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Above and Beyond: State of the Art of Uncrewed Combat Aerial Systems and Future Perspectives

edited by Elio Calcagno and Alessandro Marrone

ABSTRACT

Aerial drones have become ubiquitous on modern battlefields. However, as countermeasures and multi-layered air defences catch up to the threat, a need arises for more advanced systems able to operate against well-equipped peer- or near-peer adversaries. Uncrewed combat aerial systems (UCAS), which are conceived to satisfy this requirement, are not merely an evolution of current drones but rather a different category of aerial vehicles altogether, with distinct characteristics requiring advanced and generally much costlier technologies. Among the latter, a degree of autonomous capabilities appears to be a necessary precondition for UCAS to fulfil their potential. Systems currently in development are generally designed either as "standalone" assets able to operate independently from crewed aircraft or as "adjunct" systems made to operate collaboratively with crewed assets. Italy and Europe in general are lagging behind the state of the art when it comes to UCAS due to scarce interest after initially exploring the field in the early 2000s. For Italy and its industry, the Global Combat Air Programme for a 6th-generation combat aircraft system represents a clear opportunity to develop UCAS capabilities, though significant resources must me directed at timely R&D activities.

Defence | Italy | US | Russia | China | Turkey | Drones | Technologies | Procurement | Military policy | Military industry | Aviation

keywords

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edited by Elio Calcagno and Alessandro Marrone*

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Executive summary

Relevant operational trends in the use of armed uncrewed aerial systems

Uncrewed air systems (UAS) – also known as unmanned air vehicles (UAV) or drones –have become a recurring presence on battlefields around the globe. Since the 1980s technology has enabled the development of UAS capable of performing some routine tasks automatically, rather than autonomously, while improvements in the fields of avionics, sensors and airframes allow to equip drones with sophisticated payloads. By and large, intelligence, surveillance, and reconnaissance (ISR) missions have generally been a priority of uncrewed flight. However, the development of reusable UAS with combat payloads – both lethal and non-lethal – has increased in relevance and desirability in recent years. On the other hand, modern UAS can do far more than execute precision strikes. Today, these systems carry out a vast array of missions, which range from deploying electronic countermeasures to offering stand-off fire support for land units in conventional combat, especially for those engaged deep in hostile territory. The array of drones available on the market has also expanded significantly since the early 2000s, with small, cheap and easy to operate commercial off-the-shelf (COTS) rotary uncrewed aerial systems (RUAS) such as the DJI Mavic 3 used extensively by both Russian and Ukrainian forces.

While the use of armed UAS in asymmetric conflicts has broadly become both expected and accepted, doubts still remain over how such systems can be effectively employed in peer-to-peer conflicts, at least in the architecture and configuration originally envisaged for a the totally different scenario of counterinsurgency and stabilisation operations. Where integrated multi-layer air defence systems are in place, these represent a particular challenge to current UAS.

In 2020, the Second Nagorno-Karabakh War represented a major turning point in the deployment of armed drones. The outcome of the war was largely determined by the sheer imbalance in the military capabilities available to each side. Both countries privileged the use of uncrewed systems over risking their limited crewed fleets. Azerbaijan, however, far outmatched Armenia in this field by making an intensive use of its recently purchased fleet of 24 Turkish-made TB-2 Bayraktars.

On the other hand, the large-scale invasion of Ukraine by Russia has been the first major conventional conflict in which drones have been extensively employed by both sides. Unlike the Second Nagorno-Karabakh War, in which only Azerbaijan was able to field a substantial drone fleet, both Kyiv and Moscow have put drones at the centre of the respective combat patterns. In this conflict, armed drones play a major role, although ISR UAS and loitering munitions arguably figure even more prominently. Crucially, alongside classic MALE and HALE drones, the war has seen the opposing sides make massive use of smaller-sized RUAS, many of which are derived from COTS models.

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The advent of uncrewed combat air systems

The potential advantages of uncrewed systems in aerial warfare are clear. However, new requirements prompted by technological progress and a widespread return to peer-to-peer (or -near-peer) conflict as the main focus for military planning have caused a surge in interest and investment into more advanced systems, which are specifically designed for combat roles typical of high-intensity warfare scenarios where air space is contested by enemy air defences and fighter aircraft. These systems, which in this study will be referred to as uncrewed combat aerial systems (UCAS), represent a departure from traditional armed UAS in that they outclass these in terms of low observability, capacity for high speeds and carrying advanced combat payloads. While still costly on the whole (especially in the case of the most advanced variants), UCAS are often seen as less expensive assets than the most modern crewed combat aircraft.

Some technological hurdles must still be overcome in the coming years to achieve the required levels of performance and unlock their potential, including in the field of air-to-air combat. For instance, a UCAS must be controlled through wireless technology, mainly line-of-sight data link radio waves, meaning that the connection between the platform and operator is vulnerable to jamming-based countermeasures as well as cyber-attacks. As a result, varying degrees of autonomy are often seen as a requirement for UCAS to fulfil its potential with regard to high-intensity combat scenarios, where line of sight connections may be interrupted or degraded by enemy action or natural features for long stretches of time. Autonomy appears to be a necessary feature in order to decrease vulnerability to non-kinetic countermeasures but also, crucially, to take advantage of the much faster reaction times that artificial intelligence (AI) can offer as compared to a human pilot.

In the longer term, AI capabilities may even reach such a level of autonomy as to lead to fully autonomous assets able to independently make decisions and complete missions, though the level of technology required is still far behind. Even then, however, human operators can be expected to maintain a prominent role in setting a number of parameters relating to the operational and geographical scope of a given mission, as well as rules of engagement (ROE) and stance. Undoubtedly, the introduction of increasingly autonomous and advanced UCAS into the world's air forces is set to significantly change the field of aerial warfare in terms of doctrine and tactics, force mix, procurement and military personnel's training.

United States

The US Department of Defence (DoD) is pursuing an array of new UCAS that will contribute across a wider range of missions, but these development programmes, including the US Navy MQ-25 *Stingray* refuelling tanker and Air Force's Collaborative Combat Aircraft (CCA), have not yet transitioned into procurement.

Integration challenges appear to be the most significant impediment to US forces using uncrewed systems more extensively beyond ISR. The US military's fielded

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UAS operate as standalone systems when conducting ISR, with their sensor data going to dedicated receivers for analysis and with dedicated operators planning or controlling their missions. In circumstances when US forces use uncrewed systems for missions like Electronic Warfare or strike, the vehicle is under the direct control of an operator and largely avoids interactions with other crewed platforms or forces.

The US military is adopting concepts that will create a stronger demand for uncrewed systems to be fully integrated with the existing, mostly-crewed, force. The Joint Warfighting Concept (JWC), Distributed Maritime Operations (DMO) concept, and Joint All-Domain Command and Control (JADC2) initiative rely on distribution, adaptable force packages, and long-range effects chains connecting sensors, commanders, and weapons or electronic warfare platforms. By degrading an opponent's sensing and sense-making while affording US forces more options for offensive actions, these concepts aim to increase the US military's lethality and resilience.

The DoD is also pursuing a series of programmes that seek to expand the use of both UAS and UCAS, tailored by each US military service to its particular mission responsibilities and force design. Generally speaking, these new projects initially envision UCAS as extending the reach and capacity of crewed platforms, which may perpetuate existing vulnerabilities and be predictable to opponents. However, it is likely UCAS will increasingly be treated as independent elements of force packages and kill chains.

Five industry competitors are building demonstration vehicles under the Air Force's CCA programme, which could yield one or more baseline adjunct vehicle designs that will incorporate collaboration and autonomy technologies from the Air Force's Golden Horde and Skyborg research programmes, which were transitioned into the CCA programme in 2022.

The Navy's research and development (R&D) priority for now is the MQ-25A *Stingray* refuelling tanker, each of which would enable two strike-fighters to reach more than 1,000 nautical miles or 1,850 km from the carrier after they will join the fleet in 2026.

China and Russia

Both Russia and China have produced UCAS prototypes and studies, with the earliest seen publicly emerging in the mid-2000s, and subsequently progressed at notably different paces towards fielding operational capabilities. Despite similar doctrinal roots, the Russian Aerospace Forces (VKS) and People's Liberation Army Air Force (PLAAF) were already on notably divergent development pathways for UCAS before the Russian invasion of Ukraine in 2022. This should not come as a surprise given the radical differences in economic power, level of ambition and industrial/microelectronics capacity between the two countries.

Both the VKS and PLAAF are explicitly aiming to have combat-ready production-standard UCAS forming a part of their force structures within only a few years. The requirement for high levels of in-flight automation to avoid the vulnerabilities inherent in reliance on datalinks or satellite communication for real time control in a heavily contested electromagnetic environment creates significant challenges for developers in terms of sensor, avionics, mission system and space-weight-power and computing (SWAP-C) constraints.

China's industry is likely to be in a much better position to solve such challenges than Russia's, which will likely allow Chinese UCAS to be more flexible in terms of the mission sets that they can credibly be relied on for in high-intensity combat. However, this automation also allows expansion of UCAS fleet numbers to be largely an industrial challenge as opposed to a linked industrial and pilot-training pipeline one. Given that the VKS and the PLAAF have always struggled to match the quality of pilot training and the flexibility of mission command that Western air forces can field, UCAS may be even more attractive in future as a way of boosting aerial combat power for Russia and China than they are for the US and its allies.

Turkey

Turkey's drone warfare strategy and doctrine, at large, has taken shape during the Turkish military's operations in Syria. Between 2016 and 2020, Turkey launched four consecutive campaigns beyond its southern borders, by gradually increasing the use of robotic warfare systems. Ankara has employed its burgeoning armed UAS arsenal in a broad array of combat operations, including counterterrorism missions against ISIS and the PKK network, as well as incursions against the Syrian Arab Armed Forces.

Turkey's major uncrewed systems makers, Baykar and TUSAS, are currently pursuing a CCA design. These concepts, Kizilelma and Anka-3, respectively, revolve around the ongoing development of UCAS that can operate alongside crewed aircraft. They are powered by turbofan engines and will be equipped with advanced arms, including beyond-visual-range air-to-air missiles and land-attack capabilities of cruise missiles and aero-ballistic missiles. These assets also come with a reduced radar cross-section mainly attributed to the platforms' geometric design and internal weapons bay.

The European context

Despite early efforts suggesting the contrary, Europe has traditionally shown a significant delay in the development and acquisition of armed and unarmed UAS. This was due to several factors including, but not limited to, peculiar operational requirements, industrial rivalries and ethical qualms.

UCAS-based technological demonstrators have been pursued since the early 2000s in different countries, including Italy and France. In 2006 an industrial consortium led by Dassault Aviation (France), with the collaboration of Leonardo (Italy), Saab

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(Sweden), Airbus Defence and Space (Spain), RUAG (Switzerland) and the Hellenic Aerospace Industry (Greece), joined forces with the goal to develop nEUROn – a ground-breaking drone demonstrator with low observability, speed and payload capabilities. Despite the steep R&D costs required to achieve an advanced UCAS, complete with a degree of autonomous capabilities, a follow-on of the nEUROn never materialised. Noticeably, also feasibility studies for a joint programme by France and the UK, building respectively on the nEUROn and the British Taranis programme, failed to come to fruition.

The development of UCAS in Europe currently seems mainly centred around advanced systems that are highly integrated and networked with crewed 6th-generation combat aircraft, respectively Global Combat Air programme (GCAP) and Future Combat Air System (FCAS) in a SoS framework. In such a context, a level of fragmentation is expected, as the two competing programmes are unlikely to merge. Furthermore, an important challenge will be the integration of CCA platforms designed in the context of 6th-generation air system programmes with existing combat aircraft from the fourth and fifth generations. In this respect, interoperability is a key priority on multiple levels, and especially between new European UCAS and F-35 aircraft.

By and large, as evident from current development programmes and operational concepts, Europeans conceive future UCAS as parts of a larger combination of crewed and uncrewed next generation platforms, rather than as standalone systems. Indeed, albeit in a somewhat fragmented manner, European states have been in the process of developing and exploring the concept of CCA as the preponderant channel to develop UCAS.

Italy

Italy was one of the first countries to procure US-made RQ-1 Predator drones, with the first order (worth 55 million US dollars) of five units placed in 2001 and delivered to the Italian Air Force (*Aeronautica Militare*, AM) in 2004. The issue of arming UAS has been politically sensitive in Italy, with Rome making a formal request to Washington in 2012 to fit its MQ-9 with weapons. The request was subsequently approved in 2015, at the time making Italy only the second country worldwide after the UK to be granted permission to arm US drones.

As in most European countries, Italy's standing in terms of both advanced UAS and UCAS technology is today some way behind the state of the art and, in terms of the former, hitherto largely dependent on off-the-shelf acquisitions mainly from the US. Especially in terms of UCAS, much remains to be done in order to generate the necessary amounts of R&D to position Italian know-how well in the framework of current and future cooperative programmes. On the industry's side, Leonardo has made important investments in technologies crucial for the design and development of both 6th-generation platforms and UCAS.

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Italy's stake in the GCAP programme therefore represents a great opportunity for the country's defence industry to further develop the necessary technical know-how in the field of UCAS. As with other countries already looking into 6th-generation capabilities, GCAP participants will work for future CCA to be backward compatible with current combat aircraft designs. This is especially important in the case of the F-35, which will serve in air forces around the world for roughly another 30 years and will have to be networked with future combat capabilities including 6th-generation systems. The level of system integration that is required for UCAS and crewed aircraft to operate alongside each other means that the US will play a crucial role in opening the F-35 system architecture to foreign-made technology should the GCAP countries seek to work on a new UCAS design without Washington. With Italy, Japan and the UK all in possession of F-35, and as close partners of the US, Rome is certainly in a strong negotiating position in any discussions on this potentially thorny issue.

Conclusions

Building on the analysis presented in this study, ten key elements are worth underlining on UCAS from a European and Italian points of view:

1. The advantages of uncrewed systems
2. The difference between current armed drones and future UCAS
3. The human-in-the-loop approach to UCAS
4. The shift towards high-intensity, large scale conflicts scenarios
5. A cost-effective, high-low force mix
6. A system of systems including crewed aircraft and adjuncts
7. The choice of European cooperation
8. GCAP as the Italian way for UCAS development
9. Italy's stepping stone for UCAS transformation
10. The integration of non-US UCAS with the F-35

1. Relevant operational trends in the use of armed uncrewed aerial systems

by Michelangelo Freyrie[1]

1.1 The birth of armed drones and their early use

Uncrewed aerial systems (UAS), also known as unmanned aerial vehicles (UAV) or drones, have become a recurring presence on battlefields around the world.[2] Since the 1980s, technology has enabled the development of UAS capable of performing some routine tasks automatically, rather than autonomously, while improvements in the fields of avionics, sensors and airframes allow to equip drones with sophisticated payloads. Intelligence, surveillance, and reconnaissance (ISR) missions have generally been a priority of uncrewed flight. However, the development of reusable UAS with combat payloads – both lethal and non-lethal – has increased in relevance and desirability in recent years.

Larger, fixed-wing military drones today are generally piloted by human crews from ground control stations (GCS), which may be fixed or portable; hence, in this category, each UAS is composed of one or multiple vehicles and a GCS. The development of modern fixed-wing, military UAS has been spearheaded by the United States, which has also been the first country to employ this platform on a large scale during the Global War on Terror. While aerial drones had seen action before (in the Vietnam war, for instance),[3] the first known armed UAS to be used extensively were built upon existing technology and responded to the very specific operational requirements of US forces in the conflicts of 2000s and 2010s in Middle East, Central Asia and Africa. General Atomics' MQ-1 Predator medium-altitude, long-endurance (MALE) drone, for instance, was initially designed and employed for ISR purposes in permissive environments. However, during the hunt for Bin Laden, it became evident that an armed version of the MQ-1 itself would be the only tool that could promptly act upon the real-time intelligence it collected, significantly shortening the kill-chain.[4] From 2002 onwards, the MQ-1 was equipped with laser-guided Air-to-Ground M-114 Hellfire missiles[5] and, like its successor MQ-9 Reaper,

[1] Michelangelo Freyrie was until September 2023 a Junior Researcher in the Defence and Security Programmes at IAI.

[2] For the purpose of this study, we will not consider loitering munition and will only focus on UAS designed for re-entry and equipped with kinetic or electronic combat payloads.

[3] David Axe, "To Save Crews from Deadly Missiles Over Vietnam, The U.S. Air Force Sent Drones on Daring Suicide Missions", in *Forbes*, 28 August 2021, https://www.forbes.com/sites/davidaxe/2021/08/28/to-save-crews-from-deadly-missiles-over-vietnam-the-us-air-force-sent-drones-on-daring-suicide-missions.

[4] Richard Whittle, "Predator's Big Safari", in *Mitchell Papers*, No. 7 (August 2011), p. 22-23, https://secure.afa.org/Mitchell/reports/MP7_Predator_0811.pdf.

[5] US Air Force (USAF) website: *MQ-1B Predator*, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104469/mq-1b-predator/M.

has become a centrepiece[6] of counter-terrorism operations in Afghanistan, as well as the Sahel and the Middle East and North Africa (MENA) region.[7]

However, advanced modern UAS can do far more than execute precision strikes. Today, these systems carry out a vast array of missions, which range from deploying electronic countermeasures to offering stand-off fire support for land units in conventional combat,[8] especially for those engaged deep in hostile territory.[9]

The array of drones available on the market has also expanded significantly since the early 2000s, with small, cheap and easy to operate commercial off-the-shelf (COTS) rotary uncrewed aerial systems (RUAS) such as the DJI Mavic 3 used extensively by both Russian and Ukrainian forces.[10] While tens of thousands of this kind of drones have been used in the Ukraine conflict, most military fixed-wing UAS usually fall under NATO's weight-based Class-III designation, meaning that they weigh over 600 kg. Class-III UAS are often MALE or high-altitude, long-endurance (HALE) drones which can fly above 18,000 ft and can be operated beyond the operator's line of sight (BLOS).[11] However, under the umbrella designation, there is quite some variability in terms of velocity and maximum altitude. This is a by-product of local operational requirements, technological prowess and designated payloads. The Turkish TB-2 Bayraktar, for instance, was initially developed for counter-insurgency operations in Turkey and was later employed for counter-artillery missions and close air support in Syria.[12] The small Russian Forpost-R, on the other hand, is an indigenised version of the Israeli Searcher 2 tactical UAS.[13] Across the board, a common feature of modern UAS is that they benefit from the automatisation of navigation (automatic take-off and landing, also known as ATOL, navigation points and ground avoidance) and some identification systems.[14]

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[6] Jessica Moody, "Drones Aren't the Sahel's Silver Bullet", in *Foreign Policy*, 14 June 2023, https://foreignpolicy.com/2023/06/14/sahel-western-africa-drones-jihad-ethiopia-mali-burkina-faso-niger.

[7] See: James Michael Page and John Williams, "Drones, Afghanistan, and Beyond: Towards Analysis and Assessment in Context", in *European Journal of International Security*, Vol. 7, No. 3 (August 2022), p. 283-303, https://doi.org/10.1017/eis.2021.19; Sarah Kreps and Paul Lushenko, "US Faces Immense Obstacles to Continued Drone War in Afghanistan", in *Brookings Commentaries*, 19 October 2021, https://www.brookings.edu/?p=1526311.

[8] Jessica Moody, "Drones Aren't the Sahel's Silver Bullet", cit.

[9] AFP, "French Army Deploys Drone Strike for First Time in Mali Operation", in *The Guardian*, 23 December 2019, https://www.theguardian.com/p/dx9hk.

[10] Sidharth Kaushal, Justin Bronk and Jack Watling, "Pathways towards Multi-Domain Integration for UK Robotic and Autonomous Systems", in *RUSI Occasional Papers*, October 2023, https://www.rusi.org/explore-our-research/publications/occasional-papers/pathways-towards-multi-domain-integration-uk-robotic-and-autonomous-systems.

[11] Cfr. Osman Aksu et al., *A Comprehensive Approach to Countering Unmanned Aircraft Systems*, Kalkar, Joint Air Power Competence Centre, p. 511, https://www.japcc.org/books/a-comprehensive-approach-to-countering-unmanned-aircraft-systems.

[12] For more on Turkey's approach to UAVs and uncrewed combat aerial systems (UCAS), see chapter 5 of this study.

[13] Miko Vranic, "Ukraine Conflict: Russia Employs Forpost-R UCAV", in *Janes*, 15 March 2022, https://www.janes.com/defence-news/news-detail/ukraine-conflict-russia-employs-forpost-r-ucav.

[14] At time of writing no UCAS has been reported as employing AI to fire its ordinance, with the only

Table 1 | Example of UAS currently in use

	Max altitude (ft)	Max take-off weight (kg)	Payload capacity (kg)	Max speed (knots)	Price range (million $)[15]
Heron-TP[16]	> 45,000	5,670	2,700	220	1-40[17]
MQ-9 Reaper[18]	50,000	4,760	1,700	240	32-150[19]
TB-2 Bayraktar[20]	25,000	700	150	120	2-6[21]
Wing Loong[22]	16,000	1100	200	151	1-2[23]

recorded cases pertaining loitering munition. See: Aleksa Filipović, "Lethal Autonomous Weapon Systems (LAWS) – Towards Global Regulation or Indiscriminate Employment?", in Политичка Ревија [*Political Review*], Vol. 75, No. 1 (January 2023), p. 211-232, https://doi.org/10.5937/polrev75-43187.

[15] The price tag depends on payload, the acquisition of related systems (like command and control stations, specific variants).

[16] Israel Aerospace Industries (IAI) website: *Heron TP*, https://www.iai.co.il/node/77.

[17] AFP, "Turning to Israel, Germany to Get Weaponized Drones for the First Time", in *The Times of Israel*, 6 April 2022, https://www.timesofisrael.com/turning-to-israel-germany-to-get-weaponized-drones-for-the-first-time; Ben Knight, "Why Does Germany Want Armed Drones?", in *Deutsche Welle*, 31 May 2018, https://www.dw.com/en/a-44025798; Manu Pubby, "Government Approves $400-Million Plan to Procure Armed Heron TP Drones from Israel", in *The Economic Times*, 14 July 2018, https://economictimes.indiatimes.com/articleshow/48906195.cms.

[18] USAF website: *MQ-9 Reaper*, https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104470/mq-9-reaper.

[19] See: Stockholm International Peace Research Institute (SIPRI) website: *Trade Registers*, https://armstrade.sipri.org/armstrade/page/trade_register.php; "General Atomics Gets $188.8m for MQ-9B Deliveries to Belgium", in *Defense Brief*, 16 August 2020, https://defbrief.com/?p=5247; Military Today website: MQ-9 Reaper, https://www.militarytoday.com/aircraft/mq9_reaper.htm; "United States Approves $600m Sale of Armed Drones to Taiwan", in *Al Jazeera*, 4 November 2020, https://www.aljazeera.com/news/2020/11/4/united-states-approves-600m-sale-of-armed-drones-to-taiwan; USAF website: MQ-9 Reaper, cit.; David Hambling, "Why The Air Force Needs a Cheaper Reaper", in *Forbes*, 10 June 2020, https://www.forbes.com/sites/davidhambling/2020/06/10/why-the-air-force-needs-a-cheaper-reaper.

