The Potential for Unmanned Combat Air Systems to Gain Control of the Air in Future Warfare

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Current Unmanned Combat Air Systems developments, such as BAE's *Taranis* programme, focus on Intelligence, Surveillance, Targeting, Acquisition, and Reconnaissance, and air-to-surface missions, including that portion which is the counter-air task. The article argues that the air-to-air component of counter-air warfare is as essential. Could Unmanned Combat Air Systems, the next evolution of Unmanned Aircraft Systems, gain control of the air in future warfare? There is currently a paucity of analysis within the UK into Unmanned Combat Air Systems undertaking this task. The threat environment in which weapon systems are required to operate in will reinforce capability requirements. The effect that political, legal, and ethical issues of using Unmanned Combat Air Systems might have upon decision makers cannot be underestimated, and also requires consideration. This article examines the implication of these issues and the future utility of Unmanned Combat Air Systems gaining control of the air.

Introduction

Control of the air is the foundation for all conventional military operations against an adversary with an air defence capability. Could Unmanned Combat Air Systems (UCAS), the next evolution of Unmanned Aircraft Systems (UAS), gain control of the air in future warfare? Current UCAS development focuses on detecting and destroying Time-Sensitive Targets, utilising Intelligence, Surveillance, Targeting, Acquisition and Reconnaissance (ISTAR), and Suppression of Enemy Air Defence (SEAD) roles, the air-to-surface portion of the counter-air task. The air-to-air component of counter-air warfare, a true Time-Sensitive Target issue, is as essential. The importance that situational awareness plays in warfare is vital. Networked Enabled Capabilities (NEC) will be fundamental in establishing consistent and reliable battlefield situational awareness, and will form the basis upon which UCAS are developed and employed. Will the character and nature of warfare, forcing aircraft operations over distances not previously considered necessary, be such that UCAS are the only viable solution? There is currently a lack of cohesion and clear thought on the future utility of UCAS, particularly within the UK, which requires informed input. Ultimately, UCAS capable of gaining control of the air could offer a revolution in the way warfare is conducted in the 21st Century.

A transformation in the way warfare is conducted is in progress. This new era promises significant advances in capabilities, adaptability, and agility. A fundamental rethink is taking place in the way Command and Control (C2) is conducted, and the ways in which military objectives are achieved. A broad range of technologies has begun to enable the integration of joint-forces not previously possible, with a whole series of technological advances coming together. During the initial stages of World War I, military aviation was mainly concerned with the role of reconnaissance; however, the potential for bombing and air-to-air combat soon became apparent. 1915 saw the development of fighter aviation, including mechanical interrupter gears, which enabled guns to fire through the arc of spinning propellers. By 1916, control of the air emerged as the crucial issue in the Germans' Verdun offensive and the British Somme counteroffensive. A revolution was beginning; control of the air was increasingly viewed by air and ground commanders as a means of allowing the observation and air-to-ground attack of enemy ground forces. By 1917 it was evident that poor reconnaissance of an enemy's disposition could cost all the gains of a successful previous attack.[1] The 1st April 1918 saw the establishment of the Royal Air Force (RAF) by amalgamating the Royal Flying Corps and the Royal Naval Air Service.[2] Air power had come of age and was now seen as an integral part of military operations, with control of the air acknowledged as being an essential element of any campaign.

The RAF's *AP3000: British Air and Space Power Doctrine* emphasises the importance of the counter-air task, stating, 'Control of the air is the *primus inter pares* of the four air power roles. It has doctrinal primacy because it enables freedom of manoeuvre in all of the military domains: air, land and sea.'[3] Churchill stated 'The only security upon which sound military principles will rely is that you should be master of your own air.' Although sometimes forgotten, perhaps even by military leadership, this maxim is as extant today, as it was in 1918.

For example, the Luftwaffe during the Battle of Britain in 1940, and the Argentinean Air Force during the 1982 Falklands War, lacked any form of control of the air, and suffered the consequences. The more advanced an adversary's counter-air capability, the more important gaining and maintaining control of the air, and the more sophisticated a force's own counter-air capabilities needs to be. The ability to conduct the full gamut of air operations, unhindered, against enemy forces is vital, enabling deployment and resupply, and protection of those forces and supplies once deployed. During the 1982 Falkland's War the Argentineans started from a position of considerable strength relative to the British Task Force, yet their apparent lack of any coherent air strategy meant that they quickly lost air superiority over the Falkland Islands. The loss of a number of British ships during the 1982 Falkland's War illustrated the consequences of the British Forces not having air superiority either.

Unmanned Aircraft System/Unmanned Combat Air System Terminology

It is important to understand the UAS/UCAS terminology currently used.[4] The term UAS itself is often misunderstood, with the consequence that there is a lack of consistency with terminology. Many 'experts' refer to the air vehicle component of a UAS as a 'drone'. This is a legacy term, more fitting to the German World War II V1 Doodlebug, or target drones, used for gunnery practice. V1s were designed to impact a target, and not to be recoverable; they were effectively cruise missiles. Herein lays the problem when defining what in fact an Unmanned Aerial Vehicle (UAV) is. A UAV is not a cruise missile. In modern parlance, a UAV is an Unmanned Aircraft (UA) designed to be reusable. The Office of the US Secretary of Defense 2005 '*Unmanned Aircraft System Roadmap: 2005 – 2030*' describes UAV as:

> A powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely,…can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles.[5]

Whilst there is no internationally agreed policy regarding UAS definitions, there are a number of working agreements that attempt to align common lexicon, as far as is possible. The terms Unmanned Aircraft (UA), UAV, UAS, Unmanned Combat Aerial Vehicle (UCAV) and UCAS are used in this article. Although there are subtle differences between NATO and US terminologies, these align with the vocabulary most international UAS analysts use. There is currently no agreed definition of UCAS. Until there is conformity, the author defines UCAS as UAS designed to carry weapons, utilising a level of automation/autonomy, which may also be capable of ISTAR tasks, designed to survive in highly contested airspace.

