NEXT MISSION UNMANNED

The human factor

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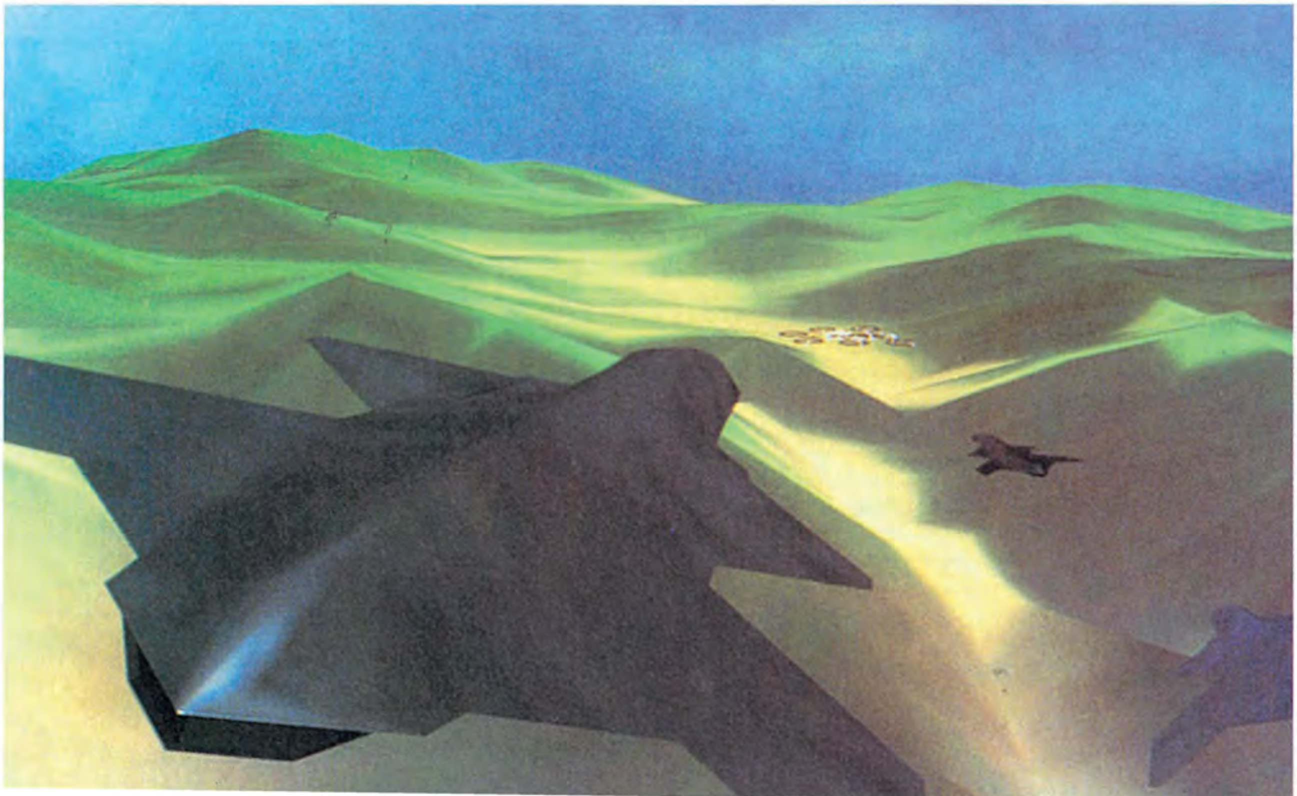
Boeing is studying a scaled-up UCAV version of its X-36 remotely piloted tailless research aircraft