[20] Baykar website: *Bayraktar TB2*, https://www.baykartech.com/en/uav/bayraktar-tb2.

[21] Ragip Soylu, "Bayraktar TB2: Kuwait Purchases Turkish-made Drones in $370m Deal", in *Middle East Eye*, 18 January 2023, https://www.middleeasteye.net/node/275921; Military Today website: *Bayraktar TB2*, https://www.militarytoday.com/aircraft/bayraktar_tb2.htm; Nick El Hajj, "Kuwait to Buy Turkish-made TB2 Drones in $367 Million Deal", in *Defense News*, 14 June 2023, https://www.defensenews.com/unmanned/2023/06/14/kuwait-to-buy-turkish-made-tb2-drones-in-367-million-deal; Jo Harper, "Looking behind Poland's Purchase of Turkish Drones", in *Deutsche Welle*, 7 June 2021, https://www.dw.com/en/a-57775109; SIPRI website: *Trade Registers*, cit.

[22] "Wing Loong Unmanned Aerial Vehicle (UAV)", in *Airforce Technology*, 2 February 2021, https://www.airforce-technology.com/?p=4896.

[23] Ben Brimelow, "Chinese Drones May Soon Swarm the Market — and That Could Be Very Bad for the US", in *Business Insider*, 16 November 2017, https://www.businessinsider.com/chinese-drones-swarm-market-2017-11; Zaheena Rasheed, "How China Became the World's Leading Exporter of Combat Drones", in *Al Jazeera*, 24 January 2023, https://www.aljazeera.com/news/2023/1/24/how-china-became-the-worlds-leading-exporter-of-combat-drones; Atul Chandra, "Why China's Armed UAVs Are a Global Export Success, and Its Fighter Jets, Not So Much", in *Defence Procurement International*, 5 November 2021, https://www.defenceprocurementinternational.com/features/air/china-has-disrupted-the-military-drone-market.

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The wide proliferation of military UAS witnessed in recent years has not yet led to a much broader geographic distribution of production, although some important countries have invested much in their industrial capabilities (i.e. Iran and Turkey) and become exporters.[24] In some cases, the lack of skilled personnel, such as engineers, has hampered the ability to produce indigenous advanced UAS designs.[25] On the other hand, many advanced countries with the necessary technological and industrial know-how have failed to keep up with the state of the art due mainly to a lack of investment or political will in the face of controversy. As a result, despite global use, the more advanced UAS are still primarily designed and assembled by powers with the political leeway to do so and benefit from competent defence industrial and technological bases such as the US, China and Israel. Some actors, such as Turkey and the Gulf countries, heavily invested in local production with the explicit purpose of using UAS export as a tool of military diplomacy;[26] while key countries such as India[27] and Russia[28] have on the contrary encountered major difficulties in industrialising indigenous designs.

Until recently, the Missile Technology Control Regime (MTCR) regime had restricted the sale of drones capable of delivering 500 kg payloads to a range of over 300 km by adhering countries (including the US and Italy). However, in 2020 the US announced it would reinterpret the guidelines to sell more drones to its partners by considering drones that fly at speeds lower than 800 km/h as belonging to a category subject to fewer restrictions.[29] In theory, this may imply that Washington still intends to avoid exporting faster drones (likely belonging to the UCAS category) except in rare cases and only to its closest and most trusted allies.

In the early 2000s, researchers outlined the potential operational advantages of drones, which at that time was a technology considered still in its infancy. They saw the persistence and long range of fixed-wing UAS as particularly promising, as well as the possibility of freeing crewed aircraft from routine missions and providing permanent fire support to ground forces.[30] Over the years, some additional advantages have emerged. ISR and armed UAS remain relatively expendable: they cost significantly less than crewed aircraft (both in terms of

[24] Interview, 11 September 2023.

[25] Interview, 28 August 2023.

[26] For an analysis of Turkey's approach to the development and use of UAS and UCAS see chapter 5 of this study. See: Federico Borsari, "Tools of Influence: Drone Proliferation in the Middle East and North Africa", in *ECFR Commentaries*, 27 May 2022, https://ecfr.eu/article/tools-of-influence-drone-proliferation-in-the-middle-east-and-north-africa.

[27] "Uncrewed Innovation in the Asia-Pacific", in *Airforce Technology*, 28 April 2023, https://www.airforce-technology.com/?p=237285.

[28] Roger McDermott, "Russia's UAVs and UCAVs: ISR and Future Strike Capabilities", in *Jamestown Publications*, 23 March 2022, https://jamestown.org/?p=92155.

[29] Paul K. Kerr, "U.S.-Proposed Missile Technology Control Regime Changes", in *CRS In Focus*, 10 May 2022, https://crsreports.congress.gov/product/details?prodcode=IF11069.

[30] Charles L. Barry and Elihu Zinet, "UCAVs—Technological, Policy, and Operational Challenges", in *Defense Horizons*, No. 3 (October 2001), http://www.dtic.mil/docs/citations/ADA421937.

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procurement price tags and cost-per-flying-hours),[31] and are thus expendable and apt for massive employment. Moreover, they put significantly less strain on the pool of available pilots than crewed platforms: drone operators are not only out of harm's way, but also require less training time and can accumulate more flight hours than traditional combat pilots.[32] In some cases, drones have also provided a degree of plausible deniability in covert operations and unconventional conflicts, while at the same time delivering strategic effects, if skilfully operated. Strikes against Saudi pipelines and oil deposits in 2019,[33] as well as the targeting of PMC Wagner strongpoints in Libya by unknown armed UAS as recently as 2022,[34] point to the usefulness of such systems in asymmetric and grey-zone scenarios.

1.2 The use of armed UAS in Nagorno-Karabakh and Ukraine

While the use of armed UAS in asymmetric conflicts has broadly become both expected and accepted, doubts still remain on how such systems can be effectively employed in peer-to-peer conflicts, at least in the architecture and configuration originally envisaged for a totally different scenario of counterinsurgency and stabilisation operations. Where integrated multi-layer air defence systems are in place, these represent a particular challenge to uncrewed aerial systems.[35] Two wars that have recently seen the employment of drones are the Second Nagorno-Karabakh War between Armenia and Azerbaijan (September-November 2020) and Russia's ongoing, large-scale invasion of Ukraine initiated in February 2022.

1.2.1 Second Nagorno-Karabakh War

The Second Nagorno-Karabakh War represented a significant turning point in the deployment of armed drones. The war's outcome was largely determined by the sheer imbalance in the military capabilities available to each side; that said, the impact of UAS captivated the wider public and experts alike, influencing successive research and reflection on the impact of drones in peer-to-peer wars. Both countries privileged the use of uncrewed systems over risking their limited crewed fleets.[36] Azerbaijan, however, far outmatched Armenia in this field by

[31] Congressional Budget Office, *Usage Patterns and Costs of Unmanned Aerial Systems*, June 2021, https://www.cbo.gov/publication/57260.

[32] Justin Bronk, "The Impact of Unmanned Combat Aerial Vehicles on Strategic Stability", in Vincent Boulanin (ed.), *The Impact of Artificial Intelligence on Strategic Stability and Nuclear Risk. Vol. I: Euro-Atlantic Perspectives*, Stockholm, SIPRI, 2019, p. 99-104, https://www.sipri.org/node/4808.

[33] Anthony H. Cordesman, "Iran, Yemen, and the Strikes on Saudi Arabia: The Changing Nature of Warfare", in *CSIS Commentaries*, 18 September 2019, https://www.csis.org/node/54035.

[34] Beatrice Farhat, "Wagner Base in Eastern Libya Hit by 'Unknown' Drone Strike", in *Al-Monitor*, 30 June 2023, https://www.al-monitor.com/node/58120.

[35] See in this regard the IAI study on short range air defence: Ottavia Credi et al., "Short Range Air Defence: Operational and Technological Developments", in *Documenti IAI*, No. 22|07 (September 2022), https://www.iai.it/en/node/15971.

[36] See: Douglas Barrie et al., "Armed Uninhabited Aerial Vehicles and the Challenges of Autonomy", in *IISS Research Papers*, December 2021, https://www.iiss.org/research-paper/2021/12/armed-uninhabited-aerial-vehicles-and-the-challenges-of-autonomy.

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making intensive use of its recently purchased fleet of 24 Turkish-made TB-2 Bayraktars.[37] The TB-2s were employed in a variety of missions, such as strikes against ground lines of communication (GLOCs) and military infrastructure deep in the Armenian rear. Attacks against Armenian ground-based air defences (GBAD) have also been particularly discussed:[38] impressively, the Bayraktars were able to conduct suppression and destruction of enemy air defences (SEAD/DEAD) missions, often working in conjunction with obsolete UAS. To this end, Azerbaijan refitted some old Antonov AN-2 propeller biplanes with basic munitions and ISR gear. Their extremely low cost made these armed UAS expendable and adequate for risky SEAD/DEAD missions: even when the AN-2 were shot down, they revealed the position of enemy GBAD, promptly struck by other drones or by loitering munitions.[39] Finally, TB2 were also effective in counter-artillery operations and the elimination of Armenian armoured vehicles,[40] showing to be particularly valuable in a combined-arms framework. The propagandistic use of the live feeds captured by the TB-2's camera was also a notable innovation with an intangible psychological impact.[41] Overall, the relatively low cost of Azerbaijani UAS meant that Baku could easily endure significant rates of attrition.[42] For a rough idea of the cost of TB systems for Azerbaijan one can take as example a 2022 deal with Romania, in which three TB-2 systems were sold for 321 million US dollars. Each system included six drones, two GCS, as well as the avionics suites and weaponry.[43] Drones allowed Azerbaijani forces to conduct combined arms warfare for cheap, although little information exists on to what extent ground forces were actually able to synchronise with drone missions.[44] The TB-2 was especially proficient when used in a combined arms context: SEAD/DEAD missions were likely supported by extensive use of Turkish-made EW systems to jam and deceive Armenian radars, further impairing Armenia's response.[45]

However, one should be careful not to generalise possible lessons drawn from the performance of Azerbaijani UAS. Part of its success was due to Armenian tactical

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[37] Jon Lake, "Azerbaijan Exercises with Turkish Drones", in *Times Aerospace*, 4 January 2022, https://www.timesaerospace.aero/news/training/azerbaijan-exercises-with-turkish-drones.

[38] Shaan Shaikhand and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense", in *CSIS Critical Questions*, 8 December 2020, https://www.csis.org/node/59145.

[39] Seth G. Jones et al., *Combined Arms Warfare and Unmanned Aircraft Systems. A New Era of Strategic Competition*, Lanham, Rowman & Littlefield, 2022, p. 9-15, https://www.csis.org/node/67704.

[40] Eado Hecht, "Drones in the Nagorno-Karabakh War: Analyzing the Data", in *Military Strategy Magazine*, Vol. 7, No. 4 (Winter 2022), p. 31-37, https://www.militarystrategymagazine.com/article/drones-in-the-nagorno-karabakh-war-analyzing-the-data.

[41] Hülya Kinik and Sinem Çelik, "The Role of Turkish Drones in Azerbaijan's Increasing Military Effectiveness: An Assessment of the Second Nagorno-Karabakh War", in *Insight Turkey*, Vol. 23, No. 4 (Fall 2021), p. 169-191, https://doi.org/10.25253/99.2021234.10.

[42] Seth G. Jones et al., *Combined Arms Warfare and Unmanned Aircraft Systems*, cit.

[43] "La Romania acquista diciotto UAS/UCAV TB2 Bayraktar", in *Ares Osservatorio Difesa*, 26 April 2023, https://aresdifesa.it/?p=40365.

[44] Ibid.

[45] Douglas Barrie et al., "Armed Uninhabited Aerial Vehicles and the Challenges of Autonomy", cit.

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and operational errors, as well as the semi-permissive environment over Nagorno-Karabakh in terms of EW and air defences.[46] In particular, Armenian GBAD was unfit for counter-UAS (C-UAS) purposes.[47] Moreover, troops did not maintain adequate operational security, e.g. by scattering their armoured formations and appropriately camouflaging their positions. Finally, the TB-2 also proved far less effective when confronted with adverse weather.[48]

1.2.2 Russian invasion of Ukraine

The large-scale invasion of Ukraine by Russia has been the first major conventional conflict in which drones have been extensively employed by both sides. Unlike the Second Nagorno-Karabakh War, in which only Azerbaijan was able to field a substantial drone fleet, both Kyiv and Moscow have put drones at the centre of their respective combat patterns. Armed drones play a major role, although ISR UAS and loitering munitions arguably figure even more prominently. Crucially, alongside classic MALE and HALE drones, the war has seen the opposing sides make massive use of smaller-sized RUAS, many of which are derived from COTS models. Each side has suffered extensive losses across the spectrum of UAS (armed and unarmed): as of writing, Ukrainian losses are estimated to amount to 10,000 UAS.[49] Inevitably, the great majority of these losses will fall under the small, commercially available UAS such as the DJI Mavic 3.[50]

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[46] Antonio Calcara et al., “Why Drones Have Not Revolutionized War: The Enduring Hider-Finder Competition in Air Warfare”, in *International Security*, Vol. 46, No. 4 (Spring 2022), p. 130-171, https://doi.org/10.1162/isec_a_00431.

[47] Julian Cooper, “The Nagorno-Karabakh War: A Spur to Moscow’s UAV Efforts?”, in *IISS Research Papers*, March 2021, https://www.iiss.org/research-paper//2021/03/nagorno-karabakh-war-moscow-uav-efforts.

[48] Joël Postma, “Drones over Nagorno-Karabakh”, in *Atlantisch Perspectief*, Vol. 45, No. 2 (2021), p. 15-20, https://www.atlcom.nl/?p=10347.

[49] Jack Watling and Nick Reynolds, “Meatgrinder: Russian Tactics in the Second Year of Its Invasion of Ukraine”, in *RUSI Special Reports*, 19 May 2023, https://rusi.org/explore-our-research/publications/special-resources/meatgrinder-russian-tactics-second-year-its-invasion-ukraine.

[50] Jakub Janovsky et al., “Attack on Europe: Documenting Ukrainian Equipment Losses During the Russian Invasion of Ukraine”, in *Oryx*, as of 7 August 2023, https://www.oryxspioenkop.com/2022/02/attack-on-europe-documenting-ukrainian.html.

Table 2 | Ukrainian-produced UAS

	Max altitude (ft)	Max take-off weight (kg)	Payload capacity (kg)	Max speed (knots)
UJ-22 Airborne[51]	16,000	unknown	20	107
PD-1[52]	9,842	45 kg	7	75
Punisher[53]	>1,300	unknown	3	105

The Ukrainian Armed Forces (*Zbroini Syly Ukrainy*, ZSU) have been relatively late, but eventually enthusiastic, adopters of armed drones. The first recorded successful MALE UAS employment dates back to late 2021, when Ukrainian forces performed various counter-artillery strikes against Russian proxies in Donbass using TB-2 Bayraktars.[55] Kyiv's purchase and employment of Bayraktars was particularly publicised in the first phases of the full-scale Russian invasion. The initial series of successful TB-2 strikes, whose videos were especially valuable in terms of propaganda,[56] proved however ephemeral. After the chaotic first weeks of operations, Russian EW and air defences became more organised and adapted to the Ukrainian use of UAS. At the same time, combat aircraft and helicopters can also be used in anti-drone roles, with larger drones particularly vulnerable to cannon fire or air-to-air missiles. While fast-flying combat aircraft might struggle to target slow-moving or hovering UAS or RUAS, helicopters could be better suited. Indeed, some unconfirmed reports claimed that Russian Mi-28 attack helicopters have been used to hunt and neutralise Ukrainian drones.[57] The low-flying and slow Bayraktar proved vulnerable enough to force the Ukrainians to limit its employment to ISR missions, away from the more immediate line of fire.[58] Still, Kyiv recognises that the Bayraktar still has a future in the ZSU, with a production site currently under construction on Ukrainian territory.[59]

[51] Eric Sof, "UKRJET UJ-22 Airborne: Ukraine's Versatile Drone for Military Operations", in *Spec Ops Magazine*, 27 April 2023, https://special-ops.org/uj-22-airborne-drone.

[52] Military Today website: *UKRJET UJ-22 Airborne*, https://www.militarytoday.com/aircraft/uj_22.htm.

[53] "PD-1 Unmanned Aerial System", in *Airforce Technology*, 4 April 2017, https://www.airforce-technology.com/?p=5216.

[54] Alia Shoaib, "Ukraine's Army Is Using a Nimble 'Game-Changing' Drone Called The Punisher That Has Completed Scores of Successful Missions Against the Russians, Say Reports", in Business Insider, 5 March 2022, https://www.businessinsider.com/ukraines-punisher-drones-hit-russian-troops-multiple-times-reports-2022-3.

[55] Warsaw Institute, "Ukraine Uses Bayraktar TB2 for First Time in Donbas", in *Russia Monitor*, 27 October 2021, https://warsawinstitute.org/?p=54603.

[56] See, for instance: Kronika24.pl, "Bayraktar - Ukrainian War Song", in *YouTube*, 23 May 2022, https://youtu.be/S3FGWPMjl6M.

[57] David Axe, "Can Russia's Mi-28 Gunships Protect Russia's Ka-52 Gunships from Ukraine's Drones?", in *Forbes*, 8 September 2023, https://www.forbes.com/sites/davidaxe/2023/09/08/can-russias-mi-28-gunships-protect-russias-ka-52-gunships-from-ukraines-drones.

[58] Alia Shoaib, "Bayraktar TB2 Drones Were Hailed as Ukraine's Savior and the Future of Warfare. A Year Later, They've Practically Disappeared", in *Business Insider*, 28 May 2023, https://www.businessinsider.com/turkeys-bayraktar-tb2-drones-ineffective-ukraine-war-2023-5.

[59] Dinara Khalilova, "Minister: Factory to Produce Bayraktar Drones under Construction in Ukraine",

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In the early stages of the war, Ukraine reportedly requested the supply of advanced US drones without success.[60] Despite some bipartisan calls to transfer MQ-1C Grey Eagle UAS,[61] so far Washington's approach has focused on the supply of loitering munitions and smaller ISR drones such as the Puma and the ScanEagle.[62] Despite not having access to more advanced Western-made drones, Ukrainian forces have nevertheless developed alternative ways to successfully deploy UAS to the battlefield. In October 2021, the Ukrainian Ministry of Defence (MoD) reformed an IT unit, dubbed Aerorozvidka, specialised in the innovative use of UAS:[63] this unit repurposed COTS drones, especially small heavy-duty quadcopters,[64] to drop mortar rounds and grenades during hit-and-runs against the advancing Russian armoured columns. Ukrainian companies have also produced innovative indigenous designs. Among these is the small-sized Punisher, developed by UA Dynamics and used by the Ukrainian special operation forces (SOF).[65] With a cruise speed of 78 kilometres per hour (km/h), and a maximum of 198 km/h, the electric UAS has a wingspan of only three metres and is designed to penetrate enemy lines up to 50 km with up to 3 kg of explosives[66] (75-mm unguided high-explosive bombs).[67] Reportedly, the Punisher operates in conjunction with Spectre-1 ISR drones, which are used to acquire targets.[68] The Punisher has allegedly seen ample use against Russian GLOCs and stationary infrastructure in the Russian rear.[69] Another notable Ukrainian drone is UJ-22 Airborne, developed by Ukrjet as a

in *The Kyiv Independent*, 10 July 2023, https://kyivindependent.com/minister-factory-to-produce-bayraktar-drones-under-construction-in-ukraine.

[60] Gordon Lubold and Nancy A. Youssef, "U.S. Refuses Advanced Drones for Ukraine to Avoid Escalation with Russia", in *The Wall Street Journal*, 9 November 2022, https://www.wsj.com/articles/u-s-wont-give-ukraine-advanced-drones-to-avoid-escalation-with-russia-11668042100.

[61] Bryant Harris, "Senators Urge Pentagon to Send Advanced Gray Eagle Drones to Ukraine", in *Defense News*, 22 November 2022, https://www.defensenews.com/congress/2022/11/22/senators-urge-pentagon-to-send-advanced-gray-eagle-drones-to-ukraine.

[62] US Department of Defense, *Fact Sheet on U.S. Security Assistance to Ukraine*, 20 November 2023, https://media.defense.gov/2023/Nov/20/2003344157/-1/-1/1/202311017_UKRAINE_FACT_SHEET_PDA_51.PDF.

[63] Julian Borger, "The Drone Operators Who Halted Russian Convoy Headed for Kyiv", in *The Guardian*, 28 March 2022, https://www.theguardian.com/p/y5ttb.

[64] Charlie Parker, "Specialist Ukrainian Drone Unit Picks Off Invading Russian Forces as They Sleep", in *The Times*, 18 March 2022, https://www.thetimes.co.uk/article/specialist-drone-unit-picks-off-invading-forces-as-they-sleep-zlx3dj7bb.

[65] "Special Operations Forces of the Armed Forces of Ukraine Will Be Armed with Ukrainian PUNISHER UAVs", in *The Odessa Journal*, 17 April 2022, https://odessa-journal.com/public/special-operations-forces-of-the-armed-forces-of-ukraine-will-be-armed-with-ukrainian-punisher-uavs.

[66] Larisa Brown, "Game-changing' Drones Helping Ukraine in Battle for the Skies", in *The Times*, 2 March 2022, https://www.thetimes.co.uk/article/game-changing-drones-helping-ukraine-in-battle-for-the-skies-lg68l8xjw.

[67] Militarnyi, *The SOF Operators Use Punisher Drone Against Mortars of the Russian Federation*, 2 November 2022, https://mil.in.ua/?p=177060.

[68] Igor Kossov, "A Game of Drones: Ukraine Builds up UAV Fleet", in *The Kyiv Independent*, 26 July 2022, https://kyivindependent.com/a-game-of-drones-ukraine-builds-up-uav-fleet.

[69] Brent M. Eastwood, "Why the Russian Military Hates Ukraine's Punisher Drone", in *19FortyFive*, 15 March 2022, https://www.19fortyfive.com/?p=42348.

multirole UAS that can also carry out strike emissions, including against tanks. It is reportedly capable of automatically releasing its payload against pre-inserted coordinates. Russian experts, as well as Western media, suspect a variant of the UJ-22 has been used to carry out various strikes against Russian cities, including Moscow.[70]

Table 3 | Russian-produced UAS

	Max altitude (ft)	Max take-off weight (kg)	Payload capacity (kg)	Max speed (knots)
Orion[71]	26,200	1,100	350	134
Forpost-R[72]	20.000	500	120[73]	unknown
Orlan-10[74]	16,400	16.5	4	80
Lastochka-M[75]	unknown	> 5	> 0.3[76]	64

The Russian Federation has also employed various types of UAS throughout the conflict, although it has proven less capable of adapting to the circumstances by producing new models. Russia has long had issues scaling up its production of reusable drones, which however have been expected to play an ever growing role in Russian military doctrine after the 2008 reforms.[77] For instance, there has been only a handful of cases of Orion and Korsar systems being deployed in Ukraine,[78] and at time of writing the Russian MoD published only one video showing a successful Orion strike.[79] To fill this gap, Moscow has reportedly modified at least some of its Orlan-10s, the workhorse of Russia's ISR UAS fleet, with pods for generic 40 mm VOG-25P fragmentation grenades.[80]

[70] Eric Sof, "UKRJET UJ-22 Airborne", cit.