Two-Seat, One-Seat, or No Seats?

Powered unmanned aircraft have been operating almost as long as manned powered flight. There have been a number of false dawns, however, preaching the virtues of unmanned aircraft. General Hap Arnold, Chief of the US Army Air Force, predicted what might be possible, when he observed on VJ Day in 1945:

> We have just won a war with a lot of heroes flying around in planes. The next war maybe fought by airplanes with no men in them at all…Take everything you've learned about aviation in war, throw it out of the window, and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen.[6]

Although not quite prescient, Arnold's words, almost 70 years later, are gaining relevancy. Current debate amongst academics and military professionals, centres on unmanned versus manned aircraft. Previous arguments have questioned the requirement for one-seat versus two-seat. Along with the trend towards single-seat aircraft operations, doctrine and tactics have evolved to take advantage of the evolution that technological advances have allowed manned flight to utilise. With the demise of non-pilot aircrew, will advances in aviation systems mean there will be fewer requirements for pilots? Have we come full circle, where navigation accuracy and the precision of weapon delivery is the predominant requirement for combat air power? Historically, the science of navigation has taken precedence over many other aspects of warfare. The Gulf Wars of 1991 and 2003, and counter-insurgency operations in Afghanistan and post-war Iraq, have demonstrated the vital role that precision weapon delivery plays in modern warfare. Max Hastings observes, in his thought provoking rendering of World War II, *All Hell Let Loose: The World at War 1939 – 1945*, 'An aspect of the conflict common to warriors in all three dimensions was that navigation was a life-or-death science. A British Army training report noted that soldiers would forgive almost any fault in their officers except incompetent map-reading....'[7] It can be argued that the primacy of navigation, and all that the mastery of it brings, is now firmly established as the priority of any nation that wishes to have, and use effectively, a military force.

Since the beginning of manned flight, pilots have been regarded as pivotal in the flying and operating of powered aircraft. Innovators added to the surge in aviation progress, with developments leading to aircraft capable of the full range of civil and military tasks, including transport, Air-to-Air Refuelling (AAR), reconnaissance, bombing and air-to-air combat. When the RAF's Tornado GR-4 goes out of service, the RAF will have no role for fast-jet qualified WSO. There are reasons for this – the main one being that, with the advent of the single-seat Typhoon, and the probable introduction of F-35 Joint Strike Fighter (JSF), there is no 'perceived' requirement for fast-jet WSO. The fact that pilots have historically been required to fly aircraft that facilitate achieving the requisite military task should not be a driver for future doctrine, tactics, or procurement. Technology is following a natural trend that will achieve the required task more efficiently, allowing greater time, effort, and resources to be focused on systems that will not require a human interface in an aircraft, or potentially, even monitoring systems.

Future UCAS Developments

UCAS have the potential to offer an innovative set of options offering advantages to air power in terms of expanded missions, tactical deterrence and, importantly, through-life costs savings. UCAS may eventually be capable of the full gamut of air missions, including: ISTAR, AAR, Close

Air Support (CAS), SEAD, interdiction, EA, and conceivably, control of the air in its entirety, including Defensive Counter Air and Offensive Counter Air operations.[8] UCAS can have a number of advantages: they can have a small radar-cross-section (RCS), if low observable technology is used, as well as being capable of carrying a large payload. UCAS could have long endurance, enabling persistence and availability, and with no aircrew, allowing operations in a toxic environment. Although the preservation of aircrew is undoubtedly important, it is questionable whether this will be paramount in any decision on UCAS development. Humans operating in high-performance combat aircraft have had to contend with the physiological constraints that high altitude flying and 'Gravity' forces place on the human body. In 2010, the F-22 Raptor was grounded for a number of months, following the loss of an F-22; the cause was suspected to be the aircraft's oxygen system malfunctioning and incapacitating the pilot. The F-22, like the F/A-18C/D, uses an on-board oxygen-generation system.[9] While rectifiable, it illustrates the problems of having a human in the cockpit. A UK medical study concluded that 'Good evidence is available to show that aircrew of high performance aircraft will experience degeneration of the cervical spine during their career which is greater than that observed in the normal population.'[10] Mitigating the effects on aircrew may be a partial driver, but it is the potential reduction in procurement and through-life costs, aligned with persistence,[11] that will be the main drivers for UCAS development.

Although Rules of Engagements (ROE) constraints and moral and political necessities may initially militate against full autonomy, the development of Artificial Intelligence (AI) and Human-Machine-Interface (HMI) technology may offer a level of integration which enables a greater degree of flexibility when conducting Combat Identification (CID) and Collateral Damage Estimation (CDE), than that of a Human-in-the-Loop (HITL) system. This would allow missions to be planned and then executed using on-board decision making – with a Human-on-the-Loop (HOTL) monitoring the system and taking action only when necessary, and perhaps, totally autonomously. Concentration of force is a fundamental principle of war that is particularly well suited to air power. Experience has shown that air power concentrated in both time and space is more effective in achieving an objective than if it were dispersed over a wider area and longer time. Moreover, a concentrated force will use support forces more efficiently, increasing overall capability and survivability. The Composite Air Operation (COMAO) concept involves packaging a large number of aircraft, with a variety of roles, to complement each other to achieve a task. Benefits of operating in large formations include minimising attrition by optimising mutual support and saturating adversary IADS.[12] Fundamental to the future employment of UCAS, will be their utility within COMAO packages. Ultimately, it may be possible for a large COMAO formation of combat and support aircraft, combining manned aircraft and UCAS, or made up entirely of UCAS, to operate together or autonomously. This autonomy may permit a quicker and more accurate response, allowing not only a high probability of survival, but ultimately the desired mission objectives being achieved. The current doctrine of gaining either air supremacy, or localised air superiority, will continue to be a priority for any COMAO.