Northrop Grumman is pursuing UCAV designs
which draw on its B-2 experience

in Air Power tomorrow

in Air Power tomorrow

By Lt Col A Noguier, French Air Force

The 20th century saw the birth of air power. It has also been the preserve of manned aircraft which proved to be the prime and most flexible means of delivering air power. However, since the first aircraft was used in combat, its potential vulnerability has been appreciated with its consequent aircrew losses and cost. By the turn of a new millennium, technology is now advancing at such a pace that Uninhabited Aerial Vehicles (UAVs) may be ideally suited to the new hostile environment of high density threat, precision strikes and minimum human losses. Could Uninhabited Combat Aerial Vehicles (UCAVs) replace manned aircraft in the future, as considered by the recent studies for the RAF Future Offensive Air System (FOAS)? Probably not, as this paper will explain, since major issues are still remaining like the overall importance of the human factor, scepticism about unmanned systems and a reluctance to remove the pilot from the cockpit. To operate alongside manned aircraft in future strike missions, acting as a 'first day of the war enabler', UCAVs would therefore have to demonstrate some hard evidence about significant affordability gains. Only then could UCAVs be developed and further employed in operations, thereby creating the necessary cultural change within the air forces.

INTRODUCTION

'The destinies of all people will be controlled by air power'.

William Mitchell

Air power is undeniably a product of 20th century technology. At the eve of a new millennium, it is difficult to foresee what air power might be like even a generation hence. Two key determinants will most probably contribute in shaping future wars; changing technology and the all-importance of the human dimension.[1] In addition, we can also assume that there will be an increasing need for actions which can demonstrate political commitment, but with minimum costs and casualty risks. Air power with its core qualities of versatility and flexibility will therefore continue to be an increasingly attractive political option. The requirement to reduce casualties on both sides will however remain of paramount importance in future operations, and still represents a major challenge for air power. In that context, unmanned or uninhabited aerial vehicles (UAV) will undoubtedly play an increasing role in tomorrow's air missions, as highlighted recently by US cruise missiles air strikes on Iraq during Operation 'Desert Fox' in December 1998.[2]

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UAVs have already proved their worth in operations during the last decades, from the Middle East conflicts to more recently in Bosnia, as joint tactical intelligence, surveillance, target acquisition and reconnaissance (ISTAR) vehicles. As technology is developing continuously and more rapidly, the role of UAVs is widening, and the next logical step should be that of combat UAV (UCAV). The US Air Force and the Royal Air Force, with its Future Offensive Air System (FOAS) concept, are seriously considering uninhabited vehicles as potential contenders for the 2015 generation of aircraft.

This research paper aims to examine to what extent technology could replace man in combat aircraft in the future. It is limited in scope, and although UAVs are truly joint assets, it will focus on an air force perspective. In addition, cruise missiles launched from air, ground or sea will not be covered, emphasis being on reusable and affordable uninhabited air vehicles. After reviewing the historical background of UAVs, this paper will consider their potential contribution to air power and examine the role that combat UAVs could fulfil in the next decades. Finally, the important technical challenge will be balanced with the overall importance of the human factor, before some recommendations for the future will be addressed.

HISTORICAL BACKGROUND

'The value of history in the art of war is not only to elucidate the resemblance of past and present, but also their essential differences'.

Sir Julian Corbett

UAVs are not a new technological concept. On the contrary, they have a long history in aviation. Although Clement Ader in France and the Wright brothers in USA are often considered to be the 'pioneers of aviation', kites, gliders and other balloons had been described centuries earlier in both myths and historical accounts.[3] As early as 1818, the French scholar Charles Rogier designed an aerial balloon system from which rockets could be fired at an enemy by using a delayed-action device.[4] Later, and even before World War I, a French artillery officer, Rene Lorin, had proposed the use of flying bombs to attack distant targets.[5] He suggested that such an aircraft could be stabilised in flight by the combination of a gyroscope and a barometer, guided along a track by radio signals from an accompanying piloted aircraft and propelled by a pulse-jet or a ram-jet engine.

The First World War saw the birth of air power and the use of aircraft in most of its current roles, together with its immense advantages and its inherent limitations. Facing heavy aircrew casualties against the German Fokker monoplanes, and unable to intercept Zeppelin airships, British military planners and researchers quickly realised that there were definite advantages in having some kind of unmanned platforms in support of manned aircraft. However, most British and American experiments came to an end with the termination of the War without having been successfully tested in combat. Therefore, the main interest in the capabilities of unmanned aerial vehicles diminished. Meanwhile, experiments with pilotless aircraft continued in the inter-war period.