[71] Global Security website: *Orion UAV / Inokhodets, 'Ambler'*, https://www.globalsecurity.org/military/world/russia/orion.htm.

[72] Miko Vranic, "Ukraine Conflict: Russia Employs Forpost-R UCAV", cit.

[73] "Russia Uses Forpost-R Armed Drone with Guided Missile to Destroy Rocket Launcher of Ukrainian Army", in *Army Recognition*, 13 March 2022, https://www.armyrecognition.com/afxaw.

[74] "Orlan-10 Uncrewed Aerial Vehicle (UAV)", in *Airforce Technology*, 24 March 2023, https://www.airforce-technology.com/?p=5069.

[75] Haye Kesteloo, "Ukrainian Troops Capture Secret Russian Lastochka-M Drone", in *Drone XL*, 21 July 2022, https://dronexl.co/?p=17901.

[76] Ryabov Kirill, "UAV 'Lastochka-M' on Exercises and in Battle", in *Military Review*, 28 July 2022, https://en.topwar.ru/199606-bpla-lastochka-m-na-uchenijah-i-v-boju.html.

[77] For more on the Russian approach to UAVs and UCAS, see chapter 4 of this study.

[78] Pavel Luzin, "Russian UAVs: What Has Gone Wrong?", in *Eurasia Daily Monitor*, Vol. 19, No. 169 (11 November 2022), https://jamestown.org/?p=94380.

[79] Russian Ministry of Defence, "Комплексы ударных беспилотников «Иноходец» нанесли удары по укреплениям и бронированной технике ВСУ" [Inokhodets drone strikes on AFU fortifications and armoured vehicles", in *YouTube*, 15 March 2022, https://youtu.be/G4oil3EmOqk.

[80] David Hambling, "Russia Is Turning Its Small Drones into (Inaccurate) Bombers", in *Forbes*, 17 May 2022, https://www.forbes.com/sites/davidhambling/2022/05/17/russia-converting-its-small-drones-into-bombers.

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Because of industrial limitations, Russia has been forced to indigenise foreign designs as well as repurposing ISR UAS to provide some fire support to its land forces. The first avenue has included the production of Forpost-R, a Russian-made version of Israeli Aerospace Industry's Searcher 2 tactical UAS. This model has been seemingly used against ZSU multiple rocket launcher systems (MLRS).[81] However, Russian troops have also adopted a more do-it-yourself (DIY) flavoured approach by dropping grenades from small Chinese-made COTS UAS, such as the DJI Mavic and the Evo 2. This stratagem is employed by both Ukraine and Russia, and like their Ukrainian counterparts, Russian dual-use uncrewed aerial systems have proven vulnerable to GPS spoofing and other EW measures.[82] Russian SOFs have reportedly also experimented with the use of a newer handheld design,[83] the Lastochka-M. Like other handheld UAS, its main purpose is to perform ISR and to drop unguided bombs over enemy positions at a tactical range.[84]

Finally, Russia has proven proficient in employing drones for EW purposes. There have been various reports of Russian forces deploying Orlan-10 UAS with RB-341V Leer-3 payloads. This system was deployed to Donbass before the ongoing full-fledged invasion and to Syria, where it was used for psychological operations. In a classic example, Leer-3 would penetrate cellular networks to send SMS to nearby enemy units with provocations[85] and instructions to surrender.[86] After 24 February 2022, Orlan-10s equipped with Leer-3 also have been used to jam widely used signals (GSM 900, GSM 1800, 3G, and 4G) within a radius of six kilometres. Similar jamming modules are carried by the Kronshtadt Orion.[87]

1.3 Are armed UAS viable in peer-to-peer conflicts?

Armed UAS have proved to be a valuable addition to global arsenals. Nevertheless, operational experience shows that the impact of uncrewed technology wildly varies depending on the context in which it is employed.[88] This supports the thesis that the drone, as a typology of weapon systems, does not seem so far to fundamentally alter the balance between defence and attack.[89] The successful use of these systems depends on a number of factors. Firstly, whether the user is employing the right system for the right task and adopting effective tactics with realistic goals. Secondly,

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81 Miko Vranic, "Ukraine Conflict: Russia Employs Forpost-R UCAV", cit.

82 Ryabov Kirill, "UAV 'Lastochka-M' on Exercises and in Battle", cit.

83 Ibid.

84 Haye Kesteloo, "Ukrainian Troops Capture Secret Russian Lastochka-M Drone", cit.

85 Boyko Nikolov, "Russian Leer-3 Jams GSMs in Ukraine and Sends SMS for Provocation", in *Bulgarian Military Industry Review*, 19 October 2022, https://bulgarianmilitary.com/?p=40830.

86 Michael Peck, "The Crazy Way Russia Could Hijack Your iPhone", in *The Buzz*, 2 April 2017, https://nationalinterest.org/node/6988.

87 Seth G. Jones et al., *Combined Arms Warfare and Unmanned Aircraft Systems*, cit., p. 16-24.

88 Interview, 21 September 2023.

89 Antonio Calcara et al., "Will the Drone Always Get Through? Offensive Myths and Defensive Realities", in *Security Studies*, Vol. 31, No. 5 (2022), p. 791-825, https://doi.org/10.1080/09636412.2022.2153734.

the number of available systems, and the rate at which new ones are supplied, should inform operational decisions. Thirdly, as demonstrated in Ukraine, UAS are often best employed in a combined arms framework and within a broader array of capabilities, including also missiles and loitering munitions.[90] Finally, and crucially, one must factor in the enemy's level of preparation in counter-UAS operations (both in terms of equipment and tactics) and its ability to quickly adapt to evolving methods.[91]

Like other air-based assets, today's armed UAS have proven vulnerable to dense deployments of air defence systems. The presence of competently organised GBAD, short-range air defences (SHORAD) and EW assets was the main constraint on the performance of UAS in SEAD/DEAD, CAS or deep strike missions. This was especially evident in Ukraine, where the most successful missions of the sort were carried out with loitering munition, long-range strikes, conventional rocket artillery and armed UAS operating as stand-off assets. Current MALE drones have proven to be especially fragile: the shootdown of a US RQ-4A Global Hawk BAMS-D by Iran in 2019[92] and the damaging of several US MQ-9 Reaper by Russian fighters in 2023 demonstrated their vulnerabilities against capable air-based assets and ground-based air defence systems.[93] These elements suggest that although armed UAS brought additional lethality to the battlefield, their effect was largely dictated by the defenders' ability to elude the attacker's detection and disrupt their targeting efforts, either by spotting it before it can strike or employing EW techniques. This is what literature has dubbed "hider-finder competition":[94] once a drone is spotted in a peer-to-peer confrontation, its survival chances drop dramatically.

This will likely influence armed UAS proliferation in the years to come. Drones are not just a cheap alternative to traditional air power: they are diverse weapons systems with varying levels of sophistication depending on their intended use, that require careful integration in a wide array of capabilities across operational domains.

The two peer-to-peer conflicts described above have seen a broad use of armed drones to perform some of the missions typically associated with conventional air power, particularly but not only at tactical level. In particular, the adaptation of COTS UAS and their equipment with grenades provided an additional tactical tool, especially during the trench warfare of winter 2022/23 in Ukraine. All in all, it can be said that small and medium-sized UAS have ever so imperfectly filled some of the gaps left by the failure of both Russian and Ukrainian crewed air power.[95]

[90] Interview, 4 September 2023.
[91] Interview, 31 August 2023.
[92] Interview, 30 August 2023.
[93] Interview, 4 September 2023.
[94] Antonio Calcara et al., "Why Drones Have Not Revolutionized War", cit.
[95] Atlantic Council, *Unmanned Aircraft Systems: Lessons for Ukraine and NATO*, 19 April 2023, https://www.atlanticcouncil.org/?p=627354.

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Additionally, one should not underestimate the propaganda value of the strikes recorded by the live feeds of uncrewed aerial systems, as both showcased by Azeri and Ukrainian strategic communication.

The wars in Ukraine and Nagorno-Karabakh really only provided a glimpse into the performance of some armed UAS types – mainly the TB-2 Bayraktar, as well as some Russian and Ukrainian models. It is likely that HALE platforms outranging enemy GBADs would have been more effective through the use of air-launched stand-off missiles.[96] Reportedly, Russian Orlan-10s deployed in a standoff manner were able to remain out of reach of Ukrainian man-portable air defence systems (MANPADS), but were also cheap enough not to be worth being intercepted with longer range air defence systems.[97] Moreover, many of the deployed UAS lacked the ability to adopt complex attack profiles to avoid radars and air defences, for instance by "hugging" the ground thanks to advanced ground avoidance systems.[98]

Smaller designs like Ukraine's Punisher, while lightly armed, may indicate potential future avenues of development. As mentioned before, larger drones such as the TB2 remain vulnerable to competently organised air defences and ad-hoc C-UAS systems. As a result, they are a less disruptive tool in a peer-vs-peer conflict. Larger UAS can still be a valuable platform to launch stand-off missiles from outside the enemy's air defence umbrella while freeing up crewed combat aircraft for other tasks. In general, HALE and MALE systems are unlikely to disappear as they can play an important role in an integrated approach to air warfare. Furthermore, they are also affordable and more expendable than crewed aircraft, which makes them appropriate for an approach based on attrition and operational mass through endemic tactical use, provided of course they are employed fittingly with their strengths and weaknesses.

This means UAS, especially those located at the more expendable side of the spectrum, can be leveraged to create combat mass and, for instance, overwhelm enemy air defences, as was for instance done in Syria, including by making an integrated use of drones, rockets, missiles and loitering munitions side-by-side.[99] In general, the trade-off between quantity and quality will depend on the survival chances in the different operational contexts, and it will be difficult to strike a balance in advance. It is expected that the less contested the airspace, the more expensive systems will be employed for longer missions involving loitering over the battlefield; the absence of air superiority will, on the other hand, favour massive use of expendable assets.[100]

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96 Interview, 30 August 2023.

97 Stavros Atlamazoglou, "Russia Has Been Able to Keep Its Most Effective Drone Flying over Ukraine Thanks to Western-Made Parts", in *Business Insider*, 28 February 2023, https://www.businessinsider.com/russia-keeps-orlan10-drone-flying-over-ukraine-with-western-parts-2023-2.

98 Anthony H. Cordesman, "Iran, Yemen, and the Strikes on Saudi Arabia", cit.

99 Douglas Barrie et al., "Armed Uninhabited Aerial Vehicles and the Challenges of Autonomy", cit.

100 Interview, 31 August 2023.

Finally, electronic measures proved to be particularly effective against armed UAS. This has implications for the potential of current drones' capabilities as wholesale substitutes for crewed aircraft. The vulnerability of satellite and radio communication, which are by no means limited to symmetric wars, means that traditional drones remain fragile systems in non-permissive electronic environments. This finding could accelerate two trends: the equipment of increasingly sophisticated EW and counter-EW outfits and investments in stealth technology, which will raise the procurement costs of uncrewed aerial vehicles and decrease their expendability.[101] That said, the value of highly skilled pilots and structural factors that prevent some countries from building up the aerial combat mass (including adverse demographics, budget concerns, force structure, etc) imply that UAS will remain comparably expendable in the years to come.[102]

[101] Interview, 28 August 2023.

[102] Interview, 30 August 2023.

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2. The advent of uncrewed combat aerial systems

by Elio Calcagno

The potential advantages of uncrewed systems in aerial warfare are clear. The absence of all instrumentation and support systems necessary for human on-board operation can free space for additional payloads, or alternatively allow for smaller and lighter systems. This, in turn, could increase speed and manoeuvrability while also decreasing a vehicle's sensor signatures.[1] In principle, the absence of a human pilot removes a set of limitations, including with regard to endurance (and thus range and persistence) and susceptibility to high-positive and negative G-force manoeuvres – the latter, in particular, ushers in a whole new thinking when it comes to manoeuvres. Although uncrewed aerial vehicles have been used in military operations for decades, they remain vulnerable to kinetic threats, including modern air-defence systems, as well as EW in contested environments, as shown by the Ukraine and Nagorno Karabakh wars.[2] More recently, further significant efforts have been put into the development of directed energy weapons (DEW) and high-power microwaves (HPM) in order to counter drones. The use of armed UAS has developed throughout the last 30 years, initially to satisfy specific requirements coming out of the counter-insurgency wars in Afghanistan and the Middle East,[3] and more recently via the Ukrainian and Turkish experience with near-peer-conflicts. As a consequence, the majority of UAS, armed and unarmed, in service today with Western militaries have been designed in order to operate in low-intensity conflict and counter-insurgency scenarios.[4]

However, new requirements prompted by technological progress and a widespread return to peer-to-peer (or -near-peer) conflict as the main focus for military planning have caused a surge in interest and investment into more advanced systems specifically designed for combat roles typical of high-intensity warfare scenarios, where air space is contested by enemy air defences and fighters.[5] These systems, which in this study will be referred to as uncrewed combat aerial systems (UCAS), represent a departure from traditional armed UAS. Indeed, the former can be broadly defined as often presenting at least two of the following features, which make them better suited to high-intensity conflict in contested environments, including by enhancing their survivability: (1) low observability; (2) capacity for high speeds; (3) capacity to carry larger loads of advanced weaponry.[6]

[1] Interview, 28 August 2023; Michael W. Byrnes, "Nightfall. Machine Autonomy in Air-to-Air Combat", in *Air & Space Power Journal*, Vol. 28, No. 3 (May-June 2014), p. 48-75, https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-28_Issue-3/F-Byrnes.pdf.

[2] See in this regard chapter 1 of this study.

[3] Lynn E. Davis et al., *Armed and Dangerous? UAVs and U.S. Security*, Santa Monica, RAND, 2014, https://www.rand.org/pubs/research_reports/RR449.html.

[4] Dominika Kunertova, "The Ukraine Drone Effect on European Militaries", in *Policy Perspectives*, Vol. 10 (15 December 2022), https://doi.org/10.3929/ethz-b-000584078.

[5] Interview, 4 September 2023.

[6] Interview, 30 August 2023.

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Among the main limitations to performance for crewed aircraft is the presence of human crews onboard. Firstly, in terms of persistence, as human beings cannot operate in the cockpit for overly long operations without sleep and access to sufficient stocks of food and water. Secondly, humans are unsuited to spending long hours or even days carrying out tedious and repetitive tasks such as surveillance and loitering.[7] Furthermore, as mentioned, pilots cannot survive sustained high-G manoeuvres over a certain threshold, meaning that in order to not kill or incapacitate their crew these platforms must limit their manoeuvrability. Such constraints are relevant in multiple ways, as crewed combat aircraft are destined to be less manoeuvrable than the air-to-air missiles designed to counter them. Increased capacity for high-speed manoeuvres also allows for low-altitude, high-speed incursions into enemy or contested airspace while avoiding detection by air defence sensors.

Crucially, training fighter pilots is a lengthy, complex and costly endeavour.[8] In turn, this, combined with the intrinsic value of the life of the human pilot, requires any sophisticated combat aircraft to be fitted with a great number of countermeasures to protect skilled human crews and the very expensive platforms they inhabit. Therefore, one of the main selling points for uncrewed vehicles, in general, has hitherto been a level of expendability that is unviable with crewed platforms.[9] As a result, until now, UCAS have often been imagined as tactically flexible tools, especially useful in high-risk missions, such as piercing through enemy A2/AD bubbles and operating in highly contested environments.[10] Furthermore, UCAS have the potential of being more stealthy than crewed counterparts as the pilot's cockpit and canopy negatively affect the aircraft's cross-section and shape, therefore increasing the radar signature.[11]

2.1 UCAS and high-intensity combat: Technological hurdles

Despite the opportunities offered by UCAS, some technological hurdles must be overcome in the coming years to achieve the required levels of performance in order to unlock their potential, including in the field of air-to-air combat. For instance, a remotely-piloted aerial system must be controlled through wireless technology, mainly line-of-sight data link radio waves, meaning that the connection between UCAS and the operator is vulnerable to jamming-based countermeasures as well

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[7] Michael Franklin, "Unmanned Combat Air Vehicles: Opportunities for the Guided Weapons Industry?", in *RUSI Occasional Papers*, September 2008, https://www.rusi.org/explore-our-research/publications/occasional-papers/unmanned-combat-air-vehicles--opportunities-for-the-guided-weapons-industry.

[8] Interview, 12 September 2023.

[9] Interview, 4 September 2023.

[10] Javier Jordan, "The Future of Unmanned Combat Aerial Vehicles: An Analysis Using the Three Horizons Framework", in *Futures*, Vol. 134 (December 2021), Article 102848, https://doi.org/10.1016/j.futures.2021.102848.

[11] Michael Franklin, "Unmanned Combat Air Vehicles", cit.

as hacking and cyber-attacks.[12] As a result, varying degrees of autonomy are often seen as a requirement for UCAS to fulfil their potential with regard to high-intensity combat scenarios, where line of sight connections may be interrupted or degraded by enemy action or natural features for long stretches of time.[13] Autonomy appears to be a necessary feature in order to decrease vulnerability to non-kinetic countermeasures but also, crucially, to take advantage of the much faster reaction times that artificial intelligence (AI) can offer as compared to a human pilot.[14] Therefore, in the near future, AI can allow UCAS to operate as partially autonomous systems, while still keeping an element of human involvement. This can take multiple forms, though they can generally ascribed to either of two main macro-categories: "'human-in-the-loop' weapons require humans to make critical operational decisions like selecting targets and pulling the trigger".[15] On the other hand, "human-on-the-loop" weapons merely retain a level of human oversight in that an operator can supervise and, if needed, override the system's actions.[16] The human-in-the-loop approach is likely going to be an important element of reassurance for political leaders and public opinion attitude towards UCAS, in light of political sensitivities already emerged in Italy, as well as in other countries such as Germany or even the UK, on arming US drones. It will also allow armed forces to retain a key decision-making element during military operations. Therefore, going forward, given technological advancements in the field of AI, the preference for "human-in-the-loop" solutions in Western countries may be explained more often than not by ethical and legal requirements rather than technological limitations.

In the longer term, AI capabilities may even reach such a level of autonomy as to lead to fully autonomous assets able to independently make decisions and complete missions, though the level of technology required is still far behind.[17] Even then, however, human operators can be expected to maintain a prominent role in setting a number of parameters, including in real time, relating relating to the operational and geographical scope of a given mission, as well as rules of engagement (ROE) and stance.[18]

Autonomous capabilities are built on an array of technological solutions, starting with AI and all its subfields, such as for instance machine learning and deep

[12] Interview, 11 September 2023; Antonio Calcara et al., "Will the Drone Always Get Through?", cit.

[13] Interviews, 4 September and 23 October 2023.

[14] Interview, 20 September 2023; Jovana Davidovic, "What's Wrong with Wanting a 'Human in the Loop'?", in *War on the Rocks*, 23 June 2022, https://warontherocks.com/?p=27175.

[15] Interviews, 4 and 20 September 2023; Amitai Etzioni and Oren Etzioni, "Pros and Cons of Autonomous Weapons Systems", in *Military Review*, Vol. 97, No. 3 (May-June 2017), p. 72-81, https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2017/Pros-and-Cons-of-Autonomous-Weapons-Systems.

[16] Ibid.

[17] Interview, 20 September 2023; Michael Franklin, "Unmanned Combat Air Vehicles: opportunities for the guided weapons industry?", in *RUSI Publications*, September 2008, https://static.rusi.org/200808_op_unmanned_combat_air_vehicles.pdf.

[18] Interview, 4 September 2023.

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learning. In turn, given the massive amount of data that needs to be elaborated in real time for the sake of navigation, tactical decision-making, as well as the detection, identification and tracking of signatures, a high capacity for on-board data processing and computing is necessary in order to achieve a higher degree of autonomy in UCAS. This necessity is contingent on how much of this computing is to be done by the UCAS themselves or, indeed, by the crewed aircraft exerting a level of control on it.

A high degree of autonomy is therefore even more desirable in the case of future UCAS specialised in air-to-air combat, where extremely quick reaction times and the ability to engage multiple moving threats simultaneously often spell the difference between victory and defeat (and life or death in crewed air combat). Most UCAS programmes already underway or known concepts are focused specifically on uncrewed platforms acting in concert with, and under the control of, crewed combat aircraft as collaborative combat aircraft (CCA), also known as "adjuncts".[19] This is the case, for instance, in the US with the US Air Force Loyal Wingman concept,[20] in Russia with the Su-70 Okhotnik-Bs, and in China with the "Dark Sword".[21] Australia has already invested over 400 million US Dollars in its Loyal Wingman programme, with the delivery of 13 Boeing-made MQ-28A Ghost Bat drones to the Royal Australian Air Force by 2025.[22] Meanwhile, in France (and consequently in Germany and Spain), the Future Combat Air System (FCAS) programme for a 6th generation combat air system has from the start envisaged crewed platforms acting as a core element in a system of systems (SoS) that also includes UCAS as CCA.[23] Indeed, France has already earmarked funding for the development of a separate UCAS, based on the multinational nEUROn demonstrator, destined to fly along the Dassault Rafale fighter aircraft.[24] The Global Combat Air Programme (GCAP) involving the UK, Italy and Japan has, from the start, been conceived not simply as a 6th-generation combat aircraft, but as a system of systems also including UCAS and adjuncts.[25]

As with crewed 6th-generation platforms, stealth technology is likely going to be a key enabling technology as UCAS eventually enter into service, both for those designed to operate independently and those intended to work as adjuncts in

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[19] The term is derived from "wingman", meaning a pilot whose plane is flying behind and to the side of a plane that is leading a group of planes flying together. See Cambridge Dictionary, https://dictionary.cambridge.org/dictionary/english/wingman.

[20] For more on the US' approach to UCAS concepts see chapter 3 of this study.

[21] For more on Russian and Chinese approaches to UCAS concepts see chapter 4 of this study.

[22] Inder Singh Bisht, "Australia Announces $317 Million Loyal Wingman Drone Investment", in *The Defense Post*, 19 May 2022, https://www.thedefensepost.com/2022/05/19/australia-loyal-wingman-drone-investment.

[23] Gareth Jennings, "IFC 2022: Airbus Reveals 'Heavy Loyal Wingman' Concept for FCAS", in *Janes*, 17 November 2022, https://www.janes.com/defence-news/news-detail/ifc-2022-airbus-reveals-heavy-loyal-wingman-concept-for-fcas.

[24] Helen Chachaty, "France Budgets €11,7 Billion For Dassault Rafale Investments", in *Aviation Week*, 19 October 2023, https://aviationweek.com/node/4615681.

[25] For more on GCAP and Italy's approach to UCAS, see chapter 7 of this study.