Thus far, little rigorous investigation into the viability of UCAS conducting the full range of counter-air roles, including gaining control of the air, is being conducted by Western states. The UK has cooperated with the US, as part of a programme, (referred to as 'Project Churchill'), forming a partnership in establishing a Concept of Operations (CONOPS) for future UCAS – this ran from 2005 to 2009.[13] Although the UK has not published any UAS/UCAS procurement timeline, the US has made available its likely developmental route for the utilisation of these systems. The US Department of Defense (DoD) has published a Roadmap for all of its unmanned systems, ground, sea and air, *FY2009-2034 Unmanned Systems Integrated Roadmap*, stating - 'The purpose of this…Roadmap is to propose a feasible vision for capitalising on unmanned systems technologies so that the Warfighter can conduct missions more effectively with less risk.'[14] Although there are no known current programmes in the public domain researching the counter-air capability of UCAS, in November 2011, the author was briefed by a representative of BAE Systems that their Advanced Projects team are reviewing a wide range of options for future combat air systems, including a UCAS capable of undertaking control of the air missions.[15] The US have published a number of documents outlining their strategy for future UAS/UCAS. In 2009, the Secretary of the USAF, Michael B. Donley, and the USAF Chief of Staff, General Norton Schwartz, signed the *USAF Unmanned Aircraft System Flight Plan 2009 – 2047*. This document sets out the USAF vision for the implementation of UAS/UCAS into USAF service, out to 2047. It states:

> [UAS] and the effects they provide have emerged as one of the most "in demand" capabilities the USAF provides the Joint Force. The attributes of persistence, endurance, efficiency, and connectivity are proven force multipliers across a spectrum of global Joint military operations….The vision is the USAF postured to harness increasingly automated, modular, globally connected, and sustainable multi-mission unmanned systems resulting in a leaner, more, adaptable and efficient air force that maximises our contribution to the Joint Force.[16]

The USAF intends the '*Flight Plan*' to be an actionable plan 'to achieve the USAF vision for the future of UAS. The USAF will implement the actions described within to evolve UAS capabilities.'[17] There are a number of assumptions which drive the focus for the USAF's vision, perhaps the most pertinent being, '…The range, reach, and lethality of 2047 combat operations will necessitate an unmanned system-of-systems to mitigate risk to mission and force, and provide perceive-act line execution….'[18] A report from the US Defense Advanced Research Projects Agency states that 'a UCAV weapon system has the potential to fully exploit the emerging information revolution and provide advanced airpower with increased tactical deterrence at a fraction of the total life cycle costs of current manned systems.'[19] Ultimately, if UCAS can do the required tasks more cheaply, and/or better than manned systems, then their development will have justification.

The debate over the future utility of UCAS is fierce, however, particularly within the US military hierarchy. In 2011, General Schwartz, apparently rejected the development of a completely unmanned long-range bomber, stating that he did not think armed, unmanned aircraft have evolved to the point at which they can operate effectively.[20] Schwartz expressed the view, '…at least for the next 25 years, maybe 50 years, there's going to be a mix of manned and unmanned [aircraft]. Beyond 50 years, anything's possible.' He also stated that he is not ready to 'contemplate a nuclear sortie on a remotely piloted aircraft….at least in the near future.'[21] His reasoning for this is not clear, after all, Intercontinental Ballistic Missiles, armed with nuclear warheads, have been part of the US arsenal for decades - these cannot be recalled. In contrast, at the same time, US Marine General James Cartwright, the vice chairman of the Joint Chiefs of Staff, has stated he believes unmanned bomber technology is ready for deployment.[22] General Cartwright, who heads the Pentagon's top-level review panel with authority to determine all of the military's major hardware requirements, believes the US should buy an affordable bomber to replace its ageing fleet of conventional-only B-1s and nuclear-capable B-52s and B-2s.[23] Cartwright further stated that he would '"…throw down the gauntlet by asking whether the bomber truly requires a human pilot, or if instead all of them could be remotely controlled….Nobody's shown me anything that requires a person in that airplane. Nobody."' Whoever is correct, the US has had UCAS projects in development for a number of years, including a project run by Northrop Grumman; this programme is likely to be a demonstrator for the US requirement for the original Next Generation Long-Range Strike System (NGLRSS) programme, now referred to as the Long-Range Strike Platform (LRSP).[24]

It is envisaged that developmental UCAS, such as Northrop Grumman's X-47B Unmanned Combat Air Demonstrator (UCAS-D), part of the overarching US Unmanned Carrier Launched Air Surveillance and Strike (UCLASS) programme, will conduct air-to-surface and surveillance missions.[25] This programme aims to demonstrate the technical feasibility, military utility and operational value for a networked system of UCAS. The X-47B first flew in 2011, with the aim of conducting trials from carriers in 2013. This programme was instigated by the Deputy Chief of Naval Operations for Information Dominance, who stated the US navy has identified a requirement '…for an aircraft carrier based aircraft system providing persistent…[ISR]… and strike capabilities that will enhance the versatility provided by an aircraft carrier…'.[26] The US does at least appear to have a coherent plan. From approximately 2030 onwards, the *USAF UAS Fight Plan* foresees the MQ-Mc version capable of performing a number of roles including: autonomous swarm, aero-medical evacuation, personnel recovery, EW, SEAD, ISTAR, CAS, air interdiction, AAR as a tanker, missile defence, strategic attack, and, significantly, counter-air missions.[27]

UCAS persistence would be enabled by a number of technologies, such as significant advances in propulsion and aerodynamics. Autonomous in-flight refuelling, potentially with unmanned tankers, and advanced power sources, would allow for increased endurance. UCAS would stay on task for as long as fuel permits, and then leave the hostile airspace to refuel and return. Similar to manned aircraft, it is currently envisaged that future UCAS will use stealth characteristics, Electronic Attack (EA), and defensive measures to penetrate hostile airspace. However, although UCAV could deploy over great distances and with a reduced logistic chains, their operating tempo may stretch any manned airborne supporting systems. If the through-life cost of a UCAS means that these systems are treated as High Value Airborne Assets (HVAA), it may mean manned fighters, themselves HVAA, are required to protect them, thereby mitigating any advantage that these systems offer. It is important, therefore, that UCAS are capable of operating independently of other HVAA, with a high chance of survival. In order to operate effectively, UCAS will need to be able to dominate the air space in which they operate.