Nevertheless, it was not before the development of the German V1 during World War II that unmanned aircraft were again considered with great interest as alternative cost effective weapons. Indeed, after the defeat of the Luftwaffe in the Battle of Britain, there was concern among German military leaders about how to maintain an air threat over Britain without risking the loss of scarce and highly trained aircrews. Although early prototypes of the V1 were available in the late 1930s, the German did not give go-ahead for production until 1941. From June 1944 to March 1945 ten thousand five hundred V1 sorties were launched against Britain. Only 2,500 survived mechanical failures and penetrated the enemy's defences to hit their target, causing nevertheless some 14,665 casualties.[6]

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V1 sweeps towards the target low over the Kent countryside

The development of UAVs continued after World War II primarily in the United States, but it has generally taken an international incident or a major conflict to attract the attention of political and military leaders to the capabilities of unmanned systems. The downing of CIA pilot Francis Gary Powers in a U2 spy plane over the Soviet Union on 1lst May 1960 led to a major effort to reconfigure the Ryan Firebee aerial target into a reconnaissance drone.[7] Furthermore, two months after Gary Powers was shot down, a US RB-47 was lost on an electronic intelligence (ELINT) mission over the Barents Sea, causing the loss of five aircrew and the capture of another two by the Soviets.[8]

From 1963 onwards, Firebee Remotely Piloted Vehicles (RPVs) successfully conducted reconnaissance missions over China, and later over North Vietnam, providing high-quality photographs of military facilities and the movements of troops. In Vietnam the use of RPVs increased as the demand for US resources grew and the losses in US airmen and aircraft mounted. Their role was gradually extended to electronic intelligence gathering, decoy and jamming, real-time communications intelligence and video, and even Psyops with leaflet dropping missions. Although lacking the flexibility of manned aircraft, for they flew autonomously over pre-planned routes, RPVs already proved their worth on missions considered too dangerous for manned aircraft such as low altitude battle damage assessment (BDA) missions. From late 1964 until the cease-fire in 1973, US RPVs flew a total of 3,435 sorties for a reported loss of only 4 per cent, confirming their essential value in the overall air campaign.[9] But as the Vietnam War wound down, so did interest in UAVs.

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One other nation, Israel, has actively and successfully employed UAVs in combat since the early 1970s. The first recorded use of an UAV in Israeli service was in Sep 1971, when Egyptian missiles batteries shot down an Israeli Stratocruiser transport near the Canal Zone in Sinai. Israel responded to this and to Egyptian high altitude reconnaissance overflights by sending BQM-34 Firebee over Egyptian territory.[10] This was repeated during the Yom Kippur War in 1973 for dangerous reconnaissance missions over SAM-infested areas following pilot losses. RPVs were used as decoys to draw fire on the first wave assault, thus reducing flak and surface to air missiles. One RPV even managed to survive an attack by thirty-two SAMS, returning safely behind Israeli lines.[11] Then, the Israeli F4s and A4s caught the Egyptians while they were reloading their SAMs batteries, and knocked out the missile defences, thereby gaining overall control of the air.[12] In addition, the Israelis began to extend the role of their RPVs from reconnaissance of missile sites and troop movements, to electronic countermeasures (ECM) functions such as decoys and jammers. During this conflict, the Israelis already realised all the advantages that unmanned aerial vehicles could provide in support of manned aircraft, and they even started to develop a combat version of UAV, almost 26 years ago. The Israelis fitted a BGM-34 RPV with a TB camera in the nose and an AGM 65 Maverick missile under the wings. The UAV was able to locate the target and to pass the TV picture to the ground control station behind the lines. The target was then selected from the ground and the AGM 65 missile was fired from the UAV, and guided automatically to its target.[13] Hence, unmanned aerial combat vehicles (UCAV) were tested successfully in the suppression of enemy air defence role by the Israeli armed forces as early as in 1973.