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mixed formations with crewed aircraft.[26] For the former, stealth capabilities would be crucial in order to increase survivability in the face of enemy aircraft and air defence systems, while the latter should have at least the same level of stealth as the crewed aircraft they are designed to fly with lest they expose the whole formation.[27]

Whereas stealth requirements in 5th-generation platforms like the F-22 Raptor and the F-35 mainly focused on a specific range of radar frequencies (X-band radars), future platforms such as the joint British, Italian and Japanese GCAP will likely have to take into account a much wider band spectrum, while also achieving a level of low-observability in the infra-red (IR) and electromagnetic spectrums.[28] The same principles will consequently apply to UCAS, which will complement or in some instances replace crewed aircraft in combat operations.

2.2 A game-changer for aerial warfare?

The introduction of increasingly autonomous and advanced UCAS into the world's air forces is set to significantly change the field of aerial warfare in terms of doctrine and tactics, force mix, procurement and human operator training.

2.2.1 Doctrine and tactics

The availability of a high number of (to differing degrees) relatively expendable UCAS is likely to lead to a major departure from current standard tactics and doctrine, which seldom sees combat losses as acceptable trade-offs due to both the value of human life but also the costs and difficulties to replace pilots and aircraft quickly in a protracted conflict. However, a distinction must be made between "attritable" systems, which represent a relatively acceptable loss (certainly more than crewed aircraft) if they fail to return to base, and truly expendable systems, the loss of which is much more likely and to some extent possibly planned.[29] While expendability is certainly an important goal in the pursuit of more capable uncrewed combat systems, it is likely that more capable, complex and expensive UCAS will play a pivotal role without being as expendable as other systems. It could be imagined as a sort of expendability hierarchy, where the human crews and pilots are the most precious assets, followed by the piloted combat aircraft, then by very capable and advanced UCAS, and finally by lower-end armed and unarmed drones.[30]

[26] Harper Jon and Connie Lee, "Owning the Skies: What to Expect from Sixth-Gen Aircraft", in *National Defense*, Vol. 104, No. 790 (2019), p. 44-49, https://digital.nationaldefensemagazine.org/september-2019/page-44; Interview, 11 September 2023.

[27] Interview, 4 September 2023.

[28] Harper Jon and Connie Lee, "Owning the Skies: What to Expect from Sixth-Gen Aircraft", cit.

[29] Interview, 23 September 2023.

[30] Interview, 30 August 2023.

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In addition, for a great deal of air forces, the advent of readily-available UCAS might represent a chance to increase deployable mass, to an extent, at an affordable cost beyond the scarcity of crewed combat aircraft. Of course, one must not forget that adversaries, including for instance those jockeying for superiority with Western forces (i.e., China), may still be capable of matching or, indeed, besting rival forces in terms of sheer numbers by investing on their own UCAS – as Beijing is doing. Conversely, the increase of mass by enemy air forces requires a substantial bolstering of multi-layered air defences both in terms of the number of batteries and stockpiled ammunition as well as doctrinal evolution.

The advent of UCAS opens up a whole realm of possibilities regarding to a collaborative approach to tactics and air operations, where a multitude of crewed and uncrewed vehicles take on specific roles collaboratively while acting as a unit, in a MuM-T dynamic. For instance, uncrewed systems have been imagined as extending the sensor range and reach of crewed assets, or indeed acting as forward-deployed sensor platforms for a group of aerial vehicles in the rear having turned their sensors off to minimise their signature, thus allowing crewed aircraft to acquire a targeting solution without revealing their position and from a stand-off distance. Likewise, low-observable UCAS could approach or penetrate an enemy A2/AD umbrella in order to fire their own missiles, with targeting solutions provided by other crewed or uncrewed assets.

Finally, UCAS are to be seen as another uncrewed military asset set to operate in concert with a variety of counterparts covering different roles and across separate operational domains, including also rotary uncrewed aerial vehicles, uncrewed underwater and surface vehicles (UUV, USV). Military doctrine, taking into account the advent of UCAS, will likely develop in relation to joint and multi-domain operations.

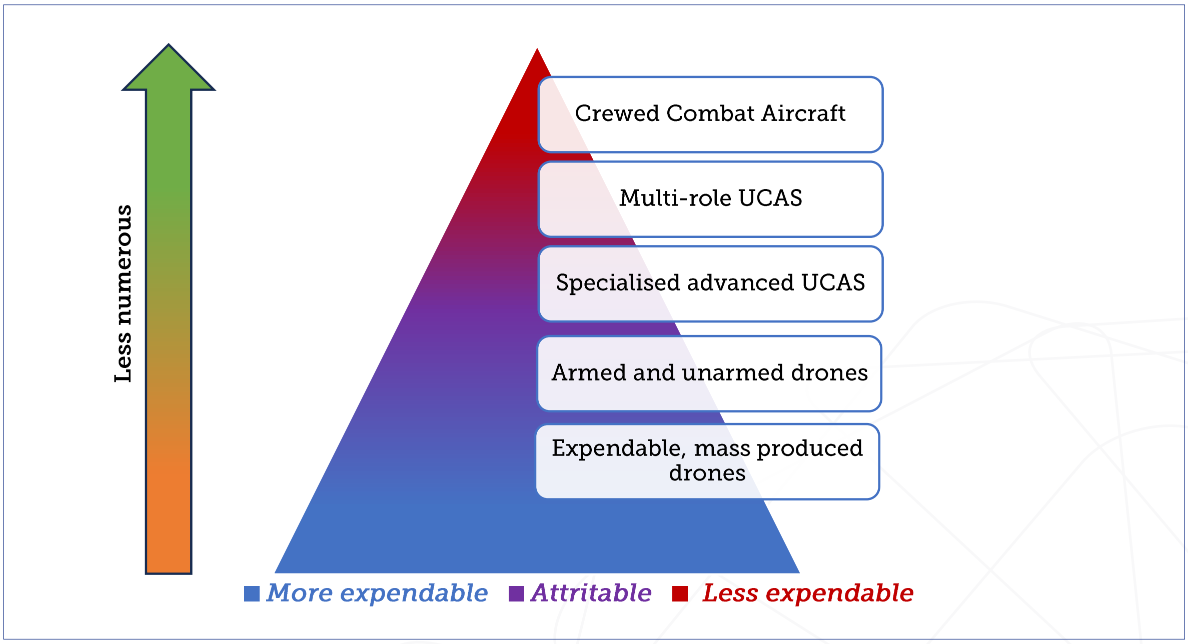
2.2.2 Force mix and procurement

In the Cold war, many air forces, even outside US and USSR, had in service a wide array of both multi-role and specialised combat aircraft. While some future UCAS may be designed as very advanced and in some cases multi-role platforms serving alongside crewed combat aircraft, thus being highly valuable (and relatively costly, though still less so than crewed counterparts),[31] it can be envisioned a departure from a more recent trend of strictly multi-role designs seen in many 5th generation fighters. Indeed, the multi-role requirement necessarily leads to larger, more complex systems in order to host all sensor and weapon systems needed to undertake a relatively wide array of missions. When it comes to future UCAS, spreading out capabilities in multiple, less complex and thus more expendable and/or attritable elements in a broader SoS could be preferable as part of a specific mix of assets. Coincidentally, such an approach also minimises the occurrence

[31] John R. Hoehn, Kelley M. Sayler and Michael E. DeVine, "Unmanned Aircraft Systems: Roles, Missions, and Future Concepts", in *CRS Reports*, No. R47188 (18 July 2022), https://crsreports.congress.gov/product/details?prodcode=R47188.

of single points of failure in this networked approach to warfighting.[32] Indeed, at this end of the spectrum, some systems could be specialised in air-to-air combat, others in aerial refuelling, others in ISR, some as decoys and so on.

In practice, following from the aforementioned expendability hierarchy, it seems likely that as drones and UCAS' numbers increase, air forces in the future may be expected to generally aim at a pyramidal high-low force mix, with high-end, very advanced and expensive crewed platforms at the top of a pyramid. As we descend below its tip, we find more attritable but still multi-role and complex UCAS, followed by more specialised UCAS, such as those operating alongside crewed aircraft as CCAs. Descending further, armed and unarmed drones, such as those already in service today, which rely on automation rather than autonomous capabilities. Finally, down at the base, expendable, mass producible and relatively cheap drones apt for large-scale swarming, surveillance, close-range battlefield support, saturating enemy air defences or generally low-intensity missions. Taken as broad categories and considering the affordability and expendability variables, it can be speculated that systems at the very top of the pyramid will be less numerous as a whole than those at the base.



The exact balance between high-end and low-end capabilities, crewed and uncrewed, as well as expendable, attritable and non-expendable, will be dictated by a variety of factors including doctrine, budgetary constraints, force posture and size, and broader defence considerations, that are likely to differ across NATO members. Yet it is clear that the addition of increasing numbers of both drones and UCAS already calls for different approaches to procurement. Few air forces besides

[32] Interview, 23 September 2023.

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the US today operate more than a handful of combat aircraft models simultaneously. As UCAS become integrated with existing fleets of crewed aircraft, including the fifth but also fourth generations, there is the possibility that procurement, logistics and supply chain management become a more complex task given the necessity to maintain multiple types of systems, some or many of which may be provided by different suppliers. There will likely be a multitude of requirements to address, for instance if crewed aircraft belonging to previous generations require different adjunct systems than more recent platforms. A further layer of complexity is added by the sensitive issue of producer countries opening up existing aircraft systems to operating UCAS made by other countries. How the US and countries using the F-35 will approach this issue will provide a fitting insight into what is potentially a highly sensitive issue.[33]

2.2.3 Training

Looking ahead, one of the key questions to be faced with respect to integrating UCAS of different types into a collaborative combat aircraft force is that of training. Firstly, air forces must reflect on whether full-fledged aircraft pilots or qualified operators are best suited to controlling different types of UCAS in light of high levels of automation and some degree of autonomy.[34] At least in part, the solution to this conundrum could vary from system to system depending on the degree of autonomy that an individual UCAS is capable of. For instance, a largely autonomous UCAS may only require a remote operator to direct it, rather than pilot it, by inputting certain mission parameters, rules of engagement or mission objectives. Ideally, this type of autonomy may enable a single officer to direct multiple assets simultaneously.[35]

An operator based on a control room is likely to require significantly less training than a traditional pilot, therefore allowing for easier scaling of a remote operator pool. Conversely, directing multiple UCAS in combat will probably necessitate a different set of skills from those hitherto required for fighters' pilots. Indeed, when considering the collaborative crewed-uncrewed combat concepts discussed above, even actual combat pilots will require very advanced training both in operating extremely complex aircraft from the cockpit and simultaneously controlling collaborative combat aircraft UCAS.

Finally, the advent of fast and manoeuvrable UCAS presents an interesting opportunity in the field of fighter pilot training given that current technologies allow the design of specialised, increasingly capable drones to replicate aerial threats from crewed enemy aircraft, including complex formations, at a fraction of the cost.[36]

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[33] Interview, 4 September 2023.

[34] Ibid.

[35] Ibid.

[36] Valerie Insinna, "Drones Could Be Key to Solving One of the US Air Force's Biggest Training Challenges", in *Breaking Defense*, 17 March 2022, https://breakingdefense.com/?p=210594.

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3. United States

by Bryan Clark[1]

US military UAS that have transitioned into procurement focus almost exclusively on ISR missions. Although vehicles like the US Air Force's MQ-9 Reaper and US Army MQ-1C *Gray Eagle* also conduct strike or electronic warfare operations, respectively, they are still primarily employed in the US military as ISR aircraft. The US Department of Defence (DoD) is now pursuing an array of new UCAS that will contribute across a wider range of missions, but these programmes, including the US Navy MQ-25 *Stingray* refuelling tanker and Air Force's CCA, are still developmental and have not yet transitioned into procurement.[2]

Integration challenges appear to be the most significant impediment to US forces using uncrewed systems more extensively outside of ISR. The US military's fielded UAS operate as standalone systems when conducting ISR, with their sensor data going to dedicated receivers for analysis and with dedicated operators planning or controlling their missions. In circumstances when US forces use uncrewed systems for missions like EW or strike, the vehicle is under the direct control of an operator and largely avoids interactions with other crewed platforms or forces.

The US military is adopting concepts that will create a stronger demand for uncrewed systems to be more fully integrated with the existing, mostly-crewed, force. The Joint Warfighting Concept (JWC), Distributed Maritime Operations (DMO) concept, and Joint All-Domain Command and Control (JADC2) initiative rely on distribution, adaptable force packages, and long-range effects chains connecting sensors, commanders, and weapons or electronic warfare platforms.[3] By degrading an opponent's sensing and sense-making while affording US forces more options for offensive actions, these concepts aim to increase the US military's lethality and resilience.

Because budget constraints will prevent the US military from becoming more distributed by simply fielding more crewed units, the US DoD is expanding the proportion of uncrewed systems in the force while investing in the ability to

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[2] John R. Hoehn and Paul K. Kerr, "Unmanned Aircraft Systems: Current and Potential Programs", in *CRS Reports*, No. R47067 (28 July 2022), https://crsreports.congress.gov/product/details?prodcode=R47067; US Department of the Navy, *Unmanned Campaign Framework*, 16 March 2021, https://www.navy.mil/Portals/1/Strategic/20210315%20Unmanned%20Campaign_Final_LowRes.pdf.

[3] John R. Hoehn, "Joint All-Domain Command and Control (JADC2)", in *CRS In Focus*, No. IF11493 (21 January 2022), https://crsreports.congress.gov/product/details?prodcode=IF11493; David Vergun, "DOD Focuses on Aspirational Challenges in Future Warfighting", in *DOD News*, 26 July 2021, https://www.defense.gov/News/News-Stories/Article/Article/2707633.

integrate them into kill chains using AI-enabled C3 software.[4] The DoD's new Replicator initiative reflects this approach and aims to eventually field thousands of uncrewed systems that would provide US forces greater capacity while enhancing the ability of operators to implement innovative operational concepts.[5]

3.1 Research and development (R&D) priorities

The DoD is pursuing a series of programmes that seek to expand the use of UAS and UCAS, tailored by each US military service to its particular mission responsibilities and force design. Generally speaking, these new projects initially envision UCAS as extending the reach and capacity of crewed platforms, which may perpetuate existing vulnerabilities and be predictable to opponents. However, it is likely UCAS will increasingly be treated as independent elements of force packages and kill chains.

After two decades of focusing on ISR UCAS like the MQ-9 Reaper and RQ-4 Global Hawk, the US Air Force is now prioritising its CCA programme, which will develop UCAS that complement or augment crewed aircraft in highly contested areas. The service plans to build at least 1,000 adjuncts that will eventually carry a variety of modular payloads, including weapons, radars, EW jamming or decoy systems, and passive radiofrequency (RF) or electro-optical/infrared (EO/IR) sensors.[6] Notionally, the service plans to combine two or more CCAs with each crewed Next Generation Air Dominance (NGAD) or F-35 fighter, allowing fighters to remain stealthy while adjuncts find targets or attack enemy air defences.[7] Five industry competitors are building demonstration vehicles under the CCA programme, which could yield one or more baseline adjunct vehicle designs that will incorporate collaboration and autonomy technologies from the Air Force's Golden Horde and Skyborg research programmes, which were transitioned into the CCA programme in 2022.[8]

Although the Air Force is emphasising combat missions for its next generation of UCAS, it is still pursuing advanced uncrewed systems to provide the penetrating, survivable ISR once afforded by platforms like the Cold War-era SR-71 *Blackbird*

[4] This trend is detailed in Bryan Clark and Dan Patt, "Unalone and Unafraid: A Plan for Integrating Uncrewed and Other Emerging Technologies into the US Military", in *Hudson Institute Reports*, August 2023, https://www.hudson.org/node/46902.

[5] Jim Garamone, "Hicks Discusses Replicator Initiative", in *DOD News*, 7 September 2023, https://www.defense.gov/News/News-Stories/Article/Article/3518827.

[6] John A. Tirpak, "Air Force General Teases New Details on CCAs Coming at AFA Conference in September", in *Air & Space Forces Magazine*, 8 August 2023, https://www.airandspaceforces.com/?p=199556; John A. Tirpak, "More Range, More Missions: Air Force Leaders Open to a Wide Variety of Uses for CCAs", in *Air & Space Forces Magazine*, 7 September 2023, https://www.airandspaceforces.com/?p=202573.

[7] Michael Marrow, "Next Gen Numbers: Air Force Plans First 'Nominal' Buy of 200 NGAD Fighters, 1,000 Drone Wingmen", in *Breaking Defense*, 7 March 2023, https://breakingdefense.com/?p=273060.

[8] John A. Tirpak, "Skyborg, Golden Horde Closing out Vanguard Phase, Moving into Program of Record", in *Air & Space Forces Magazine*, 10 November 2022, https://www.airandspaceforces.com/?p=174863.

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or U-2 *Dragon Lady*. The Air Force has reportedly been operating the stealthy Northrop-Grumman-built RQ-180 drone for a decade, and it is beginning to come out of the shadows as the Air Force retires the U-2.[9] Similarly, the Air Force is also pursuing two hypersonic surveillance drones that could conduct missions like those of the SR-71: the MAYHEM vehicle being designed by Leidos for Air Force Research Lab and the SR-72 being developed by Lockheed Martin. Neither system has been fielded.[10]

The US Navy's F-18 E/F *Super Hornet* and F-35C *Lighting II* strike-fighters are constrained in range and capacity by size and weight limitations imposed by the carrier deck. The Navy's R&D priority for now is the MQ-25A *Stingray* refuelling tanker, each of which would enable two strike-fighters to reach more than 1,000 nautical miles or 1,850 km from the carrier after they reach the fleet in 2026.[11] The Navy plans to build 76 MQ-25As at about 100 million US dollars each and is likely to expand its mission set and payloads to include ISR and, eventually, weapons. However, due to the need for MQ-25As to support aerial refuelling, the Navy is also pursuing adjunct capabilities with the Air Force to provide additional sensors, weapons, or EW capacity.

Like the US Air Force and Navy, the US Army is pursuing capabilities that augment its crewed vehicles and aircraft, centred on its Air-Launched Effects (ALE) programme. Intended to be launched primarily from rotary-wing aircraft, larger UAS such as the MQ-1C *Gray Eagle*, or ground vehicles, ALE would carry sensors and EW systems to extend the detection range of weapons platforms and improve their survivability against enemy air defence systems. The Army is evaluating large and small-class prototypes from ten different companies with the goal of fielding ALE by the mid-2020s.[12] The Army is also pursuing a Future Tactical UAS (FTUAS) to replace its existing fleet of RQ-7 *Shadow* UAS with a commercially-derived vertical take-off and landing (VTOL) vehicle. After starting the FTUAS programme with five competitors, the Army narrowed down to two prototype developers – Griffon Aerospace and Textron Industries – earlier this year. The two companies' prototypes are expected to undergo testing and evaluation during fiscal year 2025.[13]

[9] Thomas Newdick and Tyler Rogoway, "Secret RQ-180 Stealthy Unmanned Spy Plane Spotted Over Area 51", in *The Drive*, 1 November 2021, https://www.thedrive.com/the-war-zone/42949; Sacha Brodsky, "The Air Force Wants to Kill the U-2. A Secret Spy Drone May Be Waiting in the Shadows", in *Popular Mechanics*, 16 March 2023, https://www.popularmechanics.com/military/aviation/a43341123.

[10] Kris Osborn, "Air Force Research Lab Advances 'First-of-its-Kind' Armed Hypersonic Attack Drone" in *Warrior Maven Articles*, 9 March 2023, https://warriormaven.com/air/hypersonic-attack-drone-mayhem-air-force-research-lab; "Lockheed Martin Discloses Work on SR-72 Mach 6 Aircraft", in *Air & Space Forces Magazine*, 4 November 2013, https://www.airandspaceforces.com/?p=32945.

[11] Sam LaGrone, "MQ-25A Stingray IOC Pushed to 2026 Following Manufacturing Delays", in *USNI News*, 4 April 2023, https://news.usni.org/?p=102081.

[12] Jen Judson, "Army Evaluating First 'Launched Effects' Prototype", in *Defense News*, 15 May 2023, https://www.defensenews.com/land/2023/05/15/army-evaluating-first-launched-effects-prototype.

[13] Mikayla Easley, "Army Picks Griffon, Textron to Build Tactical Unmanned VTOL Aircraft Prototypes", in *DefenseScoop*, 26 September 2023, https://defensescoop.com/?p=76449.

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The US Marine Corps does not have substantial UCAS R&D of its own, though service leaders are planning to procure ALE when available and otherwise employ existing vehicles that were developed through other services' R&D. The most prominent recent example of the Corps leveraging other services' efforts is its recent experiments with the XQ-58 *Valkyrie* under development as part of the Air Force CCA programme.[14]

3.2 Current programmes and UAS and UCAS fleets

As noted above, almost all DoD UAS and UCAS programmes currently fielded in the force are primarily focused on ISR and are largely operated independently of the crewed force, although that is changing with the new uncrewed vehicles in development.[15]

The Air Force is reducing its dependence on larger, non-stealthy UCAS such as MALE MQ-9 *Reaper* and HALE RQ-4 *Global Hawk* under the assumption they are not survivable in high-threat environments, too expensive to be considered attritable, and can often be replaced by space-based systems. However, the Air Force retains some RQ-4s to be airborne communication relays and complementary ISR platforms to aging U-2 and E-8 surveillance aircraft. Going forward, the Air Force is emphasising stealthy UCAS like the RQ-170 *Sentinel* and the smaller CCA as the future of its UCAS fleet. The service's current inventory is approximately:

- MQ-9 Reaper 50 (of 366 built)
- RQ-4 Global Hawk 33
- RQ-170 Sentinel 20
- RQ-11 Raven 3,000
- RQ-20 Puma 60

Like the US Air Force, the US Navy is reducing its reliance on larger ISR-oriented UCAS in favour of smaller vehicles designed to support offensive operations. For example, the Navy reduced its MQ-4C *Triton* buy in 2023 from an originally planned 72 to 27 aircraft and truncated the helicopter-sized MQ-8C *Fire Scout* programme at 38 total airframes, only ten of which have been maintained in service. In contrast to larger UCAS, the Navy continues to buy smaller RQ-21A and Scan Eagle systems for shipboard ISR missions, although they may be capable of kinetic operations in the future.[16] The service's current inventory[17] is approximately:

[14] Aaron-Matthew Lariosa, "Marine Corps Experimental 'Loyal Wingman' Drone Makes First Flight," in *USNI News*, 5 October 2023, https://news.usni.org/?p=106117.

[15] Except as noted, inventory numbers for larger UCAS (MQ-1, MQ-9, RQ-170, MQ-4, RQ-4) are from John R. Hoehn and Paul K. Kerr, "Unmanned Aircraft Systems: Current and Potential Programs", cit.

[16] Insitu, *Insitu Announces Kinetic Capability for the Integrator Uncrewed Aircraft System (UAS)*, 5 September 2023, https://www.insitu.com/?p=6332.

[17] Except as noted, inventory information comes from the Naval Air Systems Command (NAVAIR) website: *Unmanned*, https://www.navair.navy.mil/unmanned.