The US has had the ability to conduct long-range strike missions since World War II, giving it a decisive military capability. There is debate whether this will continue to be the case. Thomas Ehrhard and Robert Work in *Range, Persistence, Stealth and Networking: The Case for a Carrier Based Unmanned Combat Air System*, view the current US capabilities to operate at long range as deficient. They believe that both land- and sea-based US fighter assets lack the necessary range and persistence for air campaigns in non-permissive scenarios. Current aircraft are best suited for striking targets at between 200 and 450 nm from their operating bases/carriers. Anti-Ship Ballistic Missiles (ASBM) and cruise missile threats are likely to force US Carrier Strike Groups to operate at least 1000 nm from adversary borders.[28] Why is this relevant? Mark Gunzinger, from the US Centre for Strategic and Budgetary Assessments, believes that a number of States, including China and Iran, are investing in Anti-Access/Area-Denial (A2/AD) doctrine that '…poses a direct and formidable challenge to the traditional forms of US conventional power-projection in all operating domains.'[29] According to Gunzinger, scenarios involving such A2/AD systems would require the US and its allies' short-range land- and sea-based combat aircraft to operate from much longer ranges than previously conceived, curtailing their ability to attack land targets deep in adversary territory, greatly reducing sortie generation rates. In addition, future, highly sophisticated, adversary IADS would likely make all areas impassable to non-stealthy aircraft and cruise missiles.[30] A RAND study, *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century*, offers the view that tactical fighter aircraft may not be the optimum platform for providing counter-air capabilities in locations so far from the nearest viable air base; larger manned or unmanned systems, utilising extremely long-range weapon systems may offer the solution.[31] Whether this is feasible is arguable, however, proper evaluation should be considered.

Cost Savings

The cost of personnel forms a large part of a country's military budget. For example the actual cost of employing an RAF flight lieutenant is calculated using their annual salary, plus other associated costs. In 2011, a flight lieutenant pilot was paid on average £50,000 annually, including flying pay.[32] The actual capitation cost (the calculation used for overall cost) includes annual salary, plus pension contributions, bringing the average annual capitation cost for a junior officer pilot to £87,800. Notwithstanding that manpower will still be required to operate an autonomous system, taking aircrew out of the equation could mean substantial savings. The cost of training an RAF Typhoon pilot to a point where he/she can begin training on an operational squadron, for example, is £4 million, as of 2008.[33] Further training to actually become, and remain, capable of conducting operational tasks would be considerably more, perhaps as much as £9 million - this is based on the capitation cost of the RAF Typhoon being £92,000 per hour,[34] with it taking approximately 60 hours further training on a squadron, before a Typhoon pilot becomes fully operational. Once operational, a Typhoon pilot currently requires 180 – 200 flying hours a year in order to conduct training, to remain operational.[35]

The range of personnel costs will vary, according to rank; however, it can be broadly seen that by reducing manpower, costs can be significantly reduced. The operating costs of a UCAS would be significantly less, essentially because the UCAV would remain on the ground, containerised, unless or until it is actually required for operations or maintenance procedures. The more autonomy the system uses would also reduce manpower requirements. A major cost saving in training and personnel could be gained by the use of simulation. Advances in this area are creating opportunities for improvement in training that have previously not been possible. Most of the training and currency requirements could be achieved through Distributed Mission Training (DMT) systems. Although the UK Armed Forces use various simulation systems to some effect, it is the US, particularly the USAF that has been at the forefront of the development of DMT, with its Live, Virtual and Constructive (LVC) Integrating Architecture (LVC-IA) Plan. USAF training specialists believe that the increased use of simulators and the ability to connect simulators and/or aircraft at dispersed locations, and new applications of LVC are essential to enable fifth-generation pilots to acquire the required skills enabling training risks to be minimised.[36] LVC simulations allow aircrew and other personnel to conduct training to an extremely high-level of fidelity and at significant cost savings. These systems may actually allow for better training - by offering the scenario that everything always works - aircraft and weapon systems are always serviceable, C2 is robust, and the weather is suitable - but, if required, effectiveness of individual systems and weapons could be degraded, to simulate austere operating conditions. This is preferable to the haphazard way in which a significant amount of live flying training is currently conducted, where the vagaries of system serviceability and the whims of the weather, significantly impact on the value of training – the author contends at great wasted cost, and, ultimately, operational effectiveness. There is a balance to be maintained, of course; however, technological advances will allow for the utilisation of these DMT systems to greatly enhance the effectiveness of counter-air operations, with associated cost savings.

The International Context in which UCAS would be Used/ Threat?

UAS are currently assuming roles in air power that have traditionally been undertaken by manned aircraft, at least in permissive environments. Recent counter-insurgency operations in Iraq and Afghanistan have concentrated on ISTAR and CAS capabilities, using UAS in increasing numbers; however, these types of systems are not presently survivable in highly contested airspace, against an adversary with a capable IADS. The context in which these systems would be used is fundamental to their developmental path. Although the military capabilities of future threats to international security should be adequately assessable, the intent of those nations that threaten stability remains less easy to predict. An understanding of where these threats are likely to come from is essential. Identification of these possible adversaries is realistically achievable; how they are deterred and, if required, militarily defeated, is not so easily attained. Any specious assumptions could lead to erroneous conclusions, in turn, potentially leading to the wrong procurement decisions. The West's main focus is currently on irregular warfare; whilst this type of conflict is likely to be on going for some time, possibly indefinitely, circumstances may drive nations to believe that the only way to survive, let alone prosper, is to instigate conflict in order to divert attention from internal domestic issues, or to establish dominance over natural resources. A lack of natural resources may prove crucial.[37] Future conflicts will likely range from peace keeping and policing roles, to minor interstate conflict, to the potential for large interstate warfare.

