should people visit the Aerospace Zone at DSEI?
A: I would offer there are 3 reasons to visit the Aerospace Zone at DSEI.
Firstly, DSEI will represent a key forum for updates on, and how to sell into, the Global Combat Air Programme (GCAP). GCAP is a trilateral collaboration between the UK, Japan and Italy to develop the next generation of fighter jet. Due to the importance of GCAP, a whole area in the boulevard has been dedicated to it. Two months ago, the UK Ministry of Defence (MOD) awarded a major contract to BAE Systems on behalf of British defence firms, Leonardo UK, MBDA UK and Rolls-Royce, to progress the design and development of this aircraft. Tempest is the UK name for the aircraft in development under GCAP. Team Tempest has been researching and evaluating a host of future combat air system capabilities since 2018 and is continuing to develop the technologies needed to deliver the next generation combat air capability.
Secondly, there will be extensive Unmanned Aerial Vehicle (UAV) capabilities being exhibited such as Mitsubishi's counter-UAV laser prototype. Since Russia's illegal and barbaric invasion of Ukraine in February 2022, UAVs have been in the spotlight both in terms of increased employment and the development of new UAV capabilities.
Thirdly, sustainable aviation that maintains an operational advantage will feature heavily. The UK Government is committed to net-zero carbon emissions by 2050 and we know that defence is a significant contributor. It will be fascinating to see how the RAF and large aerospace companies approach the challenges of being both sustainable and competitive.

Q: Could you elaborate on the importance of GCAP for DSEI?
A: As I've mentioned, GCAP will have its own dedicated exhibition stand at DSEI 23, that will feature truly immersive digital displays, showcasing some of the innovative technologies that are driving this programme. Colleagues from the UK, Japan and Italy will be on hand to talk to visitors about GCAP and the rapid progress that is being made across all areas of the programme.
In addition, there will be two GCAP panel discussions taking place at DSEI. The first will be in the Aerospace Forum and will include the international programme directors from the UK, Japan and Italy – this is the first time they will have appeared on a panel together. They will be joined by the senior Industry personnel from BAE Systems, Mitsubishi Heavy Industries and Leonardo Italy. This promises to be a fascinating update from the international partners, who will talk about the overall direction of the programme; the capability that it is delivering; interoperability with allies and other domains; people and skills; and programme milestones.

Q: Why should people visit DSEI 2023?
A: DSEI is the globally leading Defence and security show. There is no other international event that encompasses such a broad span of cross-domain capabilities,

and where senior representatives from governments and the defence industry can meet to discuss their priorities. DSEI connects governments, national armed forces, industry thought leaders and the entire defence and security supply chain on a global scale.
There is a wide range of valuable opportunities for networking, platforms for business and extensive access to relevant content and live-action demonstrations. The DSEI community can strengthen relationships, share knowledge and allow visitors to view the latest capabilities across the exhibition's Aerospace, Land, Naval, Security and Joint Zones.
The theme of 'Achieving an Integrated Force' DSEI will once more see a galvanising of UK Military, UK Defence and Security Exports (UKDSE) and the highest calibre of exhibitors from industry.

Q: What has changed since DSEI 2021 and how will this affect the show?
A: The major change since DSEI 2021 is unquestionably the war in Ukraine. The brutal and illegal invasion by Russia has focussed minds on how to deter and, if necessary, defeat, a peer/near-peer adversary in order to maintain our hard-won freedoms. The conflict represents a significant shift in how allied forces think about warfare.
DSEI is a global event but as its based in the UK will have a significant UK MOD presence. The UK can be proud to be one of the largest donors to Ukraine having committed GBP 2.3 Bn in military assistance in 2022 and has pledged to match that assistance in 2023.

Q: How does the Aerospace Zone at DSEI integrate with other domains for a joined-up approach?
A: Integration at a national level across the frontline commands is essential and I know that they are all in constant dialogue. Multi-domain operations was the underlying theme of DSEI 2021, and 'Achieving An Integrated Force' is this year's focus. The most effective fighting forces are those who can integrate best across all environments. But it's more than that – it includes integration from supply chain, SME and large Primes in company with UK Government - and all set in an international context. A hackneyed phrase – but together the component parts are much more powerful than the individual sum.
Therefore, the whole aerospace domain will play a prevalent part in DSEI 2023, but it always works best when it's connected with other domains for a joined up approach. DSEI is a key learning platform and a way to bring together people from different branches of the military to share best practice and discuss ideas.
This learning from other domains ties in with the overarching theme for DSEI 2023 of achieving an integrated force. The UK Ministry of Defence and the British Army, Royal Navy, Royal Air Force and UK Strategic Command are working to integrate at all levels and across five operational domains of Air, Cyber and electromagnetic activities (CEMA), Land, Sea and Space.