- MQ-4C Triton 27[18]
- MQ-8C Fire Scout 10 (28 in storage)[19]
- ScanEagle 20 (others contractor-owned and operated)[20]
- RQ-21A Blackjack 31 (across Navy and Marine Corps)[21]

Unlike the other services, the Army has been using its existing UCAS for offensive operations. The MQ-1C Gray Eagle, an updated version of the MQ-1 Predator that originally flew over Iraq and Afghanistan, can carry the Multifunction EW (MFEW) pod that is part of the Army's EW SoS.[22] Other than the MQ-1C, the Army inventory consists of tactical UCAS, as described below:

- MQ-1C Gray Eagle 204
- RQ-11B Raven hundreds
- RQ-7Bv2 Shadow hundreds

Like the US Army, the US Marine Corps fields mostly small, tactical UCAS intended to support battlefield ISR needs. And also like the Army, the Marine Corps is replacing several of its fixed-wing UCAS with VTOL systems that are easier to launch and recover. The Corps is replacing its RQ-11B Raven and RQ-12A Wasp UAS with commercial VTOL vehicles, including the Skydio XD2 and FLIR Systems R80 SkyRaider.[23] The larger RQ-21A *Blackjack* is being succeeded by the new Martin V-Bat VTOL UAS, which the Marine Corps is fielding on amphibious ships under a services contract with the manufacturer.[24]

- MQ-9A Reaper 2 (of a planned 18)[25]
- Small UCAS[26] hundreds
- RQ-21A Blackjack 31 (across Navy and Marine Corps)
- Martin V-Bat (contractor-owned and operated)

[18] Richard R. Burgess, "Navy Scaling Back Planned Triton Deployable Sites from Five to Three", in *Seapower Magazine*, 24 May 2023, https://seapowermagazine.org/?p=24608.

[19] Richard R. Burgess, "Navy Is Sustaining 10 Operational MQ-8C Fire Scout UAVs; Rest in Storage" in *Seapower Magazine*, 31 January 2023, https://seapowermagazine.org/?p=23308.

[20] "Navy Orders 24 Unmanned Aerial Vehicles (UAVs) and 62 Sensor Payloads in $32 Million Deal to Boeing Insitu", in *Military & Aerospace Electronics*, 21 July 2023, https://www.militaryaerospace.com/computers/article/14296666/unmanned-sensor-payloads-surveillance.

[21] Insitu website: *RQ-21*, https://www.insitu.com/products/rq21a.

[22] Andrew Eversden, "Army's Gray Eagle Jamming Pod Program Could Expand to Other Aircraft", in *Breaking Defense*, 18 April 2022, https://breakingdefense.com/?p=215922.

[23] Richard R. Burgess, "Marine Corps Replacing Fixed-Wing Small UAS with VTOL Types", in *Seapower Magazine*, 19 January 2023, https://seapowermagazine.org/?p=23196.

[24] Jen Judson, "Here's How Shield AI Wants to Boost V-Bat's Capability on a Contested Battlefield", in *Defense News*, 30 July 2021, https://www.defensenews.com/land/2021/07/30/heres-how-shield-ais-tech-will-boost-v-bats-capability-on-a-contested-battlefield.

[25] Aaron-Matthew Lariosa, "First Marine Corps MQ-9A Reaper Squadron Now Operational", in *USNI News*, 8 August 2023, https://news.usni.org/?p=104949.

[26] These are RQ-11B Raven, RQ-12A Wasp and RQ-20A Puma.

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3.3 Integration with crewed platforms

The US military's new and emerging UAS and UCAS are intended largely to work with their crewed counterparts to extend the reach, capacity, or persistence of the existing force. This is partly a reaction to the shrinking number of crewed units in the US military due to rising readiness, procurement, and personnel costs.[27] The US Air Force CCA, US Navy MQ-25A, and US Army ALE programmes reflect manned-unmanned teaming (MUM-T) approaches the DoD is pursuing to compensate for growing capacity shortfalls.[28]

As UAS and UCAS move from being independent systems to mainline members of the force, the DoD is attempting to retain the system-level benefits they individually provide while also gaining their value at the SoS level. In such a context, while generally not cheap, uncrewed aerial systems are less expensive to buy, operate, and maintain compared to their manned counterparts and can be used in contested environments where vehicles could be lost with relatively little regret.[29] Indeed, at the SoS level, UCAS can enable a more adaptable and resilient force if they are operated at scale. By adding many new nodes that could be configured as sensors, weapons, or EW systems, uncrewed systems part of a wider network could allow US forces to recompose kill chains in the face of losses, mitigate enemy countermeasures, or overwhelm enemy decision-making or defences.

To harvest the SoS-level value of uncrewed systems the DoD, is prioritising programmes that incorporate less-expensive and more numerous UCAS to enable scale and mass, such as ALE, CCA, or Replicator. Although mass is sometimes stated as a rationale for these programmes, the more important impact is on enabling operational innovation. Deputy Secretary of Defence Kathleen Hicks noted in her announcement for the Replicator programme that it would help unlock the creativity of US warfighters, by giving them a large number and diversity of vehicles which DoD leaders hope will be able to carry modular and interchangeable payloads.[30]

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[27] Mackenzie Eaglen, "A Shrinking U.S. Air Force Cannot Deter America's Enemies", in *19FortyFive*, 25 May 2023, https://www.19fortyfive.com/?p=108643; Jerry Hendrix, "The Age of American Naval Dominance Is Over", in *The Atlantic*, 13 March 2023, https://www.theatlantic.com/article/673090.

[28] Stephen Losey, "How Autonomous Wingmen Will Help the Air Force Win the Next War", in *Defense News*, 15 February 2022, https://www.defensenews.com/air/2022/02/13/how-autonomous-wingmen-will-help-fighter-pilots-in-the-next-war; Sam LaGrone, "CNO: Navy to Finalize Large Unmanned Surface Vessel Requirements Later This Year," in *USNI News*, 5 April 2023, https://news.usni.org/?p=102122.

[29] See: John R. Hoehn, Kelley M. Sayler and Michael E. DeVine, "Unmanned Aircraft Systems: Roles, Missions, and Future Concepts", in *CRS Reports*, 18 July 2022, https://crsreports.congress.gov/product/details?prodcode=R47188. However, the 2019 downing of a MQ-4 broad area maritime surveillance (BAMS) demonstrator by Iran highlights how even expensive UCAS can be considered expendable. See Jim Garamone, "Iran Shoots Down US Global Hawk Operating in International Airspace", in *DOD Articles*, 20 June 2019, https://www.defense.gov/News/News-Stories/article/article/1882497/iran-shoots-down-us-global-hawk-operating-in-international-airspace.

[30] Jim Garamone, "Hicks Discusses Replicator Initiative", cit.

The continued evolution of US UCAS programmes away from the large, non-stealthy ISR vehicles of the 2000s to the small and many vehicles of the 2020s will depend on improvements in the cost and miniaturisation of mission systems like sensors, radios, and EW systems, which are benefitting from commercial developments. The UCAS evolution will also require more deliberate and sustained processes to integrate UCAS with the crewed force, where the DoD and US defence vendors are finding that software can often ease the process of enabling interoperable communications, data sharing, and command and control.[31]

[31] For more on these processes in DoD, see Bryan Clark and Dan Patt, "Unalone and Unafraid", cit.

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4. China and Russia

by Justin Bronk[1]

Both Russia and China have produced uncrewed combat aerial vehicle prototypes and studies, with the earliest seen publicly emerging in the mid-2000s, and subsequently progressed at notably different paces towards fielding operational capabilities. Despite similar doctrinal roots, the Russian Aerospace Forces (VKS) and People's Liberation Army Air Force (PLAAF) were already on notably divergent developmental pathways for UCAS before the Russian invasion of Ukraine in 2022. This should not come as a surprise given the radical differences in economic power, level of capability ambition and increasingly industrial and microelectronics capacity between the two countries.

4.1 Russia

In Russia, the earliest publicly disclosed development roughly fitting this categorisation was a demonstrator model of a flying-wing type UCAS called "Skat", which was a self-funded project by Mikoyan (later part of the Russian Aircraft Corporation "MiG") that began in 2005 and was displayed at the Moscow Airshow in 2007. Despite having weapons bays for air-to-ground bombs and/or missiles, the model was relatively simple and did not enter flight testing. While little is known publicly about what development was undertaken beyond the aerodynamic studies to produce a mock-up model, it is highly unlikely that such early work included any advanced work on the in-flight automation, sensors and other avionics that would have been required to progress towards a viable combat air system. The Skat programme did not initially progress beyond this early design phase due to a lack of funding or interest from the Russian Armed Forces.[2] The MiG design bureau has been plagued by significant financial and industrial capacity problems due to a lack of orders and investment since the end of the Cold War.[3] Likely as a result of this weakness, what knowledge had been gained through the Skat development effort was later folded into a joint programme between MiG and the much larger and more advanced Sukhoi design bureau in 2011.[4]

This joint Sukhoi-MiG effort would ultimately produce the Su-70 Okhotnik-B heavy strike UCAS, which performed its first test flight in August 2019.[5] The Su-70 is a fairly

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[2] "Источник: РСК 'МиГ' возобновила работы над ударным беспилотником 'Скат'" [Source: RSK 'MiG' resumed work on the 'Skat' attack drone], in *TASS*, 10 September 2018, https://tass.ru/armiya-i-opk/5547736.

[3] Matthew Bodner, "Russia's Once-mighty Fighter Jet Firm MiG Struggling as Rivals Make Gains", in *The Moscow Times*, 2 July 2015, https://www.themoscowtimes.com/2015/07/02/a47871.

[4] Vladimir Karnozov, "MiG and Sukhoi to Join Forces on Russian UCAV", in *Flight Global*, 11 August 2011, https://www.flightglobal.com/101484.article.

[5] Justin Bronk, "First Flight of Russia's S-70 Okhotnik-B UCAV", in *RUSI Defence Systems*, 9 August

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large, tailless flying wing design with a single AL-31 series turbofan engine with a curved intake situated on the upper section of the fuselage to hide the turbine face from enemy radar emitters. It has internal weapons bays and a reported maximum take-off weight (MTOW) in the 44000lb class, which suggests impressive internal fuel capacity.[6] Unlike some other UCAS demonstrator programmes such as the British Taranis or French-led nEUROn (involving Sweden, Italy, Spain and other European actors), Russia has continued to develop the Su-70 beyond the initial flying prototype.[7] In December 2021 a second, more refined airframe was rolled out for flight trials including a significantly stealthier shrouded engine exhaust section and generally "cleaner" airframe.[8] Furthermore, in 2022 Russia reportedly conducted weapons separation trials with both unguided and precision-guided bombs and missiles from the second Su-70 airframe.[9]

The external design of the Su-70 suggests that the aircraft is optimised for strike operations against known enemy ground targets that are located a significant distance inside enemy-controlled or contested airspace. With a non-afterburning variant of the AL-31, significant fuel capacity and low-drag design optimised for efficient subsonic cruise, it should have an impressive combat radius without in-flight refuelling and be relatively difficult to detect and track at longer distances using traditional X- and Ku-band radars. Furthermore, comparative Russian industrial weaknesses in micro-electronics, avionics and automated information processing would be less of a hindrance for a UCAS designed for penetrating strike missions against known static targets than for one intended to conduct missions that involve dealing with dynamic targets and complex scenarios.

On the other hand, Russian sources have touted the UCAS as being intended to operate in mixed formations alongside the Sukhoi Su-57 low-observable fighter aircraft; with the current plan being for a single Su-57 to coordinate the actions of up to four Su-70 Okhotnik-Bs.[10] Flight trials have been conducted with prototypes operating side by side and both types have been seen wearing special paint schemes that make direct reference to the Su-57/Su-70 pairing.[11] This is in line

2019, https://www.rusi.org/explore-our-research/publications/rusi-defence-systems/first-flight-russias-s-70-okhotnik-b-ucav.

[6] "Russia Rolls out First Flight Prototype of State-of-the Art Okhotnik Heavy Strike Drone", in *TASS*, 14 December 2021, https://tass.com/defense/1375043.

[7] Christina Mackenzie, "Conference Call Confusion: Is the Joint French, British Fighter Program 'Terminated'?", in *Defense News*, 28 February 2019, https://www.defensenews.com/industry/2019/02/28/conference-call-confusion-is-the-joint-french-british-fighter-program-terminated.

[8] "Russia Rolls out First Flight Prototype of State-of-the Art Okhotnik Heavy Strike Drone", cit.

[9] Miko Vranic, "Russian Okhotnik UCAV Conducts First PGM Launches", in *Janes*, 31 May 2022, https://www.janes.com/defence-news/russian-okhotnik-ucav-conducts-first-pgm-launches.

[10] "Russia Rolls out First Flight Prototype of State-of-the Art Okhotnik Heavy Strike Drone", cit.

[11] Tom Demerly, "Russian Sukhoi's 5th Generation Su-57 'Felon' in Stunning New Photos from MAKS 2019", in *The Aviationist*, 5 November 2019, https://theaviationist.com/2019/11/05/russian-sukhois-5th-generation-su-57-felon-in-stunning-new-photos-from-maks-2019; Tom Demerly, "Video: Russia's New Su-70 Okhotnik-B or 'Hunter-B' Drone Makes First Flight", in *The Aviationist*, 7 August

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with various Western and Chinese concepts for collaborative combat aircraft or adjunct type UCAS that are intended to provide a cheaper way to enhance combat mass alongside traditional piloted fighters. However, operationally this concept means tethering the long-range/endurance but subsonic Su-70 to the significantly shorter range/endurance and supersonic Su-57. These risks preventing the Su-57 from fully exploiting its own performance, whilst also preventing the Su-70 from fully exploiting its much greater endurance and range – at least if it must return to base once its controlling fighter does. It also adds significant additional complexity to the datalink, avionics, software development and regulatory and testing requirements for both the Su-70 and Su-57 programmes, compared to treating each as a self-contained mission system. The Su-57 already faces complex sensor processing and avionics integration challenges due to its multi-radar design and Russia's limited access to high-end micro-electronics, especially after the imposition of wide-ranging sanctions following the invasion of Ukraine in February 2022. Monitoring and controlling the activities of potentially multiple Su-70 "wingmen" will add significantly to the complexity of in-cockpit workload for Su-57 pilots, and this is undoubtedly why the planned integration between Su-70 and Su-57 has been slated for a planned but so far not developed twin-seat derivative of the Su-57.[12] Even before the impact of expanded Western sanctions and radical Russian financial reprioritisation of defence spending were brought on by the invasion of Ukraine, a supposedly mature single-seat Su-57M was tentatively scheduled to enter production in 2025.[13] Therefore, it now seems highly unlikely that a twin-seat Su-57, or even single-seater avionics suitable for controlling Su-70s in representative combat conditions will enter VKS service this decade.

This leaves the upgraded twin-seat Su-30SM2 multirole fighter as the sole practical candidate for any adjunct type CONOPS for the Su-70 if it enters VKS frontline service. This upgraded SM2 version of the Su-30 not only has a second pilot to manage the workload of coordinating UCAS wingmen, but also the required OSNOD datalink to provide the required in-flight connectivity and data transfer rates.[14] However, the Su-30SM2 is not a stealth design and has proven somewhat vulnerable even to Ukrainian ground-based SAM systems during the invasion of Ukraine. Thus, it is unlikely that it would be able to risk operating far forward enough at medium or high altitudes to support deep penetrating Su-70 sorties with real-time command and control in a high-intensity scenario such as any direct clash between Russian and NATO forces. This would not necessarily prevent the Su-70 from being employed as "eyes forward" and possibly as additional air-to-air missile carriers for Su-30SM2 formations in a defensive-counter-air role. However, it likely means that if the Su-70 is used for deep penetration sorties

2019, https://theaviationist.com/2019/08/07/video-russias-new-su-70-okhotnik-b-or-hunter-b-drone-makes-first-flight.

[12] "Russia Rolls out First Flight Prototype of State-of-the Art Okhotnik Heavy Strike Drone", cit.

[13] "Production of Upgraded Version of Su-57 Fighter Is to Start in 2025 — Source", in *TASS*, 9 August 2021, https://tass.com/defense/1323823.

[14] Charlie Gao, "1 Thing the Russian Military and Its Stealth Fighters Can't Fight Without", in *The Reboot*, 1 April 2021, https://nationalinterest.org/node/181752.

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into airspace defended by NATO forces, it could only be credibly employed to strike known static targets with air-to-ground weaponry. Very significant levels of in-flight automation would be required for more dynamic missions, such as hunting high-value air assets such as tanker or AWACS aircraft beyond the real-time datalink command range of crewed fighters. This is likely to be beyond what the Russian aerospace industry can currently producing at any significant scale, due to systemic micro-electronics production limitations, Western sanctions and multiple competing priorities for funding and components.

4.2 China

Chinese UCAS development, on the other hand, is already significantly more advanced and is being pursued on a much larger scale than in Russia. The Chinese "Sharp Sword" UCAS demonstrator was first flight tested in 2013, as one of seven demonstrators developed for the Aviation Industry Corporation of China (AVIC) 601-S competition.[15] The Hongdu Aviation Industry Group, a subsidiary of AVIC, was the design team that developed the "Sharp Sword" demonstrator that appears to have been selected for further development as China's first publicly acknowledged UCAS programme. Hongdu has subsequently refined the design into the Gonji-11 (GJ-11), a significantly refined version of which was displayed as a supposedly "operational system" at the Chinese Communist Party's (CCP) 70th anniversary day parade in Beijing in October 2019.[16] Like the Russian Su-70 and most Western UCAS prototypes, the GJ-11 is a tailless flying wing design. It is powered by a single non-afterburning turbofan engine with a curved-ducted intake mounted in the upper fuselage to reduce its frontal radar cross section and a shrouded exhaust section to reduce RCS and, presumably, infra-red signature.[17]

The GJ-11 designation suggests that this UCAS is primarily optimised for the penetrating strike role, since "*gonji*" means "attack" in Chinese. The airframe appears to be configured with two internal weapons bays suitable for carriage of 2000lb class air-to-ground weapons, and is reportedly equipped with an internal satellite communications array to facilitate command and control beyond line of sight.[18] Unlike Russia, China possesses aerospace and electronics industrial sectors that are more than capable of producing the required level of avionics, sensor and mission systems required to enable highly automated long range strike and potentially even counter-air operations beyond visual range in the heavy electronic warfare environment that would characterise any future clash between Chinese and American forces in the Indo-Pacific. The CCP is also unlikely to shy

[15] Global Security website: *Gongji-11 (GJ-11) Sharp Sword / Lijian*, https://www.globalsecurity.org/military/world/china/lijian.htm.

[16] Joseph Trevithick, "China Showcases Stealthier Sharp Sword Unmanned Combat Air Vehicle Configuration", in *The Warzone*, 1 October 2019, https://www.thedrive.com/the-war-zone/30111.

[17] Ibid.

[18] Andreas Rupprecht, *Modern Chinese Warplanes: Chinese Air Force. Combat Aircraft and Units*, Výrobce, Harpia Publishing, 2018, p. 105.

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away from the development of UCAS with highly automated lethal capabilities due to the ethical and legal concerns that have so far acted as a barrier to the US and European nations from openly pursuing such capabilities beyond prototype testing.[19]

Other Chinese UCAS prototypes or demonstrators that have been revealed in public include the "Dark Sword" that was supposedly a supersonic CCA type platform. Photos of a partially revealed fuselage were "leaked" in 2018, complementing previously shown mock-up images.[20] However, it is unclear whether this represents an active development programme for service with the PLAAF, especially given the highly secretive and often misinformation-prone Chinese military aviation public information space. Another more traditional UCAS mock-up, called the CH-7, was displayed by the China Academy of Aerospace Aerodynamics at the Zhuhai Airshow in 2018, alongside a claim that it would be starting flight trials in 2019.[21] The airframe appears to be a cranked-kite tailless stealth design similar to the Northrop Grumman X-47B demonstrator, and claimed missions ranged from ISR through strike and attacks on high-value aircraft assets. The CH-7 was also boasted as being available for export customers, and so might represent an effort by its developers to recoup funding spent on the development of a prototype that ultimately lost out to another programmer (possibly the GJ-11) for development by the PLAAF itself.

Conclusion

In conclusion, UCAS development is active in both Russia and China. Both the VKS and PLAAF are explicitly aiming to have combat-ready production-standard UCAS forming a part of their force structures within only a few years. The requirement for high levels of in-flight automation to avoid the vulnerabilities inherent in reliance on datalinks or satellite communication links for real time control in a heavily contested electromagnetic environment create significant challenges for developers in terms of sensor, avionics, mission system and space-weight-power and computing (SWAP-C) constraints. Chinese industry is likely to be in a much better position to solve such challenges than Russia's, which will likely allow Chinese UCAS to be more flexible in terms of the mission sets that they can credibly be relied on for in high-intensity combat. However, this automation also allows the expansion of UCAS fleet numbers to be largely an industrial challenge as opposed to a linked industrial and pilot-training pipeline one. Given that the VKS and the PLAAF have always struggled to match the quality of pilot training and the

[19] For more detail on the lack of development in Western UCAVs despite technological barriers having been long surpassed, see Tyler Rogoway, "The Alarming Case of the USAF's Mysteriously Missing Unmanned Combat Air Vehicles", in *The Warzone*, 2 July 2020, https://www.thedrive.com/the-war-zone/3889.

[20] Tyler Rogoway, "Image of China's Stealthy 'Dark Sword' Fighter-Like Combat Drone Emerges", in *The Warzone*, 5 June 2018, https://www.thedrive.com/the-war-zone/21324.

[21] Zhao Lei, "Stealth Drone About to Hit World Market", in *China Daily*, 6 November 2018, https://www.chinadaily.com.cn/a/201811/06/WS5be0e888a310eff303286bac.html.

flexibility of mission command that Western air forces can product, UCAS may be even more attractive in future as a way of boosting aerial combat power for Russia and China than they are for the US and its allies.

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5. Turkey

by Can Kasapoğlu[1]

5.1 Military strategy, doctrine and concepts of operation (CONOPS)

Turkey's drone warfare military strategy and doctrine, at large, has taken shape during the Turkish military's operations in Syria. Between 2016 and 2020, Turkey launched four consecutive campaigns beyond its southern borders, marking gradually increasing use of robotic warfare systems use. The Turkish military has employed its burgeoning UAS arsenal in a broad array of combat operations, including counterterrorism missions against ISIS and the PKK network, as well as punitive incursions against the Syrian Arab Armed Forces. Up until then, the Turkish Air Force's powerful F-16 and F-4/2020 fleet, as well as the Turkish Army's attack helicopters, were the primary weapons of choice when operating beyond Turkey's borders. The underlying reason behind the Turkish General Staff's drone warfare reliance was, in essence, the threats posed by the Russian Aerospace Forces, SAM systems, MANPADS, as well as the Syrian Arab Army's air defences. The main motive, therefore, was preventing captured pilot situations and minimising expensive material losses.