The UK's Development, Concepts and Doctrine Centre (DCDC) views the era out to 2040 to be a time of transition: 'Out to 2040, the focus of global power will move away from the US and Europe towards Asia….[the US] is likely to remain the pre-eminent military power, although, in political, economic and military terms, she is likely to be increasingly constrained as others grow in influence and confidence.'[38] Some analysts believe China is likely to overtake the US as the World's No 1 economic power by 2020.[39] There is also a view that China will reach technological parity with the US, sometime between 2040 and 2050.[40] Aligned with China's increasing economic power is its desire to become a major military power, able to influence the *status quo* in the Western Pacific. This will make China the centre of gravity for the foreign and military policies of the US and its allies in the coming decades. While the US does not view China as an existential threat to the US mainland, it believes that China poses a threat to stability in the region. China's emerging A2/AD doctrine will force States, especially the US, to mould foreign and military policies to militate against China gaining dominance in the Western Pacific and the South China Sea.[41] Not only does China wish to include Taiwan in its sphere of influence, it also desires to hold sway over the abundant natural resources that lay beneath the South China Seas. China is also hedging against access being denied through the Strait of Malacca, through which most of its oil supplies transit.[42] For many of the same reasons, the US and its allies do not wish China to hold dominance in this part of the world. The Middle East, with Iran at its centre, will also test international relations. Iran is also developing a strategy of anti-access and area denial.[43] China and Iran's A2/AD doctrine will likely force the US and its allies to operate from land bases and carriers at greater ranges than those currently planned. The development of ASBM and other systems capable of pinning forces down at ranges that make current weapon systems unviable in deterring aggression in these regions requires inspired evaluation. Air systems, *inter alia*, which are capable of operating at ranges outside of these threats are necessary. At whatever distances from bases, the dictum that control of the air is the foundation for all conventional military operations against an adversary with an air defence capability, will remain true.

What do the Experts Think?

A survey of RAF aircrew and officers, MOD engineers and aviation specialists, and pertinent civilians, collecting views on whether UCAS could gain control of the air in future warfare by 2040, and also, moral and motivational issues, *inter alia*, was conducted by the author.

The intention was to determine any emerging trends in thought, in particular, identifying divergence in interviewee's views, dependent on their experience and qualifications, both academic and military. Analysis of the responses has validated the hypothesis that investigating UCAS utility in the counter-air role has merit. There were 74 responses to the survey in total, of whom 47 were aircrew , ranging from junior aircrew to a number of senior commanders. Many of those interviewed have relevant experience in counter-air operations. Ninety-eight per cent stated they believed UCAS could gain control of the air by 2040. These are pilots, navigators, and counter-air specialists with an understanding of all the relevant strands and many vagaries that the fundamentals of air-to-air combat have traditionally entailed. It seems counterintuitive, but none was tempted to protect the man in the cockpit; none had the 'pilots/aircrew are gods' attitude which has prevailed in air forces around the world, ever since aircraft were first used as weapons of war. The civilians interviewed were included in the question regarding the moral use of UCAS. Eighty-six per cent of interviewees have no moral concerns with the use of UCAS. This does not mean, however, that consideration is not required when developing training for personnel, taking into account a potential lack of understanding of air power, if these personnel have not themselves been immersed in the philosophy of warfare, or indeed have not participated in combat operations. There may also be a risk of detachment when authorising weapon release, perhaps leading to a lack of emotional connectivity with the battlespace.

What motivates someone to want to join an air force to fly? Is it the act of being able to fly a complex, fast and very potent aircraft? Is it the prospect of flying helicopters in extremely challenging scenarios? Alternatively, is it merely the act of flying, in fact, flying anything? Some do not actually join to fly; a significant number of personnel know that they can never fly, but decide to join because they wish to be involved in aviation *per se*. If the RAF, or the UK military establishment, does become autonomous unmanned systems centric, or even semi-autonomous, the recruitment of personnel to conduct the roles required to operate and manage these systems will need to be tailored to ensure that the most suitable personnel were motivated to join the Services. What will be the character of these personnel? What intellectual qualities will be required? Will the whole ethos of the RAF change, and if so, will it matter? The views of the interviewees go some way to answering these questions. The questionnaire asked: 'Would a predominance of UCAS being the RAF's combat strength in 2040 affect the motivation for personnel wanting to join?' The majority, eighty-two per cent, do not believe recruitment will be affected, there will just be a different motivation; indeed, there was an underlying opinion that recruitment, whilst attracting a different type of person, could be enhanced. Future personnel would be attracted by the technology driven role of the RAF. Some interviewees opined that, whilst recruiting could be affected initially, overtime, perceptions would change, to the extent that it would not be a significant factor. Eighteen per cent had some issues, with the main concern being over the 'fighter ethos' being eroded.

What Weapon Systems would UCAS Require?

If UCAS were to be used in the air-to-air role, the weapon systems used would require intense scrutiny. Most conflicts since World War II have involved some form of aerial warfare. The Korean