Credit: Clarion Defence and Security

Pictured is the Team Tempest area at DSEI 2021. GCAP will receive its own dedicated stand at DSEI 2023.

Credit: JFTC

EX LOYAL LEDA 2022, featured an Article 5 scenario encompassing both traditional warfare domains as well as space and cyber domains, and hybrid warfare.

live chats are conducted that enhances the participants' understanding while increasing their basic level of knowledge about the mission and the operating environment. Phase two is a one week residential phase. It is executed at JFTC and the trainees develop the necessary skills that will prepare them to effectively operate in this challenging environment. This is done through the direct interaction with experts and team building events. For a majority of the participants, NMI pre-deployment training at JFTC is the first opportunity for them to meet their future comrades. Personal interactions help to establish a solid foundation for future cooperation and enables them to smoothly transition in theatre.

To date, JFTC has trained approximately 20,000 staff members and advisors for various NATO missions, including Iraq, Afghanistan, and Kosovo. Its extensive experience in delivering high-quality training has made JFTC a trusted and valued partner to NATO allied forces. JFTC's training programmes are designed to prepare personnel for the challenges they will face in the real world and to enhance their readiness to support NATO missions.

Support to Future Operations

The Joint Force Training Centre holds a crucial position in NATO Command Structure and NATO Force Structure exercises. With its adaptable and flexible approach, the institution is ready to respond to the ever-changing training environment of the Alliance. It excels in delivering complex, high-intensity computer assisted exercises, serving as an Officer Conducting and/or Directing Exercise (OCE/ODE).

JFTC's importance in the Alliance's training programme is further highlighted by its key role in the LEDA exercise series as the Officer Directing the Exercise (ODE). The LEDA exercises bring together thousands of warfighters and non-military personnel from across NATO, with Exercise Control comprising 700-800 personnel, who control the exercise from JFTC in Bydgoszcz. The last edition of this series took place in 2022.

LOYAL LEDA 2022, was a land domain tactical-level Computer Assisted Exercise / Command Post Exercise sponsored by NATO Allied Land Command. It was based on a robust Article 5 scenario that encompassed a wide range of modern warfare challenges, to include those deriving from space and cyber domains as well as hybrid warfare.

The exercise was held at the end of 2022, after more than a year of meticulous planning, coordination, and preparation. JFTC, as the ODE, was responsible for the exercise that provided a venue for training, evaluation and certifying NATO Rapid Deployable Corps-Türkiye as the designated NATO Warfighting Corps for 2023.Moreover, LOLE22 trained Headquarters Multinational Corps South-East and Headquarters Multinational Division South-East in the planning and execution of an Article 5 Major Joint Operation against a peer adversary. The Centre was responsible for proper preparation and execution of the exercise and made sure all objectives were met. JFTC experts also contributed significantly to the experimentation activities of the exercise.

Additionally, JFTC serves as the OCE/ODE for the annual NATO Key Leader Training – Exercises STEADFAST PYRAMID AND PINNACLE (STPYPI), scheduled by the Supreme Headquarters Allied Powers Europe (SHAPE). This training programme offers an introduction to recently appointed NATO Flag and General Officers to the Alliance's planning process, doctrine, and policy. The exercises are conducted at the Joint Headquarters of the Latvian National Armed Forces in Riga, where the Host Nation provides the venue for both events. NATO has conducted the STPYPI exercise series for 27 years and JFTC has been responsible for its preparation and execution since 2018.

The purpose is to train senior commanders and staff officers in the planning, preparation, and execution of joint operations through the application of informed decision-making, operational art, and the operational planning process. The attendees gain a better understanding of the context and connections associated with a compre-

Credit: JFTC

Participants for EX STEADFAST PINNACLE 2022.