While the 2016 anti-ISIS campaign Operation Euphrates Shield, and the anti-PKK/YPG incursions, such as Operation Olive Branch (2018) and Operation Fountain of Peace (2019), demonstrated the Turkish drone warfare system's warfighting capabilities against asymmetric adversaries, it was the 2020 Operation Spring Shield that tested these assets' limits against a near-peer adversary: the Syrian Arab Army accompanied by Iran-harvested paramilitaries. The Bayraktar TB-2 and ANKA UCAS inflicted heavy casualties on the Syrian Arab Army, which lacked adequate sensor-network capacity, electromagnetic spectrum resiliency, and situational awareness.[2]

During the dangerous Syria expeditions, the Turkish drone warfare CONOPS in the making focused on transforming uncrewed platforms from legacy "war on terror" assets into conventional warfare systems delivering artillery spotting and battle damage assessment tasks for fire-support units, as well as suppression and / or destruction of enemy air defences (DEAD/SEAD) weapon of choice. Especially during Spring Shield, Turkish drone warfare assets were also employed in combat in close cooperation with electronic warfare systems, predominantly the KORAL manufactured by ASELSAN,[3] marking a new capability for Turkey's UAS programmes.

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[1] Can Kasapoğlu is Defence Analyst at the Centre for Economics and Foreign Policy Studies (EDAM).

[2] Ayşe Betül Bal, "Damage Caused to Assad Regime Assets Demonstrates Turkey's High UAV Capabilities", in *Daily Sabah*, 1 March 2020, https://www.dailysabah.com/business/defense/damage-caused-to-assad-regime-assets-demonstrates-turkeys-high-uav-capabilities.

[3] Milli Savunma, *Aselsan KORAL Mobil Elektronik Harp Sistemi* [Aselsan KORAL Mobile Electronic Warfare System], 9 May 2016, https://www.millisavunma.com/aselsan-koral-mobil-elektronik-harp-sistemi.

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In the meantime, the DEAD/SEAD aspect of the Turkish way of drone warfare matured during the Turkish intervention in Libya, where the Baykar-made TB-2 drones famed as "the Pantsir-hunter", with reference to General Khalifa Haftar's Russian (Wagner) and the Emirates-transferred Pantsir short-to-mid range mobile air defence systems. Turkey's intervention in Libya marked the first time that Ankara used UCAS transfers in the "Foreign Internal Defense" mission to support the UN-recognised government of the country against General Haftar's formations.

In 2020, the Second Nagorno Karabakh War manifested the culmination of the Turkish way of drone warfare, with the very first transfer of Turkish CONOPS (AMONG with Turkish-made armed UAS) – to an ally's conventional armed forces. Following Turkey's footsteps in Syria, the Azerbaijani Armed Forces employed Baku's Israeli and Turkish-made robotic systems (Harop loitering munitions and the TB-2 UCAS) to prey on a number of Armenian combat assets, such as mobile air defences, strategic surface-to-air missile (SAM) systems, troop concentrations, armoured platforms, and even ballistic missile TELARs (transporter-erector-launcher).[4] Significantly, Baku's drone salvos to eliminate Armenian air defences at the outset of the war mimicked Ankara's tactics during Operation Spring Shield.

5.2 Defence industrial trends: Relevant programmes (past, present and future) in terms of UCAS

At present, the Turkish breakthrough in the UCAS segment is spilling over to other industries, establishing an across-the-spectrum drone warfare ecosystem. Alongside the projects in the UCAS category, the number of initiatives in uncrewed ground vehicles (UGV) and uncrewed surface/underwater vehicle (USV/UUVs) are rapidly increasing.[5]

In the naval domain, the progress of the innovation is skyrocketing. Starting with uncrewed surface vehicles, the Turkish naval drone industry now includes a variety of solutions, such as semisubmersible drones (Havelsan's ÇAKA)[6] and anti-submarine warfare (ARW) assets like Ares Shipyard and Meteksan's ULAQ DSH/ASW.[7] Some of these systems have already proved themselves in NATO exercises,[8] while others are currently receiving their final touch-ups before they enter service.

[4] Can Kasapoğlu, "Hard-Fighting in the Caucasus: The Azerbaijani Armed Forces' Combat Performance and Military Strategy in the 2020 Nagorno-Karabakh War", in *SAM Papers*, No. 18 (February 2021), http://sam.gov.tr/sam-papers-18-en.en.mfa.

[5] Can Kasapoğlu and Sine Özkaraşahin, "Robotic Rise in the Seas: Turkish Unmanned Naval Deterrent in the Making", in *EDAM*, 8 December 2022, https://edam.org.tr/en/foreign-policy-and-security/977326-robotic-rise-in-the-seas-turkish-unmanned-naval-deterrent-in-the-making.

[6] Havelsan, *Havelsan to Launch ÇAKA S-KUSV at IDEF'23*, 25 July 2023, https://www.havelsan.com.tr/en/news/daily/havelsan-to-launch-caka-s-kusv-at-idef-23.

[7] "ULAQ denizaltı avlayacak – ULAQ ASW DSH" [ULAQ will hunt submarines], in *Defense Here*, 24 April 2021, https://www.defensehere.com/tr/ulaq-denizalti-avlayacak-ulaq-asw-dsh.

[8] Tolga Yanik and Gokhan Ergocun, "Turkish Unmanned Surface Vehicle Shows Naval Capacities in NATO Exercise", in *Anadolu Agency*, 1 October 2022, http://v.aa.com.tr/2695961.

In the aerial domain, arms makers, which initially focused on tactical and MALE drones, have started to delve into strategic solutions with deep strike capabilities.

In Turkey's defence technological and industrial base, two UCAS producers, private drone company Baykar and the state-owned TUSAŞ, stand out thanks to their arms' design philosophies, combat records, and export portfolios. These two firms' strategic drone programmes are now sailing in two directions.

The first trend pertains to the production of strategic HALE systems with very large payload capacities like the Akinci and Aksungur. Featuring sonobuoys and magnetic anomaly detectors, TUSAŞ' Aksungur comes with a unique anti-submarine warfare (ASW) edge. The Aksungur has already entered the Turkish Navy's arsenal.[9]

Baykar's Akinci pursued an interesting weapon system configuration too. The Roketsan-made TRG-230 equips the baseline with aero-ballistic missile capabilities, while the SOM cruise missile provides the HALE drone air-launched cruise missile edge with a combat range of 200-250 kilometres. Long-range missiles yield decisive strategic advantages in hostile airspace, particularly against high-value targets, without entering the adversary's air defence engagement envelopes.

The second strategic trajectory is the CCA design currently architected by Turkey's major uncrewed systems makers, Baykar and TUSAŞ. These concepts, Kizilelma[10] and Anka-3,[11] respectively, revolve around the ongoing development of uncrewed combat aircraft that can operate alongside manned aircraft. The platforms in question are powered by turbofan engines and will be equipped with advanced arms, including beyond-visual-range air-to-air missile configurations and land-attack capabilities of cruise missiles and aero-ballistic missiles. These assets also come with a reduced radar cross-section, mainly attributed to the platforms' geometric design and internal weapons bay. The chief military value of the next-generation robotic aerial systems will come to the fore in the late 2030 – early 2040 period, when they take to the skies with Turkey's national combat aircraft, KAAN, following a manned-unmanned concept of operation.

The third pronounced defence technological trajectory is the development of a new naval aviation deterrent centred on the Turkish warship TCG Anadolu.[12]

[9] "AKSUNGUR İHA envantere girdi" [AKSUNGUR UAV entered the inventory], in *Turkish Defence News*, 20 October 2021, https://www.savunmasanayist.com/aksungur-iha-envantere-girdi.

[10] Gareth Jennings, "Turkish 'Loyal Wingman' Conducts Taxi and Take-Off Trials Ahead of First Flight", in *Janes*, 21 November 2022, https://www.janes.com/defence-news/news-detail/turkish-loyal-wingman-conducts-taxi-and-take-off-trials-ahead-of-first-flight.

[11] "TUSAŞ Prepares Turkish Loyal Wingman: OKU", in *TurDef*, 7 August 2023, https://www.turdef.com/article/tusas-prepares-turkish-loyal-wingman-oku-concept.

[12] Burak Ege Bekdil, "The Operational – and Political – Benefits of Turkey's New Warship", in *Defense News*, 3 May 2023, https://www.defensenews.com/naval/2023/05/03/the-operational-and-political-benefits-of-turkeys-new-warship.

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Following the procurement of the Russian S-400 air defence system, which led to Ankara's expulsion from the F-35 Joint Strike Fighter programme, significantly altered Turkish plans for fitting the Anadolu with short-take-off vertical landing (STOVL) F-35Bs. Such a turn of events has forced Turkey to look elsewhere in order to find a viable naval aviation option for the Turkish military. In the absence of any other modern STOVL multi-role fighter alternative, Ankara opted for a third – very ambitious – way: operating the TCG Anadolu as a drone carrier.

Baykar's TB-3, with foldable wings and beyond-line-of-sight communication capabilities, will form the backbone of the warship's main armed UAS capability. Eventually, Turkish defence planners are aiming to embark on the twin-engine (probably powered by Ivchenko-Progress AI-322), afterburner-equipped variant of the indigenous, multi-role uncrewed combat vehicle Kizilelma baseline (Kizilelma-C; a variant intended to be supersonic) on the TCG Anadolu. The low-observable Kizilelma has a maximum take-off weight of 6,000 kilograms and a 1,500 kg effective payload.[13]

Apart from conventional drone designs, Turkey is showing a growing interest in loitering munitions too. The Kemankesh baseline,[14] Baykar's UCAS-launched kamikaze drone, offers a telling example in this respect. Featuring electro-optic sensor features along with a warhead, the system brings together intelligence and strike capabilities in one platform. Besides, it will be able to share real-time intelligence with the mothership that released the Kemankesh. It remains to be seen if other Turkish drone makers will follow suit and enter the smart munitions segment in Baykar's footsteps.

5.3 Research and development (R&D) priorities

Turkey has a broad drone strategic culture across its services. The Turkish Armed Forces (army, air force and navy), gendarmerie, coast guard and police special operations detachments of the Ministry of Interior Affairs, and the intelligence service are all drone operators. According to Selçuk Bayraktar, the technology chief of Baykar, Turkey's arsenal (covering all these diverse customers and operators) includes over 150 Bayraktar TB-2s and around a dozen Akinci HALE drones.[15] Other open-source data showcases that the Turkish Armed Forces currently possess over 40 TUSAŞ Anka UCAS and around six Aksungur drones. At present, over 50 Bayraktar TB-3 are in production to enter the arsenal within a few years. When other complementary systems such as kamikaze drones, uncrewed rotary wing platforms, and surveillance UAS are included in the calculations, the number

[13] Baykar website: *Bayraktar Kızılelma*, https://www.baykartech.com/en/uav/bayraktar-kizilelma.

[14] Göksel Yıldırım, "Türkiye'nin yeni seyir füzesi KEMANKEŞ ortaya çıktı" [Turkey's new cruise missile KEMANKEŞ revealed], in *Anadolu Agency*, 27 April 2023, http://v.aa.com.tr/2882673.

[15] "Selçuk Bayraktar açıkladı… Türkiye'nin Kaç SİHA'sı var?" [Selçuk Bayraktar explained… How many UAVs does Turkey have?], in *Turkish Defence News*, 4 January 2023, https://www.savunmasanayist.com/selcuk-bayraktar-acikladi-turkiyenin-kac-sihasi-var.

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of operational Turkish uncrewed aerial systems at the nation's disposal exceeds hundreds. A significant R&D priority pertains to the development of indigenous swarm capabilities. In 2019, the former chief of the Defence Industry Agency (*Savunma Sanayii Başkanlığı* – SSB), Ismail Demir, announced that Turkish UAS producers are working on using the Akinci armed UAS as a mothership for the indigenous loitering munition Alpagu.[16]

Featuring both autonomous and manual operation, STM's rotary-wing and fixed-wing kamikaze drone solutions, such as the Kargu, Alpagu and Kargu-2, stand out as remarkable indigenous solutions in the kamikaze drone market.[17] Besides their combat-proven performance, what makes these systems special are their machine-learning capabilities boosted by advanced convolutional algorithms.

Besides these ambitious projects, the Turkish uncrewed systems producers are also striving to constantly improve the weapon system configurations and available payloads for existing platforms. In this regard, the communication pod UYGAR,[18] introduced at Teknofest 2023 in Ankara, looms large as an interesting example. Developed for TUSAŞ' Anka, it provides stable and safe 4G/LTE communication within a two to five km range.

Conclusion

The Turkish UCAS industry is expanding rapidly, evolving into a multi-domain, across the spectrum segment of the burgeoning defence technological and industrial base. With uncrewed projects dominating the ongoing R&D efforts in the nation's aerial, ground, and naval domains, the Turkish UCAS market hints at the future operating environment as well. UCAS will not take over conventional warfare anytime soon. Yet, this new environment will be characterised by a significant level of MUM-T.

Finally, Turkey does not only sell robotic warfare solutions in an off-the-shelf fashion. Indeed, its export arrangements spark defence ecosystems beyond its borders, such as in Ukraine and Azerbaijan, and boost its defence-cooperation portfolio through high-tech transactions. After all, Ankara's drone breakthrough is also a vector for direct and indirect military involvement in the conflicts of choice, as observed in the case of Libya.

[16] Ismail Demir, "Milli İHA platformlarımızdan atılabilen sürü vurucu İHA sistemi ve farklı konseptler üzerine çalışıyoruz" [We are working on the UAV swarm strike system and different concepts that can be launched from our national UAV platforms], in *Twitter*, 26 May 2019, https://twitter.com/IsmailDemirSSB/status/1132725606418919426.

[17] Halit Turan, "Turkish Drones Continue to Rise in Numbers, Make Global Splash", in *Daily Sabah*, 19 April 2021, https://www.dailysabah.com/business/defense/turkishdrones-continue-to-rise-in-numbers-make-global-splash.

[18] "İHA'ları baz istasyonu yapan UYGAR, Teknofest'te boy gösterdi!" [UYGAR Communication Pod that turns UAVs into base stations, appeared at Teknofest!], in *TRT Haber*, 5 September 2023, https://www.trhaber.com/bilim-teknoloji/iha-lari-baz-istasyonu-yapan-uygar-teknofest-te-boy-gosterdi-h123699.html.

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6. The European context

by Ottavia Credi[1]

Despite early efforts suggesting the contrary, Europe has traditionally shown a significant delay in the development and acquisition of armed and unarmed UAS.[2] This was due to several factors including, but not limited to, peculiar operational requirement, industrial rivalries and ethical qualms. Through the years, European states have worked on the development of a number of medium-altitude, long-endurance, dual-use UAS yet they did not put as much effort in the launch of related multinational procurement programmes.[3]

In recent years, however, European countries have started to partially invert this trend.[4] There is a higher degree of cooperation on "traditional" UAS-related projects in order to pool resources and markets, share expertise, and collectively enhance capabilities. The development of advanced drones involves a combination of high-end aerospace engineering capabilities, AI, sensor technology, and weapons integration in a wider ecosystem of defence assets. Indeed, many in Europe see cooperation as a necessary precondition for achieving the level of effectiveness required by armed UAS, especially with a view to future UCAS concepts.[5]

By and large, as evident from current development programmes and operational concepts, Europeans conceive future UCAS as parts of a larger combination of crewed and uncrewed next generation platforms, rather than standalone systems.[6] Indeed, albeit in a somewhat fragmented manner, European states have been in the process of developing and exploring the concept of CCA as the preponderant channel of development in the field of UCAS.

6.1 Main EU defence frameworks

EU member states can count on several defence initiatives in the context of which they can conduct military research, development and innovation activities. The two most relevant frameworks are the Permanent Structured Cooperation (PESCO), within which the EU provides a process aimed at increasing cooperation towards stronger military and technological capabilities, and the European Defence Fund (EDF), aimed at fostering collaboration among member states in developing defence capabilities, including uncrewed systems, through an economic incentive based on its 7,9 billion-euro-budget over seven years.

[1] Ottavia Credi was until October 2023 a Researcher in the Defence and Security Programmes at IAI.
[2] Interview, 4 September 2023.
[3] Douglas Barrie et al., "Armed Uninhabited Aerial Vehicles and the Challenges of Autonomy", cit.
[4] Interview, 30 August 2023.
[5] Interview, 20 September 2023.
[6] Interview, 30 August 2023.

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The PESCO framework includes a number of projects feeding into European technological capabilities related to UAS and/or UCAS development.[7] For instance, with the Air Power project, adhering member states aim to increase the air superiority capabilities of their armed forces, through innovative technological components.[8] In 2021, the project partners published a white paper outlining a number of key technologies that need to be developed to obtain future air superiority systems, including next-generation sensors, high-performance engines, and directed energy weapons. As of October 2023, the Project is working to develop a road map for the design and development of new platforms and systems, which is expected to be completed in 2024. The Next Generation Small RPAS (NGSR) project intends to develop the next generation of tactical UAS, envisaged as dual-use, multi-purpose/multi-role systems.[9] Furthermore, in PESCO Italy leads the Rotorcraft Docking Station for Drones project, meant to create a new capability to launch, operate, and recover mini- and micro- UAS from rotorcraft platforms.[10] Yet, the most relevant PESCO project in terms of European UAS and UCAS capabilities is today the European Medium Altitude Long Endurance Remotely Piloted Aircraft Systems – better known as MALE RPAS or Eurodrone, discussed in the next paragraph.[11] According to some, PESCO could be the right framework within which European countries could develop a hypersonic UCAS, which could then aspire to EDF funds.[12]

Within the EDF, the European Initiative for Collaborative Air Combat Standardisation (EICACS) project was conceived with the clear understanding that future air combat will include crewed and uncrewed systems.[13] Therefore, EICACS intends to increase European interoperability and facilitate the integration of future UCAS and, in doing so, it works in collaboration with PESCO's EU Collaborative Warfare Capabilities (ECOWAR) project.[14]

In the context of the European Defence Agency (EDA), Project MALE RPAS Training Technology Demonstrator (RTTD) aims to develop tactics, harmonise different approaches to training, and strengthen the relationship between different national user communities.[15] Through the European MALE RPAS User Community, the EDA

[7] Interview, 1 September 2023.

[8] PESCO website: *Air Power*, https://www.pesco.europa.eu/?p=2757.

[9] PESCO website: *Next Generation Small RPAS (NGSR)*, https://www.pesco.europa.eu/?p=2734.

[10] PESCO website: *Rotorcraft Docking Station for Drones*, https://www.pesco.europa.eu/?p=2743.

[11] PESCO website: *European Medium Altitude Long Endurance Remotely Piloted Aircraft Systems – MALE RPAS (Eurodrone)*, https://www.pesco.europa.eu/?p=795.

[12] Interview, 4 September 2023.

[13] European Commission, *EICACS Factsheet*, 25 January 2023, https://defence-industry-space.ec.europa.eu/system/files/2023-01/Factsheet_EDF21_EICACS.pdf.

[14] For further information, see PESCO website: *EU Collaborative Warfare Capabilities (ECOWAR)*, https://www.pesco.europa.eu/?p=1768.

[15] European Defence Agency (EDA) website: *UAS Integration*, https://eda.europa.eu/what-we-do/all-activities/activities-search/uas-integration.

facilitates dialogue amongst member states concerning the MALE UAS domain. This forum is meant to encourage EDA countries to exchange information, best practices and operational experience, as well as identify opportunities for industrial cooperation.

The Agency also launched the European Air Transport Training (EATT), a multinational effort to enhance interoperability and training among European air forces, in the context of which member states conduct joint training exercises and missions, which also include scenarios involving UCAS working alongside crewed aircrafts.[16]

As a number of stakeholders have observed, some cooperative programmes within the aforementioned frameworks have experienced a lack of clarity as to the respective roles by involved parties, the overall goal of each project, and their ability and willingness to meet a given set of shared standards.[17] This is somehow a recurring feature of some PESCO initiatives, mainly in the first waves of projects.[18] Another concern is the ability to guarantee that any new, technologically advanced product is met with market demand – if that is not the case, European defence activities risk being stuck at the research and development phase.[19] As the PESCO initiatives are launched and funded by EU member states (plus the eventual involvement of the EDF to cover part of the costs), the market issues should be addressed directly by the participating member states, which know what quantity of the resulting products would be to meet their requirements.

6.2 The Eurodrone programme

The most significant current European UAS programme, in terms of overall investment and involved partners, is the Eurodrone: a joint programme featuring Airbus as prime contractor and Leonardo and Dassault Aviation as main partners, involving France, Germany, Italy, Spain and Czechia. The initiative is managed by the Organisation for Joint Armament Co-operation (*Organisation Conjointe de Coopération en matière d'Armement*, OCCAR). Participating countries have set for the programme the objective of meeting European needs for an advanced UAS.[20] Notably, Eurodrone represents the first uncrewed aerial system designed to fly in non-segregated airspace, a useful feature especially in surveillance and ISR missions where it may be required to use civilian air space without disrupting civilian traffic. Eurodrone's twin-turboprop propulsion system, which allowed it

[16] For further information, see: EDA, *EATT-15 Factsheet*, May 2015, https://eatc-mil.com/uploads/news/EATT15.pdf; EDA, *EAATTC 16-1 Factsheet*, September 2015, https://eda.europa.eu/docs/default-source/eda-factsheets/eaattc-16-1_factsheet; EDA, *EAATTC 17-3 Factsheet*, September 2015, https://eda.europa.eu/docs/default-source/eda-factsheets/eaattc17-3-factsheet.

[17] Interviews, 30 August and 1 September 2023.

[18] Interview, 30 October 2023.

[19] Interview, 28 August 2023.

[20] Leonardo website: *The Next Generation Uncrewed Aircraft System (UAS)*, https://uncrewed.leonardo.com/en/products/eurodrone.

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to gain the certifications necessary to fly in un-segregated airspace, should also guarantee substantial on-board power for the mission system.[21] The platform's open architecture should allow its capabilities to be enhanced, updated and adapted according to the future needs of the user.[22]

Once in service, Eurodrone will operate to support intelligence, surveillance, target acquisition and reconnaissance (ISTAR) missions, including armed ISTAR operations. In particular, it is meant to collect and integrate data from different on-board sensors, and record and send such data in real-time to the ground station in order to obtain a complete tactical picture.[23] Through its advanced modular capability, it is designed to provide advanced strategic performance capabilities and was seen at its inception as boosting an independent technological base in the field of uncrewed aviation.[24] Indeed, among the stated goals of the Eurodrone programme, from an EU perspective, is the development of secure European technological capabilities in the UAS field.[25]

Like most in-service large UAS today, the Eurodrone is not properly suited (nor was it designed) to operate in peer-to-peer scenarios in contested airspace. Instead, having resulted in operational requirements deeply rooted in crisis management and stability operations as a key focus, it is likely to be more useful in asymmetric conflicts, crisis contingencies as well as in a broad range of surveillance operations.[26] At the same time, according to some experts, due to its size and performance (ceiling, endurance, payload), the Eurodrone can be considered as a very large MALE or a small HALE and can operate stand-off as needed, therefore avoiding to be exposed to some of the anti-access threats.

Building on that base, while currently envisaged tasks focus on ISTAR, Eurodrone is fit to be armed to engage and neutralise a wide range of static and moving threats – at sea and on land, in all weather conditions. A significant development in this regard was reported in October 2022, when France's General Directorate of Armaments (*Direction générale de l'armement*, DGA) announced it intended to equip its future fleet of Eurodrones with MBDA's Akeron LP air-to-ground missiles, which features a warhead able to hit different types of targets.[27] As the Akeron LP has

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[21] Ibid.