War, the Israeli/Arab conflicts of 1967 and 1973, the Vietnam War and the Falkland's War involved air-to-air engagements, some of which required aggressive visual manoeuvring in order to engage and kill an adversary, employing either, short-range infrared (IR) air-to-air missiles (AAM) or air-to-air guns (AAG). However, since the 1980s, conflicts, such as the 1991 Gulf War, Bosnia and Kosovo, most successful airborne engagements have been conducted Beyond-Visual-Range (BVR) with Radar Frequency (RF) AAM, or Within-Visual-Range (WVR), with RF and IR AAM. Sometimes neglected in the enthusiasm for advanced technology is the gap between actual technical viability and any practical or operational benefit. That a given capability is technically feasible does not necessarily mean that it is operationally useful in an actual combat scenario. Frequently misunderstood, or indeed, little understood by some air power proponents, is the likelihood of an AAM actually achieving a kill. AAM Kill Probability (P_k) affects the choice of how many AAM need to be launched in order to kill an adversary aircraft. In addition, this in turn, affects almost every other consideration, such as the number of AAM carried on a fighter, affecting the required size of that fighter, and/or the number of fighters necessary to counter potential adversaries. The basis on which the formula for AAM P_k is founded, is the probability of a single shot kill (P_{ssk}). From this, the ratio of AAM to the P_k required is calculated. This depends on a number of factors, but will essentially be constructed on a series of AAM live-firing trials against the full breadth of expected adversary target profiles, and simulated firings, which are conducted in a Hardware-in-the-Loop facility, which is a ground-based test, using actual aircraft and missile sensors and the EA techniques, which would be used against them. These are normally centred on the ability of the Air-to-Air System (AAS), as a whole, to operate in the full range of conditions likely to be encountered during an air battle.

Pre-Vietnam War trials estimated the AIM-7 Sparrow RF AAM P_k was approximately 0.70. Its actual demonstrated P_k during the Vietnam War was 0.09 (56 of 612 kills).[44] US fighters were required to use the air-to-air gun on North Vietnamese Russian MiG fighters, almost 100 times more than anticipated.[45] Since the advent of BVR AAM, approximately 663 air-to-air kills have been recorded by Western and Israeli equipped BVR AAM-equipped forces. 16.1% (107 of 663) kills have been with RF AAM, of which only 3.9% (26 of 663) have been BVR.[46] During the Vietnam War, US fighter crews conducted approximately 600 air-to-air engagements in Southeast Asia from 1965 to 1973, achieving 190 kills against 75 losses - a ratio of 2.5:1.[47] From March 1965, to the end of US air operations against North Vietnam in January 1973, only two BVR kills (0.3%) were officially recorded out of a total of 612 reported AIM-7 AAM used.[48] The Yom Kippur War of October 1973 was a much shorter conflict, but the air-to-air combat was intense. Despite the large number of engagements, with 261 kills claimed, Israeli Air Force (IAF) F-4 Phantoms only fired 12 AIM-7 AAM, claiming 5 kills – 0.02 % (5 of 261); with one a single BVR kill - 0.004 %.[49] During the major air battles between Israeli and Syrian fighters that occurred over the Bekaa Valley in Syria in June 1982, the Israelis are thought to have shot down 82 Syrian fighters.[50] Twenty-three AIM-7 AAM were launched, achieving 12 kills (.42 P_k), with only a single BVR kill achieved.[51] From 1965 to 1982, 10.7 % (69 of 647) firings of RF AAM by US and Israeli aircrews occurred at distances beyond five nautical miles.[52] From these only four achieved kills, giving a 5.8% kill percentage.[53]

Attempts to achieve BVR firings by US and Israeli aircrews during these conflicts were few, and are indicative of the problems inherent in the early evolution of BVR combat. Prior to the 1991 Gulf War, 0.06% (4 of 614) kills achieved were BVR. Since 1991, 45% (22 of 49) kills achieved have been BVR. Statistically, this appears an exceptional increase, with the proportion of BVR kills increasing 69 fold.[54] However, how applicable is this? Since the 1991 Gulf War, with US and Allied Forces enforcing a No-Fly-Zone over Bosnia and Iraq, and during the 1999 Kosovo campaign, Western air forces have recorded ten AIM-120 AMRAAM kills, with 17 AMRAAM fired in total. Thirteen AMRAAM have been launched to achieve six BVR kills, giving a BVR P_k of 0.46.[55] Significantly, the Iraqi MiGs shot down were fleeing and non-manoeuvring; of note, Serbian J-21 Jastreb aircraft engaged during the Kosovo conflict had no radar or Electronic Counter Measures (ECM), and the MiG-29 Fulcrums shot down had inoperative radars. In addition, there are no reports of ECM used by any adversary fighter, and no fighter had comparable BVR weapons. All engagements involved numerical parity or superiority.[56] Although a significant achievement for forces operating at great distances from their own bases, and proving the efficacy of AWACS and other assets, the fact that the opposition was relatively inept and incapable of posing any real threat needs to be acknowledged. This is absolutely essential when analysing the actual effectiveness of counter-air systems involved. Current AIM-120 AAM has demonstrated an overall 0.59 P_k in combat to date.[57] Too few AMRAAM have been used in air-to-air scenarios to offer any meaningful statistical analysis. Without a near-peer, or peer adversary, with all the capabilities these will have, AMRAAM performance in the 'real world' can only be guessed at by using open sources. From 1965 to 1991, 205 of 614 air-to-air kills were achieved by use of the gun; since 1991, including the 1991 Gulf War, there have been no gun kills in air-to-air combat, although two gun kills were achieved by A-10 air-to-ground attack aircraft against helicopters.[58] The requirement for a gun must be seriously questioned. The author considers it axiomatic that unless any AAS can operate effectively in a complex EA/denial environment, then any NEC, and all other sensors, weapons and qualities of aircraft and aircrew will be severely tested, particular if outnumbered in aircraft and weapon effects.

The US F-35 JSF is being procured for the USAF mainly as a replacement for the F-16 Fighting Falcon. Whilst it is relatively manoeuvrable, it is not in the same category as the US F-22 Raptor, UK Typhoon, French Rafale or the Russian Su-27 Flanker and MiG-29 OVT Fulcrum. How much research, development and expense should there be towards an air vehicle, whether manned or unmanned, that is capable of pure 'dog fighting' - that is, highly manoeuvrable, visual air combat? It is arguable whether this ability to out manoeuvre fighters is relevant in an era when long-range BVR AAM capability is of such importance. Whether future BVR weapon systems are robust enough to allow UCAS to conduct counter-air operations in future warfare is the core question. The kill probability of air-to-air missiles/systems is fundamental to future system procurement. High Off-Boresight (HOBS) weapon systems, aligned with NEC, may offer the way forward. Persistence is a key force multiplier of UCAS. However, for missions requiring engagement of an adversary, weapons expenditure may become a limiting factor. Although currently too large for fighter size aircraft, advances in the development of Directed Energy Weapons (DEW) may alleviate this problem by permitting a range of targets to be engaged, either lethally, or non-lethally, allowing an engagement capability to persist for as long as a UCAV can remain airborne.[59] Whatever weapon system used, whether on manned or unmanned aircraft, their lethality, aligned with situational awareness, will be the critical nodes.