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hensive approach to a collective defence situation. Additionally, they actively interact with non-NATO organisations during the planning phase and learn how to effectively integrate them into their operations. Exercise STEADFAST PYRAMID is designed for senior staff officers who will support commanders during NATO operational planning and joint operations. Exercise STEADFAST PINNACLE, on the other hand, is intended for commanders selected to assume command within the NATO Command Structure (NCS) and NATO Force Structure (NFS).

JFTC provides NATO entities properly equipped facilities necessary to conduct tactical level exercises. Two such exercises were planned for this year: Exercise GRIFFIN LIGHTNING 2023, conducted in March by Multinational Corps Northeast, and Exercise CITADEL BONUS 2023, which will be executed by Rapid Reaction Corps France at the end of the year. JFTC is thus an essential training institution for the Alliance, providing a diverse range of training exercises and programmes which enhances the operational readiness of all NATO forces.

Contribution to Warfare Development

JFTC houses the only Battle Laboratory within NATO Allied Command Transformation (ACT) and possesses both the capacity and capability to promote Warfare Development based on Higher Headquarters direction and guidance.

The Centre provides support to ACT led Warfare Development Agenda (WDA) by concentrating at the joint tactical level via three Lines of Effort (LOE): Experimentation, Wargaming and Innovation. All LOE's are interconnected within overarching strategic priorities, which includes Multi- Domain Operations (MDO) and adaptation to Deterrence and Defence of the Alliance (DDA).

JFTC hosts the Coalition Warrior Interoperability Exercise (CWIX), NATO's largest annual interoperability testing event, which gathers more than 2,000 participants from 40 nations. During this event various agencies and organisations are able to collaborate, verify and validate the interoperability between various systems. This event attracts scientists, industry representatives, and military operators, from around the globe, and provides them an environment where they can explore, experiment and examine current and emerging capabilities. Additionally, it encourages innovation by identifying and addressing interoperability gaps, providing an opportunity to explore alternative approaches, and allows emerging technologies to be tested. Overall, CWIX is vital to ensuring NATO forces maintain the military advantage in an increasingly complex and uncertain global security environment.

Finally, to maximise the benefits from such events, JFTC will then link CWIX experimentation and testing to LEDA exercise series, in order to create an open continuum framework for the Alliance in order to further experimentation and testing for the benefit of NATO warfighters at the tactical level. For example, during Exercise LOYAL LEDA 2024, JFTC intends to execute six experimentation activities that range from discovery to hypothesis testing to validation.

Credit: JFTC

Experimentation and testing for warfare development are an important part of JFTC's work.

Support to JTEC

In 2015, JFTC took on the leading role in preparations for NATO-Georgia Exercise 2016, based on a non-Article 5 peacekeeping support operations scenario. After a successful execution of the event, the Centre used its experience in planning and delivering NATO training to mentor and support the newly established NATO-Georgia Joint Training and Evaluation Centre (JTEC). In 2019, JTEC directed the NATO-Georgia Exercise, and JFTC mentored them during the event. The outcome of that exercise confirmed JTEC's capability to plan and deliver a multinational brigade level command post exercise and computer assisted exercise that met NATO standards.

In 2022, JFTC and its advisors at JTEC successfully completed another iteration of the NATO-Georgia Exercise. For the second time, JTEC, supported by JFTC, was the Officer Directing Exercise. JFTC mentors assisted all key positions in the Exercise Control (EXCON) structure in order to enhance interoperability as well as to share experience, skills and knowledge. The next NATO-Georgia Exercise will be held in 2025.

Summary

Over the years, cooperation between JFTC and NATO-Georgia JTEC has evolved and developed significantly - from mentorship to partnership. The Partnership Agreement between the two centres was officially signed on 11 December 2020.

At JFTC, we live by our motto, "Transformation Through Training", and over nearly 20 years, JFTC has been instrumental in ensuring NATO forces are ready to deter and defend the Alliance against any adversary. By synthesising NATO training requirements with cutting-edge technology, state-of-the-art communication and information systems architecture and a responsive support capability, JFTC plays a critical role in the NATO transformation process.

As the geopolitical situation evolves so must NATO adapt. With the programme of work increasing year by year, JFTC aggressively organises both its workforce and infrastructure. JFTC is continuously adapting to the ever-changing realities and is ensuring they remained postured to provide the right training at the right time. In conclusion, whether through training or capability building, JFTC remains on the cutting edge of enhancing NATO's ability to project stability, deter adversaries and defend the Alliance. ■

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