[22] Gianni Dragoni, "Difesa, firmato il contratto per l'Eurodrone con Airbus, Leonardo e Dassault", in *Il Sole 24 Ore*, 24 February 2022, https://www.ilsole24ore.com/art/difesa-firmato-contratto-l-eurodrone-airbus-leonardo-e-dassault-AECjUwFB.

[23] "Cresce il ruolo di Leonardo nel programma Eurodrone", in *Ares Osservatorio Difesa*, 19 June 2023, https://aresdifesa.it/?p=41808; Chiara Rossi, "Leonardo crescerà nel programma Eurodrone, tutti i dettagli", in Start Magazine, 19 June 2023, https://www.startmag.it/?p=238497.

[24] Leonardo website: *The Next Generation Uncrewed Aircraft System (UAS)*, cit.; Airbus website: *Eurodrone*, https://www.airbus.com/en/defence/eurodrone.

[25] OCCAR website: *MALE RPAS – Medium Altitude Long Endurance Remotely Piloted Aircraft System*, https://www.occar.int/node/14.

[26] Interview, 1 September 2013.

[27] Gareth Jennings, "MBDA Akeron LP Missile to Arm Eurodrone", in *Janes*, 6 October 2022, https://www.janes.com/defence-news/news-detail/mbda-akeron-lp-missile-to-arm-eurodrone; Joe Saballa,

a range of 15 km when launched from altitude, this capability is most likely being acquired for use in asymmetrical conflict scenarios in the absence of advanced enemy air defence systems. Since the Eurodrone will be able to carry up to 2,300 kg in payload,[28] it will be surely fitted with a wide range of weapons, including guided bombs such as the 227 kg GBU-49 and heavier air to ground missiles, whose range will span tens of kilometres.

The Eurodrone is seen as a strategic capability within EU, being mentioned as such by the 2022 Strategic Compass.[29] This status has allowed it to draw funding from the European Defence Industrial Development Programme (EDIDP), with an overall budget of approximately 290 million euros.[30] Notably, this represented one of the first and most important interactions between PESCO and the EDF precursors.

In 2022, Airbus and OCCAR signed the contract for the development of 20 Eurodrone systems and five years of initial in-service support for a total expense of approximately 7.1 billion euros.[31] Each system will consist of three drones and two ground control stations (GCS), for a total of 60 UAS, and each country involved in the programme contributes with a financial share that is proportional to the drones it will purchase. For instance, Italy is committed to buying five Eurodrone systems, therefore fifteen drones and ten GCS, for under two billion euros – half of which will be dedicated solely to the development phase.[32] Meanwhile France and Spain both agreed to purchase four systems, whilst Germany will procure seven.[33] Currently, the programme envisages the delivery of the first system in 2028, and the delivery of fifteen UAS and ten GCS in 2035 – a considerably longer timeframe than initially planned.

The design, development, integration and production phases of the Eurodrone's Airborne Mission System (AMS), which integrates a suite of advanced sensors including radar and the Multi-Purpose Mission Computer (MPMC), will be

"France to Equip Eurodrones with Akeron Air-to-Ground Missile", in *The Defense Post*, 10 October 2022, https://www.thedefensepost.com/2022/10/10/france-eurodrones-akeron-missile.

[28] Airbus, *Dataposter Eurodrone*, June 2023, https://www.airbus.com/sites/g/files/jlcbta136/files/2023-06/Dataposter_Eurodrone.pdf.

[29] Council of the European Union, *A Strategic Compass for Security and Defence*, 21 March 2022, https://www.eeas.europa.eu/node/410976.

[30] European Commission, *MALE RPAS Factsheet*, 30 June 2021, https://defence-industry-space.ec.europa.eu/male-rpas_en.

[31] Gianni Dragoni, "Difesa, firmato il contratto per l'Eurodrone con Airbus, Leonardo e Dassault", cit.

[32] Airbus website: *Eurodrone*, cit.

[33] Direction générale de l'armament, *Le ministère des Armées commande douze Eurodrone (4 systèmes)*, 28 February 2022, https://www.defense.gouv.fr/node/1200; Clemens Bilan, "Airbus producirá los Eurodrone en las factorías de Cádiz y Tablada (Sevilla)", in *El País*, 12 December 2022, https://elpais.com/economia/2022-12-12/airbus-producira-los-eurodrone-en-las-factorias-de-cadiz-y-tablada-sevilla.html; Sandra Süßmuth, "Die Eurodrohne ist auf dem Weg", in *Bundeswehr website*, 24 March 2021, https://www.bundeswehr.de/de/organisation/luftwaffe/aktuelles/die-eurodrohne-ist-auf-dem-weg-5044732.

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conducted at Leonardo's facilities in Caselle Torinese (Italy).[34]

A major stumbling block in consortium negotiations was hit when the industrial partners discussed who, between Avio Aero – controlled by General Electric – and Safran, would supply Eurodrone's 120 engines, with the two companies respectively offering the Catalyst and the Ardiden TP3.[35] The choice eventually fell on the newer and most advanced Catalyst, which is the first turboprop to feature additive manufactured components, making the engine lighter and more efficient.[36]

6.3 The nEUROn programme

In 2006, an industrial consortium led by Dassault Aviation (France) with the collaboration of Leonardo (Italy), Saab (Sweden), Airbus Defence and Space (Spain), RUAG (Switzerland) and the Hellenic Aerospace Industry (Greece) joined forces with the goal to develop nEUROn. This was a ground-breaking drone demonstrator with low observability, speed and payload capabilities that put it much more firmly in the UCAS than the UAS category.[37]

The nEUROn demonstrator took off for its maiden flight in December 2012.[38] The programme involved the design, development, production and testing of the drone and, overall, it required the investment of approximately 400 million euros. The nEUROn consortium set a series of well-defined objectives, including conducting air-to-ground missions, creating a stealth platform characterised by a low radar and infrared signature, and carrying out a demonstration of autonomous target detection and recognition.

Amongst nEUROn's aims was the collective development of know-how and capabilities which should provide participating countries and the respective national industries a technological edge in this particular field. The flight demonstrator allowed participants to test key technologies for combat aircrafts, with significant implications for future crewed and uncrewed systems.[39] The demonstrator resulting from the programme is characterised by low observability in terms of both radar and infrared signatures, an internal weapon bay, and the capability to conduct autonomous flights and weapon launches. An Infrared Search and Track (IRST) sensor is able to locate targets within a radius of approximately

[34] "Cresce il ruolo di Leonardo nel programma Eurodrone", cit.

[35] Chiara Rossi, "Leonardo crescerà nel programma Eurodrone, tutti i dettagli", cit.

[36] Marco Battaglia, "Il motore italiano dell'EuroDrone. La firma tra Airbus e Avio Aero", in *Formiche*, 1 September 2022, https://formiche.net/?p=1495063.

[37] Technological demonstrators are crucial in the process of technology maturation, as they allow to develop a better understanding of their functioning, thus decreasing risks in the operational use phases.

[38] Chiara Rossi, "Leonardo, tutti i dettagli sul programma bersaglio dell'attacco contro l'ex Finmeccanica", in *Start Magazine*, 28 December 2020, https://www.startmag.it/?p=132271.

[39] Dassault Aviation website: *nEUROn Programme Milestones*, https://www.dassault-aviation.com/en/defense/neuron/programme-milestones.

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fifty kilometres (km).[40]

The significance of nEUROn as a first in terms of European collaboration on new, innovative concepts for stealth and combat systems should not be understated. Nevertheless, once the initial phases of nEUROn were completed, the involved entities turned gradually to different requirements, more in tune with the need for designs better suited to asymmetric and counter-insurgency operations, before finally realising the need for UAS capable to operate and conduct the mission in a very contested environment.[41] It will likely set the basis for future UCAS programmes in Europe, at least for participating countries and industrial players.[42] Yet, despite the steep R&D costs required to achieve an advanced UCAS, complete with a degree of autonomous capabilities, the fragmentation looms large on the European continent. A follow-on of the nEUROn never materialised, while feasibility studies for a joint programme by France and the UK, building respectively on the nEUROn and the entirely national Taranis programme, failed to come to fruition.[43] The 2023 *Loi de programmation militaire* (Military Planning Law) has pledged sizeable resources to re-activate the vehicle to conduct further activities, in support of a national initiative for a next-gen UCAS that will support French needs, and it is likely to be "mated" with the evolved Rafale.

6.4 The Barracuda programme

In 2003, Airbus Defence and Space launched the Barracuda, a German-Spanish initiative to develop a stealthy combat UCAS. The first prototype of the Barracuda flew in 2006. It had a maximum speed of Mach 0.85 and a range of 5,300 km, and displayed a reduced radar signature and a highly manoeuvrable design, thanks to its large delta wings and thrust vectoring engines.[44]

The drone was equipped with a variety of advanced sensors – such as synthetic aperture radar (SAR), electro-optical and infrared (EO/IR) sensors – and weapons – including air-to-air and air-to-ground missiles – allowing it to conduct a variety of missions from combat to reconnaissance.

[40] Franco Iacch, "Test di combattimento contro nemici reali per il drone nEUROn", in *Il Giornale*, 10 January 2019, https://www.ilgiornale.it/news/mondo/test-combattimento-contro-nemici-reali-drone-neuron-1626723.html.

[41] Interviews, 1 and 22 September 2023 and 30 October 2023.

[42] Interview, 1 September 2023; Dassault Aviation website: *nEUROn Programme Milestones*, cit.; Leonardo, Alenia *Aermacchi, nEUROn, the European UCAV Technological Demonstrator*, 30 November 2012, https://www.leonardo.com/it/news-and-stories-detail/-/detail/alenia-aermacchi-neuron-the-european-ucav-technological-demonstrator.

[43] Eva Grey, "Taranis vs. nEUROn – Europe's Combat Drone Revolution", in *Airforce Technology*, 5 May 2014, https://www.airforce-technology.com/?p=9880.

[44] Airbus, *"The Father of Them All": How the Barracuda Drone's Legacy Flies on*, 30 May 2023, https://www.airbus.com/en/node/50636; "Barracuda Demonstrator Unmanned Air Vehicle Developed by EADS Military Air Systems", in *Army Technology*, 27 August 2008, https://www.army-technology.com/?p=13311.

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In 2012, the project was cancelled due to budget cuts and feeble political support. Still, the Barracuda represented a significant technological achievement, and the lessons learned from the project proved helpful for the development of the FCAS.[45]

6.5 Next steps for Europe

As expected, given the multitude of differing doctrines, political sensitivities, approaches to warfare and industrial policy, European states have been finding it difficult to find common requirements when pursuing highly strategic programmes, such as, for instance, Eurodrone or the nEUROn industrial follow-on.

Meanwhile, the development of UCAS in Europe currently seems mainly centred around advanced systems that are highly integrated and networked with crewed 6th generation combat aircraft like GCAP and FCAS in a SoS framework.[46] It is, therefore, probable that the latter in the form of adjuncts and the former are intrinsically linked, at least up to the medium term. In such a context, a level of fragmentation is to be expected, as the two competing programmes are unlikely to merge. Furthermore, an important challenge will be the integration of CCA platforms designed in the context of 6th-generation air system programmes with existing combat aircraft from the fourth and fifth generations. In this respect, interoperability is a key priority on multiple levels, and especially between new European UCAS and F-35 aircrafts.

[45] For more information of the FCAS project, see Airbus website: *Future Combat Air System (FCAS)*, https://www.airbus.com/en/node/2086.

[46] Interview, 23 September 2023.

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7. Italy

by Elio Calcagno and Alessandro Marrone

7.1 The Ministry of Defence's approach to UAS

In the MoD's public documents, as is generally the case for most emerging and disruptive technologies, drones are generally perceived described as a threat, such as for instance in the most recent Multi-year Programming Documents (*Documenti programmatici pluriennali*, DPP) since 2021.[1] Yet there is a dissonance between political discourse and the Italian military's approach to both UAS and UCAS, as Italy's armed forces have made extensive use of drones in ISTAR roles in military operations at home and abroad for nearly two decades.

Indeed, recognising the value of UAS for ISTAR tasks, Rome embarked on a number of key acquisitions early on. Indeed, Italy was one of the first countries to procure US-made RQ-1 Predator drones, with the first order (worth 55 million US dollars) of five units placed in 2001 and delivered to the Italian Air Force (*Aeronautica Militare*, AM) in 2004. Starting in 2008, Rome placed further orders for the much more capable MQ-9 Reapers to be operated by the AM, while the Army (*Esercito Italiano*, EI) acquired its first RQ-7 Shadow drones and the Navy (*Marina Militare*, MM) opted for the ScanEagle Seymour. Among further acquisitions and upgrade/update programmes, Italian drones have since served alongside the armed forces in deployments around the so-called "wider Mediterranean" region, including Iraq, Afghanistan, Libya, Djibouti, Kosovo, and Syria.

The issue of arming aerial drones has been politically sensitive in Italy, with Rome making a formal request to Washington in 2012 to fit its MQ-9 with weapons.[2] The request was subsequently approved in 2015, at the time making Italy only the second country worldwide after the UK to be granted permission to arm US drones.[3] Against the backdrop of scarce and non-systematic attention by public opinion to defence matters, this issue is part of a broader reluctance by the Italian institutions, political leadership and policy community to be outspoken, frank and consistent on what the armed forces actually do, should do in worst-case scenarios, and need to do in order to carry out their missions – a reluctance that was particularly strong until the 2010s[4] and has never faded completely. In practice, this was evident during Italian military involvement in campaigns such as Kosovo, Afghanistan and Libya,

[1] Italian MoD website: *Documenti Programmatici*, https://www.difesa.it/Content/Pagine/Notaaggiuntiva.aspx.

[2] "Usa: 'Ok a richiesta italiana di armare due droni'", in *La Repubblica*, 4 November 2015, https://www.repubblica.it/esteri/2015/11/04/news/usa_ok_a_richiesta_italiana_di_armare_due_droni_-126626514.

[3] Andrea Shalal, "U.S. Government Approves Italy's Request to Arm Its Drones", in *Reuters*, 4 November 2015, https://www.reuters.com/article/us-italy-usa-drones-idUSKCN0ST1VI20151104.

[4] See in this regard, among others, Alessandro Marrone and Paola Tessari, "The Italian Debate on Defence Matters", in *Documenti IAI*, No. 13|07 (November 2017), https://www.iai.it/en/node/477.

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which successive governments struggled to refer to publicly as "wars". Moreover, as in other European countries, especially in previous years, armed drones have raised widespread concerns among public opinion, linked not only to real critical elements – such as the question of decision-making and keeping humans in the loop – but also to a number of perceptions and biases part of the "killer robot" narrative. Whether and how the extensive use of drones in recent conflicts has influenced and eroded this narrative remains to be seen.

A shift in this approach is nevertheless visible for example in the 2021-2023 Multi-year Programming Document, where it was announced that an investment of 168 million euro would be made over a period of seven years in order to upgrade Italian MQ-9 UAS with weapon payload capabilities (despite Washington greenlighting the armament of Italian Reapers half a decade earlier).[5] According to this document, as well as its successor for 2022-2024, the objective was to increase convoy protection capabilities but also the system's performance in high-intensity scenarios.[6] The political and public dimensions of the armed drones issue still constitute an important element of the Italian decision-making process in this regard.

At the same time, from an Italian perspective in the last decade the most important UAS programme in terms of cooperative investments and procurement has been the Eurodrone.[7] Cost estimates for Italy's involvement in the programme amount to just under 2 billion euro, including service, for a total of five Eurodrone systems (each including fifteen UAS),[8] though questions remain over this programme's suitability in some future conflict scenarios.[9] While size and payload capacity allow these drones to be armed with advanced weaponry,[10] it is as yet unclear whether Rome and other European partners are planning to follow this route, though Paris intends to equip this system with Akeron LP air-to-ground missiles.[11] Given its ability to fly in un-segregated airspace along with civilian traffic, the Eurodrone might come as a useful ISR asset in the context of international peacekeeping, capacity building and crisis management that Italian troops lead or participate in around the world. More in general, this system may yet be highly effective in counterinsurgency missions and in every scenario where the opponents have limited chances to deploy appropriate countermeasures and advanced air defences.

[5] Italian MoD, *Documento programmatico pluriennale della Difesa per il triennio 2021-2023*, 2021, https://www.difesa.it/Content/Documents/20210804%20DPP%202021-2023%20per%20pubblicazione.pdf.

[6] Italian MoD, *Documento programmatico pluriennale della Difesa per il triennio 2022-2024*, 2022, https://www.difesa.it/Il_Ministro/Documents/DPP_2022_2024.pdf.

[7] For more on the Eurodrone and European cooperation programmes in the fields of UAS and UCAS, see chapter 5 of this study.

[8] Gianni Dragoni, "Difesa, firmato il contratto per l'Eurodrone con Airbus, Leonardo e Dassault", cit.

[9] Interview, 1 September 2023.

[10] For more details on how France plans to arm the Eurodrone, see chapter 6 of this study.

[11] For more on the Eurodrone and the European context, see chapter 6 of this study.

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Among the prime contractors involved in the programme, Italy is represented by Leonardo. The company will carry out the design and production of the drone's wing structure and develop the airborne mission system, the airborne electrical and environmental control system, as well as the airborne armament system.[12] Furthermore, Avio Aero, part of the General Electric (GE) group, has won a bid to supply the drone's engines, despite French pressures due to GE being an American entity and having a French (Safran) engine as the alternative. The Catalyst engines powering the Eurodrone have been designed from scratch for a variety of uses, including commercial ones, and will be a new-gen engine built entirely in Europe, and thus will be free of any US International Traffic in Arms Regulations (ITAR) export restrictions.[13]

7.2 Italian investments on UAS technology

The domestic industry made its first foray into the field of modern UAS already in the 1980s and 1990s with the Mirach series, starting with the Mirach 20 (target drone) and Mirach 26 (reconnaissance UAS) systems and leading to the Mirach Mirach 100/5 and eventually the Mirach 40 target drones.[14] These efforts spawned the Falco family of UAS, with the Falco EVO variant also enjoying some success in foreign markets including Pakistan and Jordan. The Falco Astore was the first Italian-made drone to be designed to carry precision-guided weapons (the Turkish-made laser-guided CİRİT missile), while the latest iteration of the Falco, the Xplorer, represents a departure from previous models in terms of payload capacity.[15] The Xplorer MALE UAS has over double the payload capacity of its predecessor and, crucially, Leonardo has planned to use it with MBDA's Brimstone 3 precision-guided missile.[16]

The earliest and most relevant among Italian technological demonstrator programmes in the field of UAS and UCAS technology were undoubtedly Alenia Aermacchi's Sky-X,[17] Sky-Y and Molynx. Except for the Sky-X, the other two systems were all designed primarily to carry out ISTAR missions and were equipped with propeller engines. With a wingspan of little over 9 metres – significantly smaller than the US-made MQ-1 Predator – and a range of over 900 km, the Sky-Y was designed as a MALE UAS.[18] With development starting in 2006, Sky-Y was the

[12] Leonardo, *Leonardo's Growing Role in the Multinational Eurodrone Programme*, 19 June 2023, https://www.leonardo.com/en/press-release-detail/-/detail/19.06.2023-leonardo-s-growing-role-in-the-multinational-eurodrone-programme.

[13] Avio Aero website: *The Catalyst Engine*, https://www.avioaero.com/en/the-catalyst-engine.

[14] Leonardo, *Twenty-five Years of Mirach 100/5*, 19 January 2022, https://www.leonardo.com/en/news-and-stories-detail/-/detail/19-01-2022-twenty-five-years-of-mirach-100-5.

[15] Paolo Valpolini, "PAS 2023 – Weaponising Leonardo's Falco Xplorer", in *EDR On-Line*, 23 June 2023, https://www.edrmagazine.eu/?p=30688.

[16] Tim Martin, "Leonardo Moves out with Brimstone Missile Integration on Falco Xplorer MALE UAV", in *Breaking Defense*, 21 June 2023, https://breakingdefense.com/?p=292671.

[17] The company has become part of Leonardo by constituting the bulk of its aircraft division.

[18] "Sky-Y MALE Unmanned Aerial Vehicle (UAV)", in *Airforce Technology*, 1 June 2010, https://www.

first European MALE UAS to take flight in 2007.[19] The Molynx was a concept for a heavier HALE UAS, with a wingspan of 25 metres, twin engines and foreseen to be capable of completely automated flight (from take-off to landing and everything in-between), with a remote operator only assigning macro tasks.[20]

Alenia Aermacchi's third demonstrator from that era, the Sky-X, was a truly pioneering system, much closer to the UCAS category than the aforementioned UAS. It featured jet-engine propulsion, swept wings, an internal payload bay and a jet engine mounted on the top side of the fuselage to allow for some level of low observability.[21] When it first flew in 2005, the Sky-X was considered to be the first uncrewed aircraft with a jet engine to weigh over 1,000 kg and with an internal bay. The design was also conceived to be compatible with configurable payloads, including for ground attack.[22] The Sky-X proved to be a particularly fruitful and pioneering experience, allowing Italian industry to showcase its proven technological know-how as Italy gained a prominent role in the French-led nEUROn programme.[23] As demonstrators, neither the Sky-X nor the Sky-Y were part of a roadmap leading directly to a marketable product. Instead, they reflected a strategy for Alenia Aermacchi to enter the uncrewed aerial system field with an experimental approach.[24]

Italian efforts in the UCAS field continued under the aegis of nEUROn, somewhat suspending purely national ones. In this European consortium, although Dassault assumed a leadership role, the companies later becoming divisions of Leonardo where responsible for important aspects of the programme, including the development of the UCAS' weapon bay and combat capabilities, of its critical airborne security systems and its low observable data system.[25] In this context, on top of development work, Italian players did run tests with the nEUROn demonstrator as it was transferred to Italy in 2015, as well as during other test campaigns in France.[26] Although Leonardo's involvement in the programme helped develop a useful body of technologies and knowledge in the UCAS field,[27]

airforce-technology.com/?p=3095.

19 Ibid.

20 Alenia Aeronautica, *Molynx MALE* (factsheet), June 2009, https://webapi.partcommunity.com/23d-libs/tpa/alenia_aeronautica/pdf/molinx.pdf.

21 Leonardo, *Sky-X, Precursor of Future Loyal Wingman, the Uncrewed "Followers" for the Next Generation Aircraft*, 31 May 2021, https://www.leonardo.com/en/news-and-stories-detail/-/detail/sky-x-precursor-of-future-loyal-wingman-the-unmanned-followers-for-the-next-generation-aircraft.

22 Ibid.

23 Interview, 22 September 2023.

24 Interview, 23 October 2023.

25 Leonardo website: *Technology Demonstrators*, https://unmanned.leonardo.com/en/technology-demonstrators.

26 Dassault Aviation website: *nEUROn Programme Milestones*, cit.

27 Interview, 23 October 2023.

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the lack of a follow-on to nEUROn[28] and very limited national investments in Italy have essentially negated what could have been an advantageous position to make the country a prominent player in this field. Instead, the sort of disengagement that followed nEUROn contributed to opening up the current gap with the state of the art.