Automation or Autonomy?

The term autonomous is often used when referring to the operation of UAS/UCAS; this has caused some concern among certain sectors of the military and media, with the belief that the use of autonomous UAS/UCAS would not be acceptable in some scenarios. The debate over the meaning of autonomy is ongoing. DCDC defines an automatic system as 'A system, in response to one or more sensors, [that] is programmed to logically follow a predefined set of rules in order to provide an outcome. Knowing the set of rules under which it is operating means that its output is predictable.'[60] Autonomy is described by DCDC as, '…A system that is capable of understanding higher intent; will be effective, self-aware and their response to inputs indistinguishable from or superior to, that of a manned aircraft. As such, they must be capable of achieving the same level of situational understanding as a human.' Gillespie and West, in *The International C2 Journal*, describe autonomous/automatic systems '…[as] act[ing] on results from their own processing of instructions from external sources; without necessarily involving human operators after initiation. Automatic systems are directly controlled by either a human or quantified input parameters with no interpretation by the automaton.'[61]

It is evident that there is no consistent view of what autonomy is. DCDC's view of autonomy comes closest to the author's vision of UCAS employment, but this is still in reality only a high level of automation. With automation, DCDC describes 'its output is predictable'. It should be expected that any weapon system's output is predictable, when working correctly. Similarly, a pilot's output should be predictable, as would be UCAS's. Even adversary actions should be predictable. This is not in the sense that adversaries' actions can be predicted; but it does mean that 'systems' will follow a set of rules, defined within pre-programmed matrices, while manned systems will use tactics and procedures that are constrained by the laws of physics and convention. Unpredictable actions should not be confused with a pilot, for example, who carries out a manoeuvre that allows him to defeat an adversary in air-to-air combat, one that his adversary was not expecting. This manoeuvre would not be invented on the spot; it would be one that was within the pilot's skill-set; one that had been practised - one that would be the best manoeuvre for that situation. It may seem unpredictable to the adversary, but in reality, it is in the bounds of what the pilot and the aircraft could actually do - within the bounds of tactical doctrine and the laws of physics. Strict convention would have been followed to achieve the best result; if not, against a capable adversary pilot, the fight would be lost.

The author defines 'Automatic Systems', as systems which use pre-programmed instructions, however complex – these may be aided by AI software. He defines 'Autonomous Systems' as systems that make decisions which are not based on specific directions from pre-programmed instructions, but more random decisions, based on their own interpretation of influences.
It is probable that UCAS will only act autonomously, when communications links are lost, and

then, only when the mission was essential, and in the sense that there is no human input to its decision-making, but as the decision making is based on pre-programmed instructions, the UCAS will still, in reality, be in an 'automatic mode'. The author argues that a high level of automation is actually how UCAS would be utilised. This is an important distinction, as it will help both military and political decision makers understand the legal boundaries within which new weapon systems are required to operate, according to the LOAC. Whatever interpretation is used, automatic/autonomous systems are already in the inventory of most militaries.

UCAS and the Law of Armed Conflict

The question of whether UCAS will be permitted to operate totally autonomously is an emotive one. The Law of Armed Conflict (LOAC), which is based on Customary International Humanitarian Law, as defined by the International Committee of the Red Cross[62], may mean that authorities are not willing to take the risk of allowing decisions to be made by a 'machine', without reach-back to a command centre. Civilian personnel who are illegal combatants constitute a legitimate military target, can be legally prosecuted for their wartime actions, and do not enjoy the same prisoner of war protections as lawful combatants under the Geneva Conventions.[63] This is an obvious area of the LOAC requiring consideration, particularly concerning the programming of software, should UCAS be used autonomously. It could be argued that it is the software engineers who write the code for UCAS that are ultimately responsible for its actions. However, this is not the position with extant weapon systems that are autonomous. Cruise missiles, Anti-Radiation Missiles, Surface-to-Air Missile (SAM) and AAM, are just some examples of weapons systems that once launched, can use on- or off-board systems to continue to seek their target, independent of the launching platform. The US AEGIS sea-based, and the Patriot land-based SAM systems have been in service since the 1970/80s – these are intended to be operated automatically, in an environment that requires engagement decisions to be made more quickly than those by a human. Although mistakes have been made, these systems continue to be operated, with both technical and operational procedure improvements having been implemented. Military commanders have satisfied themselves that how these weapons operate and the level of risk that they pose in causing collateral damage is acceptable within the LOAC. Ultimately, individual States are responsible for ensuring that weapon developments adhere to Article 36 of the 1977 Additional Protocol I to the Geneva Conventions of 1949. Article 36 requires '…each State Party to ensure that the use of any new weapons, means or methods of warfare that it studies, develops, acquires or adopts comply with the rules of Customary International Humanitarian Law.'[64] The LOAC calls for the responsibility of a human to be in the loop when decisions are made for release of weapons. The 'Nuremburg Principle' obliges that someone will always be held accountable for an action that is taken that falls inside or outside of international law – that is, they are legally and morally accountable. Is it against Customary International Humanitarian Law if UCAS are used without a human at least 'on the loop'? The author does not believe so. As long as responsibility is taken within the command chain, at all levels of decision-making, then no laws are broken. The same logic would apply to UCAS as manned systems. It is straightforward – if the criteria could not be met, then UCAS would not be utilised autonomously. Criteria may change, however, particularly if the stakes are high. The development of AI and HMI technology should offer a level of integration enabling a greater degree of certainty when conducting CID and CDE, than that of HITL systems. It would also allow missions to be planned and then executed using on-board decision making – with a HOTL monitoring the system and taking action only when necessary, and perhaps autonomously, if this is deemed desirable.

Conclusion

The advantages that extended endurance/persistence, and the potential for swifter and more efficient actions that UCAS bring to warfare, may be transformational. The A2/AD strategies that countries such as China and Iran are evolving, will stress current Western and planned manned air-breathing weapon systems. Systems that are capable of operating from ranges and for periods, hitherto not required, are needed to counter these new emerging strategies. UCAS have the potential to offer a revolutionary new set of options with enormous long-term payoffs to air power in terms of expanded mission tasks, tactical deterrence and, importantly, affordability. Missions could be conducted for extended periods, using less airborne platforms. Operating costs would be substantially less than that of manned systems, if used autonomously. If these systems were shown to be survivable, and capable of achieving the desired task, potential adversaries may well pause before entering into a conflict situation. Current development is concentrating on ISTAR and air-to-surface missions. If viewed dispassionately, there is nothing particularly difficult in conducting the air-to-air role, if situational awareness is adequate, and the weapon systems are effective. It is relative, however; viewed as a three-dimensional chess game, air combat has stressed the capabilities of modern air systems and aircrew, up to now. In reality, if the 'unknowns' are 'known', it is essentially a case of completing a set of prescribed manoeuvres and decisions, that, although complex at times, with the continuing development of computer processing power, should be programmable. Situational awareness is the key. If only partial situational awareness exists, a logical pattern of actions should still be programmable. Given any counter-air scenario, there is little doubt that a human, with the correct training, being in the right frame of mind, and having the required skill and situational awareness, could make the correct decisions. However, because most humans are affected physically and mentally when operating high-performance aircraft in dynamic and stressful environments, assimilating the information is extremely difficult without taking some time; whereas, if the process was automated to a level that did not require human input, then the outcome would probably be fundamentally improved. The days of fighter pilot versus fighter pilot in visual air combat may not be over, but they will surely continue to follow the trend of the past thirty years, becoming even less common in the future. With situational awareness, gained through NEC, there is no technical reason why UCAS could not carry out the full gamut of combat air tasks currently undertaken by manned fighters.

A UCAS, or any manned system for that matter, would not require being as manoeuvrable as current counter-air aircraft. This will be achieved by HOBS weapon systems, aligned with NEC and weapons with a high kill probability, potentially DEW, negating the requirement for what is currently known as a 'knife fight in a telephone box', by fighter crews. The effectors for gaining control of the air, combine sensors, aircraft, weapons, personnel, training, and the logistics chain. Effective ISTAR, SEAD, and general air-to-surface missions will require all of the current enablers; these have proven to be effective in most conflicts since the Vietnam War. There is doubt, however, in the efficacy of current air-to-air enabling assets - that is, the aircraft, sensors and weapons currently utilised. AAM have not fulfilled their initial promise. While statistics since 1991 show that the kill probability of air-to-air systems have significantly improved, these have not improved to the extent that they offer a guarantee of winning an air-to-air battle against a peer or even a near-peer adversary. Future negation systems offering a high kill probability are required. When countering an adversary with numerical superiority, the quality of own weapon systems, aircrew training and C2 are paramount. When opposing an adversary that has both superiority in numbers and weapon systems, and whose training and C2 is adequate, then it is highly likely that control of the air will not be gained.

The efficacy of whether UCAS conduct missions totally autonomously or semi-autonomously, controlled by a single pilot in a fighter, or an operator in a large aircraft, such as an AWACS, or from a stationary C2 node, should be assessable. This will take time and funding; technological advances will inform decisions based on a series of connected trials, programmes, and academic and scientific analysis. Until novel systems, not currently conceived, are available, it will fall to air-breathing systems to take the fight to the enemy. Ultimately, it may be possible for a large COMAO formation of combat and support aircraft, combining manned aircraft and UCAS, or made up entirely of UCAS, to operate together, or autonomously. This autonomy may permit a quicker and more accurate response, allowing not only a high probability of survival, but also achieving the desired strategic effect. UCAS would use the algorithms within their pre-programmed systems, using look-up tables that would contain all conceivable eventualities; computing processing technology should continue to advance, allowing systems to conduct operations to the level of a human, but faster and more accurately. AI programs, such as Agent software, could be used to aid the decision process, but only within a defined set of rules. Autonomous systems would not make random decisions without the constraints that would normally be placed on humans. Data fusion of information collated through NEC, allowing the employment of kinetic effects, such as AAM or DEW, could be utilised on UCAS. With a high level of automation/autonomy, and situational awareness, the 'system' could make all the appropriate decisions on required tactics, leading to successful engagements. Development of these systems should allow the appropriate effect to be obtained before the visual arena is entered – or at least to an extent that does not warrant development of close visual combat systems that require the air vehicle component to be highly agile. The capability to fly high and fast will still be applicable, allowing extra energy for launching AAM, and aiding survivability against both SAM and AAM.

Whether UCAS are developed or not, it is the economics and effectiveness of weapon systems which are likely to affect decisions on procurement and capability. Air-breathing systems that are capable of operating at range and for long periods will be required. Gaining control of the air is one of the main pillars of air power, and its importance will likely remain extant. Unless there is some 'magic bullet' programme, the author believes that the development of UCAS, capable of achieving control of the air, is essential. More focused intellectual rigour is required in investigating the potential uses of UCAS, including that of gaining control of the air, in its totality. If nothing else, it is hoped that this article will generate 'informed' debate about their future utility.

Notes

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[64] International Committee of the Red Cross, "A Guide to the Legal Review of New Weapons, Means and Methods of Warfare: Measures to Implement Article 36 of Additional Protocol I of 1977," in *No 864*, ed. International Committee of the Red Cross (Geneva: 2006).