As in most European countries, Italy's standing in terms of both advanced UAS and UCAS technology is today some way behind leading players and, in terms of the former, hitherto largely dependent on off-the-shelf acquisitions mainly from the US. Especially in terms of UCAS, much remains to be done in order to generate the necessary amounts of R&D to position Italian know-how well in the framework of current and future cooperative programmes. On the industry's side, Leonardo has made important investments in technologies crucial for the design and development of future combat aircraft, including 6th-generation platforms and UCAS. For instance, the Product Capability and Concept Laboratory (PC2Lab), located in Turin, has been updated to allow pilots and engineers to formulate, test and develop new operational concepts for the next-generation combat air systems, including both crewed and uncrewed assets and the interaction between the two.[29] Crucially, PC2Lab is also being used to test pilots' ability to manage simultaneously their own aircraft as a core platform and a number of adjuncts without being overloaded.[30]

7.3 The GCAP opportunity and challenge

Generally speaking, 6th-generation combat aircraft systems are already conceived as consisting of a mixed formation of crewed and uncrewed platforms operating collaboratively. The same applies to the GCAP programme involving the UK, Italy and Japan.[31] The Italian industry has a growing stake in GCAP, thanks to the involvement of Leonardo as a strategic partner in the programme as well as Elettronica, Avio Aero and MBDA Italia.[32] Here lies the opportunity to connect better than in the past armed forces' needs with domestic industry investments in UCAS technologies.

As with other countries already looking into 6th-generation capabilities, GCAP participants will work for future UCAS and adjunct capabilities to be backward compatible with current combat aircraft designs. This is especially important in the case of the F-35, which will serve in air forces around the world for roughly

[28] For more on the nEUROn programme, see chapter 6 of this study.

[29] Leonardo, *Battle Lab, Home to the Sixth-Generation Air Combat System*, 18 August 2021, https://www.leonardo.com/en/news-and-stories-detail/-/detail/battle-lab-home-to-the-sixth-generation-air-combat-system-1.

[30] Ibid.

[31] Interview, 20 September 2023.

[32] "L'industria italiana firma il contratto per lo sviluppo del GCAP", in *Analisi Difesa*, 26 January 2023, https://www.analisidifesa.it/2023/01/lindustria-italiana-firma-il-contratto-per-lo-sviluppo-del-gcap.

another 30 years and will have to be networked with future combat capabilities, including 6th-generation systems.[33] The level of system integration that is required for UCAS, CCAs and crewed aircraft to operate alongside each other means that the US will play a crucial role in opening the F-35 system architecture to foreign-made technology should the GCAP countries seek to work on a new UCAS design.[34] With Japan, the UK and Italy all in possession of F-35 systems, and as close partners of the US, Rome is certainly in a stronger negotiating position in any discussions on this potentially thorny issue.

Finally, compared to countries not in possession of the F-35, Italy boasts years of pioneering experience operating these 5th-generation platforms,[35] which already required a substantial leap in terms of doctrine and approaches to maintenance and logistics compared to their 3rd- and 4th-generation counterparts. While the GCAP programme inevitably brings along definite challenges for participating nations due especially to a number of technological gaps to fill (for instance stealth technology),[36] it also presents Italy with a clear opportunity to bring its experiences to bear.

[33] Interview, 4 September 2023.
[34] Interview, 4 September 2023.
[35] Interview, 25 October 2023.
[36] See chapter 6 of this study.

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Conclusions

by Alessandro Marrone and Michele Nones[1]

Building on the analysis presented in previous chapters, ten key elements are worth underlining on UCAS from European and Italian points of view:
1. The advantages of uncrewed systems;
2. The difference between current armed drones and future UCAS;
3. The human-in-the-loop approach to UCAS;
4. The shift towards high-intensity, large scale conflicts scenarios;
5. A cost-effective, high-low force mix;
6. A system of systems including crewed aircraft and adjuncts;
7. The choice of European cooperation;
8. GCAP as the Italian way for UCAS development;
9. Italy's stepping stone for UCAS transformation;
10. The integration of non-US UCAS with the F-35.

The advantages of uncrewed systems

First, as mentioned in chapter 2, the potential advantages of uncrewed systems in aerial warfare are clear. The absence of all instrumentation and support systems (including highly efficient protection) necessary for on-board human crew free up space for additional payloads, or alternatively allow for smaller and lighter systems. This, in turn, would increase speed and manoeuvrability while also helping decrease a vehicle's sensor signatures. In principle, the absence of a human pilot removes a set of limitations, including with regard to endurance (and thus range and persistence) and susceptibility to high-positive and negative G-force manoeuvres – the latter, in particular, ushers in a whole new thinking when it comes to combat manoeuvres. Increased capacity for high-energy manoeuvres, including unconventional ones, also enables low altitude, high-speed incursions into enemy or contested airspace while avoiding detection or at least engagement by enemy air defence. As a whole, UCAS deserve political, military and budgetary investments as a key capability of tomorrow's airpower, also within joint and multi-domain operations.

The difference between current armed drones and future UCAS

The defence policy community should be fully aware of the difference between armed drones such as the ones employed in the ongoing war in Ukraine, as discussed in chapter 1 of this study, and future UCAS fit for more complex air operations in high-intensity, peer-to-peer scenarios, including air-to-air combat. Autonomy, speed, lethality and low-observability are key features for platforms meant to operate in the face of advanced airborne threats and land-based air

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defence systems alongside 4th, 5th and 6th-generation aircraft. As a result, while having some commonalities with tactical armed drones, UCAS substantially differ from them in terms of performance, operational use, efficacy and costs. The cost issue is particularly relevant, and deserves a nuanced approach in that, while uncrewed systems are generally cheaper than crewed aircraft, UCAS should not be seen as merely a cheap replacement for piloted platforms. Instead, they should rather be looked at as force multipliers, the price of which will depend on the tasks each system will be required to fulfil, the related capabilities and the survivability level. Furthermore, as discussed in chapter 2 of this study, if UCAS are to rise to their potential, they will have to be procured in high enough numbers to guarantee their operators to build a level of mass commensurate with the principal threats and the forces available to the main adversaries.

The human-in-the-loop approach to UCAS

Thanks to AI, future UCAS will be more autonomous than current armed UAS, which in turn are already more autonomous than their early predecessors, in order to fulfil their potential with regard to high-intensity combat scenarios, where line of sight or even BLOS communications may be interrupted or degraded by enemy action. Yet, they will still feature humans “in the loop” when it comes not only to mission parameters relating to the operational and geographical scope, ROE and stance, but also concerning key decisions. The human element should be present in the planning and definition of the mission’s ROE, not necessarily in its execution as dictated by the tactical scenario. This, in turn, requires a step-change of armed forces personnel education and training to effectively learn how to use the new capabilities by mitigating risks and exploiting the clear opportunities they offer. The human-in-the-loop (as opposed to merely human-on-the-loop)[2] approach is going to be an important element of reassurance for political leaders and public opinion attitude towards UCAS, in light of the aforementioned sensitivities already emerged in Italy,[3] as well as in other countries such as Germany or even UK, on arming US drones. It will also allow armed forces to retain a key decision-making element during military operations.

In general, the effective integration of UCAS in future air warfare, also in conjunction with piloted aircraft, depends not only on available technologies and autonomous capabilities, but also on a correct understanding of the type of control/supervision required by human pilots from their cockpit and by the operators in a control centre. As mentioned above, UCAS should become a force multiplier and add value as, when employed alongside manned aircraft, they will increase the combat effectiveness of the entire flying force. The pilots/operators should be able to control these platforms to an extent that does not overburden them with information and required inputs. At the same time, given the speed at which UCAS will need to process sensor data and react to real-time threats, human

[2] See in this regard chapter 2 of this study.

[3] See in this regard chapter 7 of this study.

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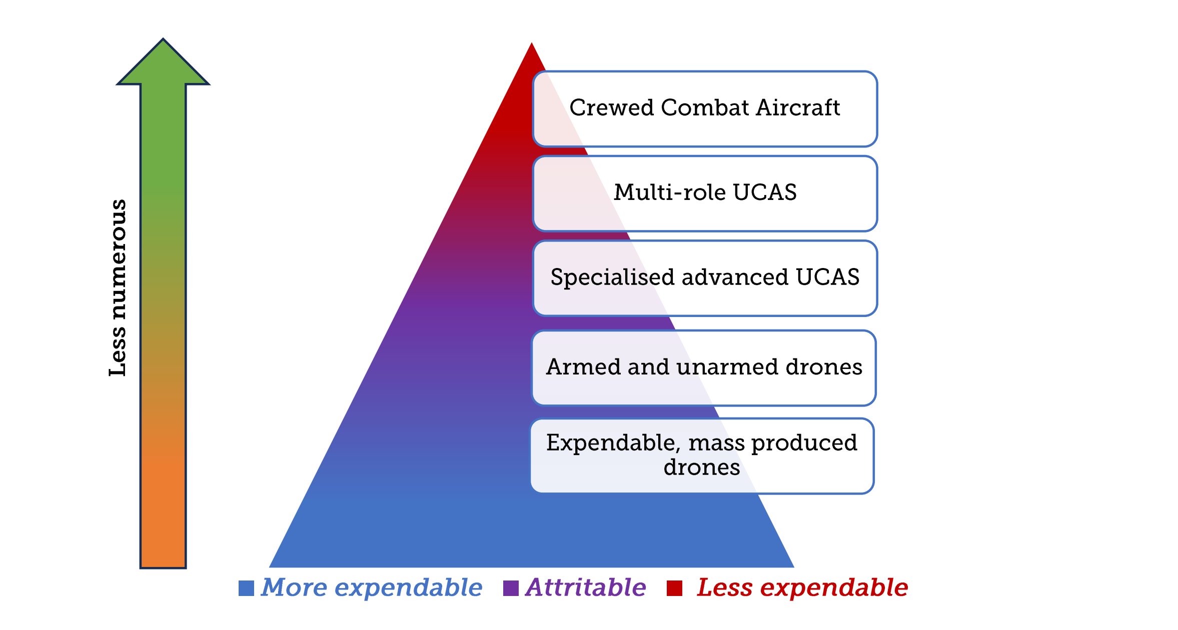
control should not become a bottleneck thereby constraining their role. Therefore, the most effective systems are likely to be those striking the right balance between autonomy and human supervision. Such a balance will definitively benefit from the AI use not only by UCAS, but also from crewed platforms and ground stations.

The shift towards high-intensity, large scale conflicts scenarios

As for other military capabilities planned or in the making in Europe, the 2022 Russian invasion of Ukraine represents a turning point. Scenarios of a high-intensity, large scale conflict against a peer or near-peer adversary are back as top priority for NATO, its deterrence and defence posture (including readiness, force structure and strength) and planning process, deeply influencing capability targets and requirements for European countries. Each conflict is unique, and NATO boasts air combat capabilities (in part thanks to US forces deployed and/or deployable in Europe) in many ways vastly superior to those of either Ukraine or Russia in both qualitative and quantitative terms. The low observability of Western advanced combat aircraft offers clear advantages in air-to-air warfare and in air defence penetration. The effectiveness of advanced air defence systems versus non-stealth conventional combat aircraft is likely to be a useful lesson from the Ukraine war for all air forces, bearing in mind both Ukrainian and Russian air defences had not to face advanced stealth aircraft and only few low-signature missiles have been employed. UCAS will offer clear opportunities in this respect. Moreover, the defence of Europe is likely to fall more and more on European shoulders, given the US' enduring prioritisation of China and the Indo-Pacific, albeit with the two theatres increasingly interconnected from Washington's perspective. Accordingly, current or future plans for UCAS should account for this kind of scenario, by putting a premium on the low observability and lethality of high-performance, high-tech platforms. Noticeably, a significant number of countermeasures and protection (including in the cyber domain) have to be designed into future UCAS in order to achieve levels of resilience commensurate with the operational requirements of scenarios such as peer-to-peer conflicts. Ensuring a technological edge made up also by advanced UCAS against opponents striving to challenge such edge will enable Western air forces to obtain and maintain air superiority in high-intensity scenarios.

A cost-effective, high-low force mix

Preparing for high-intensity scenarios means assessing the relative expendability of UCAS in relation to crewed fighter aircraft and cheaper armed/unarmed drones. As proposed by chapter 2 of this study, air forces in the future may be expected to generally aim at a pyramidal high-low force mix, with high-end, very advanced and expensive crewed platforms at the top of a pyramid. As we descend below its tip, we find more attritable but still multi-role and complex UCAS, followed by more specialised UCAS, such as those operating alongside crewed aircraft as adjuncts. Descending further, armed and unarmed drones, such as those already in service today, which rely on automation rather than autonomous capabilities. Finally, down at the base, expendable, mass producible and relatively cheap drones apt for large-scale swarming, surveillance, close-range battlefield support, saturating the enemy aerial defence or generally low-intensity missions.



A system of systems including crewed aircraft and adjuncts

In light of the aforementioned points on the human-in-the-loop and the shift towards high-intensity scenarios, a sixth key element concerns UCAS integration as adjuncts within a system of systems centred on crewed fighter aircraft. This is the case in the US with the Air Force Loyal Wingman concept,[4] in Russia with the Su-70 Okhotnik-Bs and in China with the Dark Sword.[5] Australia, too, has already invested over 400 million US dollars in its Loyal Wingman programme, which at least officially is probably the most operationally advanced worldwide, having reached initial operational capability with the Boeing Ghost Bat. In Europe, the Franco-German-Spanish FCAS programme has envisaged from the outset crewed platforms acting as a core element in an SoS that also includes CCAs. France has also earmarked funding for the development of a separate national UCAS, based on the multinational nEUROn demonstrator, destined to fly along the 4th-generation Rafale fighter aircraft and possibly to operate stand alone. Indeed, while in some cases the development of UCAS capabilities is strictly tied with 6th-generation combat aircraft systems, the most modern 4th-generation aircraft such as the Eurofighter, and obviously 5th-generation F-35, are expected to remain in service for decades and will thus be complemented by CCAs of their own. These UCAS may be the same as, related to, or substantially different from their 6th-generation system counterparts. Furthermore, aerial combat will increasingly involve systems

[4] On the US see chapter 3 of this study.

[5] On Russia and China see chapter 4 of this study.

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of systems, where crewed aircraft are merely central nodes in a wider network which will include UCAS, but may in some cases – depending on the mission – also feature armed and unarmed UAS and RUAS. Overall, this is a widespread approach that places UCAS as adjunct of fighter aircraft's pilots and strongly resonates with air forces' structure, doctrine, identity and vision. Moreover, the Ukraine war serves as a reminder of how aerial warfare does not exist in isolation: interoperability will have to be approached with a view to integrating UCAS and wider air combat systems with assets in multiple domains.

The choice of European cooperation

As is the case for several other key military capabilities, Europeans will need to prove they have a vision, are able to set clear priorities, and are willing to invest adequate financial resources. Those few European countries willing and able to seriously engage in UCAS cooperation will have to reflect upon common requirements, reducing fragmentation and striving to mitigate critical dependencies from non-European suppliers. Cooperation in the defence sector is based on interest – be it political, operational, technological and/or industrial – and European countries should work to build such a common interest through collaborative programmes. It will be a strategic choice to go ahead either on a national programme (as France has already somehow announced) and/or with one/few selected partners.

GCAP as the Italian way for UCAS development

In Europe, the main avenue for UCAS development appears to be tied to 6th-generation aircraft SoS, but the major European countries are committed to two competing programmes, namely FCAS and GCAP. This is a structural factor which is going to largely limit intra-European cooperation within the respective perimeters of these two programmes. At the same time, with France already pursuing a national UCAS in parallel with the ones to be developed under the FCAS programme, European efforts are heading for a substantial level of fragmentation. Accordingly, Italy has to consider the possibility to work with the UK as well as with Japan on future UCAS (though it is not yet clear whether the same tripartite configuration will apply to UCAS as it will be for the core platform) or at least on some of the different adjuncts that will make up the wider SoS. Undoubtedly, any level of cooperation among Rome, London and Tokyo will benefit from these countries' experience operating 5th-generation aircraft technologies; a key element that is missing in the FCAS consortium. Thus, betting on UCAS development and integration within GCAP is surely one way to connect Italian military requirements with the national industrial base, and bridge R&D activities with the ultimate goal of industrial production and procurement – something that has been lacking in Italy in the past two decades, despite promising investments on armed drones early on.[6]

[6] See in this regard chapter 7 of this study.

At the same time, while adequate investments are important in the early stages of GCAP in order to secure and maintain a role that ensures proper returns in terms of R&D and technological know-how, this should not exclude outright the pursuit of complementary national or bilateral/multilateral programmes where possible, even in pursuit of specific technologies rather than products. GCAP is a generational programme of a complexity rarely seen before and will span far beyond initial R&D and development to include multiple updates involving both the core platform and the adjunct systems. The Italian industry will thus be called to attain and constantly build upon key capacities in order to safeguard its competitiveness in strategic areas. Time is of essence now: similarly to London and Paris, Rome has to invest significant resources on timely R&D activities in order to catch up with state-of-the-art technology and retain a meaningful degree of operational and technological sovereignty on UCAS and related key technologies. To this end, it is paramount the Italian Ministry of Defence, and particularly the air force, sets out clear and solid requirements. The first-class operational experience with drones[7] and the forward-looking attitude of the Italian air force's doctrinal and capability development provide a sound basis for such endeavour.

Italy's stepping stone for UCAS transformation

Italy's procurement and pioneering deployment of the F-35 represents an invaluable experience in that it required a paradigm shift in the way combat aircraft are operated and maintained. This was true not just for pilots who had to adapt to 5th-generation platforms – with all their peculiarities in terms of low observability, performance and related tactics, techniques and procedures (TTP) – but also for the crews and personnel managing the platforms on the ground in terms of maintenance and updates. The advent of UCAS could imply similar challenges to future operators, with the added dimension of autonomous capabilities and likely new doctrines resulting from the need for a more collaborative and networked way of aerial combat. The Italian air force experience in transformation and adaptation presents a solid stepping stone in order to meet the UCAS transformative challenges.

The integration of non-US UCAS with the F-35

Last but not least, as mentioned before, UCAS will have to be integrated into air operations with both 4th, 5th and 6th-generation aircraft, operating in close collaboration with these crewed platforms and/or alone, featuring a seamless interaction in terms of data fusion as well as command and control. Successful integration also entails a robust degree of openness to newly developed, non-US UCAS by the F-35 platforms in service in most NATO members and partner countries, including Italy, Japan and the UK as co-leaders of the GCAP programme. Such openness already happened, to a certain extent and with some difficulties, regarding the integration of non-US weapons on the F-35 procured by Italian and other air forces in Europe, and should be pursued as a pragmatic and win-

[7] On Italy's use of US armed drones see chapter 7 of this study.

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win arrangement in the context of UCAS. To this end, it is necessary to table a timely and strong politico-strategic dialogue among GCAP-participating capitals and Washington in order to fully exploit the potential also of non-US UCAS to the benefit of national and international security.

Updated 7 December 2023

Acronyms

A2/AD	Anti-access/Area-Denial
AI	Artificial intelligence
ALE	Air-launched effects
AM	Aeronautica Militare (Italian Air Force)
AMS	Airborne Mission Systems
ASW	Anti-submarine warfare
ATOL	Automatic take-off and landing
AVIC	Aviation Industry Corporation of China
AWACS	Airborne early warning and control
BAMS	Broad area maritime surveillance
BLOS	Beyond operator’s line of sight
CCA	Collaborative combat aircraft
CCP	Chinese Communist Party
CONOPS	Concept of Operations
COTS	Commercial off-the-shelf
C-UAS	Counter Uncrewed Aerial Systems
DEW	Directed energy weapons
DGA	Direction générale de l’armement (French Procurement agency)
DIY	Do-it-yourself
DMO	Distributed maritime operations
DoD	Department of Defence
DPP	Documenti Programmatici Pluriennali (Multi-annual Programme Documents)
EATT	European Air Transport Training
ECOWAR	EU Collaborative Warfare Capabilities
EDA	European Defence Agency
EDF	European Defence Found
EDIDP	European Defence Industrial Development Programme

EICACS	European Initiative for Collaborative Air Combat Standardisation
EO/IR	Electro-optical/infrared
EU	European Union
EW	Electronic Warfare
FCAS	Future Combat Air System
FTUAS	Future Tactical UAS
GBAD	Ground-based air defences
GCAP	Global Combat Air Programme
GCS	Ground control station
GE	General Electric
GJ-11	Gonji-11
GLOCs	Ground lines of communication
HALE	High-altitude, long-endurance
HPM	High power microwave
IR	Infra-red
IRS	Intelligence, surveillance and reconnaissance
IRST	Infrared Search and Track
ISIS	Islamic State of Iraq and Syria
ISTAR	Intelligence, surveillance, target acquisition and reconnaissance
ITAR	International Traffic in Arms Regulation
JADC2	Joint All-Domain Command and Control
JWC	Joint Warfighting Concept
LAWS	Lethal autonomous weapons systems
MALE	Medium-altitude, long-endurance
MANPADS	Man-portable air defence systems
MENA	Middle East and North Africa
MFEW	Multifunction EW
MLRS	Multiple rocket launcher systems
MM	Marina Militare (Italian Navy)
MoD	Ministry of Defence
MPMC	Multi-Purpose Mission Computer
MTCR	Missile technology control regime
MTOW	Maximum take-off weight
MUM-T	Manned-unmanned teaming
NATO	North Atlantic Treaty Organisation
NGAD	Next Generation Air Dominance
NGSR	Next Generation Small RPAS
OCCAR	Organisation Conjointe de Coopérationen matière d'Armement (Joint Armament Cooperation Organisation)

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OSNOD	бъединенная система навигации и обмена данными (Integrated navigation and data exchange system)
PC2Lab	Product Capability and Concept Laboratory
PESCO	Permanent Structured Cooperation
PKK	Kurdistan Workers Party
PLAAF	People's Liberation Army Air Force
PMC	Private military company
R&D	Research and Development
RF	Radiofrequency
ROE	Rules of engagement
RPAS	Remotely Piloted Aircraft System
RTTD	RPAS Training Technology Demonstrator
RUAS	Rotary uncrewed aerial systems
SAM	Surface-to-Air Missiles
SAR	Synthetic aperture radar
SEAD/DEAD	Suppression and Destruction of enemy air defences
SHORAD	Short-range air defences
SOF	Special operation forces
SOS	System of systems
SSB	Savunma Sanayii Başkanlığı (Presidency of Defence Industry)
STOVL	Short-take-off vertical landing
SWAP-C	Space-weight-power and computing
TELAR	Transport-erector-launcher
TTP	Tactics techniques and procedures
UAS	Uncrewed Aerial Systems
UAV	Uncrewed Aerial Vehicles
UCAS	Uncrewed Combat Aerial Systems
UGV	Uncrewed ground vehicles
US	United States
USAF	United States Air Force
USSR	Union of Soviet Socialist Republics
USV	Uncrewed surface vehicles
UUV	Uncrewed underwater vehicles
VKS	Russian Aerospace Forces
VTOL	Vertical take-off and landing
YPG	People's Defence Units
ZSU	Zbroini Syly Ukrainy (Armed Forces of Ukraine)

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