In 1982, the Israelis were committed again to war, this time in the Bekaa Valley against the Syrians. They had already learned some hard lessons in previous conflicts, but newer and more sophisticated air defence systems presented them with major challenges. The Israelis realised that the key to dominating Lebanese airspace was to rid the area of Syrian-manned Soviet-built SA-6 missiles. In that task, UAVs took a major role and were initially used to locate the position of air defences in Lebanon and Syria, and at the same time to map out the air and ground order of battle including critical electronic emission information. Then, on the morning of the operation, UAVs carrying electronic warfare payloads, simulating scores of targets, approached the target area with low level ingress profiles. Cruising over the Mediterranean, ELINT-equipped Boeing 707 and E2C Hawkeye radar and control aircraft carefully monitored the situation. As Syrian missile batteries started to launch missiles against what they believed to be the threat, UAVs transmitted real-time data to ground controllers who guided Israeli air force strike fighters to their targets. UAVs flew an average of 70 sorties per day during the 1982 Lebanon War. Their missions were vital to Israel's success which included 22 MIGs downed and 17 out of 19 Syrian SAM sites destroyed in the first three hours of the war, with no admitted Israeli air losses.[14] This act of war remains one of the most impressive examples of the use of air power in which UAVs took an active part.

Shortly following the Israeli successes, the US Navy lost three aircraft to Syrian anti-aircraft batteries during a retaliatory strike against Syrian positions in Lebanon's Bekaa Valley in 1983. The cost, including the loss of life, aircraft, and political dignity suffered by the US, was far greater than any benefits obtained by the attack itself. As a consequence, these experiences helped to convince US military sceptics of the need to introduce advanced UAV systems to perform some of the hazardous missions done by manned aircraft.

The Gulf War highlighted the overall importance of tactical UAVs as a battlefield-intelligence gathering platform. Indeed, general awareness and military-wide acceptance of the real value of UAVs had still not emerged in the United States and other western countries until their use during

Operation Desert Shield and Desert Storm. US Pioneer remotely piloted vehicles (RPV) provided highly valued near real-time reconnaissance, surveillance and target acquisition, and battle damage assessment day and night, while spending long hours staring down at the vast desert surface. Pioneer UAVs often worked in synergy with the US E8 Joint Surveillance and Target Attack Radar System (JSTARS). JSTARS radar detected a potential high priority mobile target then, UAVs were flown into the area to confirm the sighting. A UCAVs could have completed the mission (especially the highly decisive ones against SCUD launchers) by dropping weapons on to the target before it started to move. Unfortunately such UCAVs did not exist at that time, and when manned aircraft arrived in the area, after the reconnaissance assessment made by Pioneer UAVs, often the mobile targets had disappeared. However, the need for unmanned aircraft was recognised by the Americans and they started to develop an ambitious programme which led a few years later to the predator medium altitude endurance UAV.

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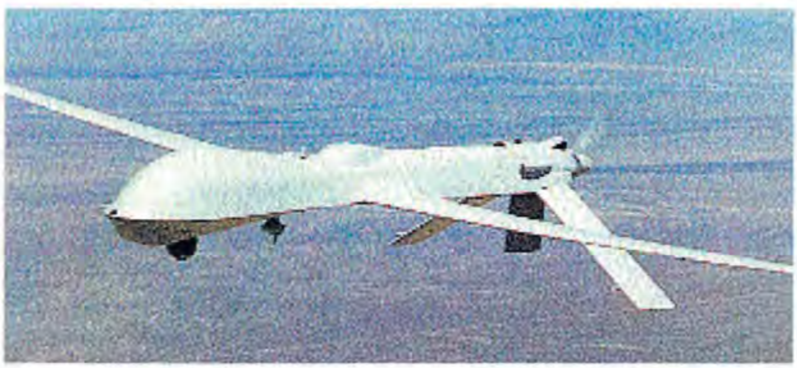

Again, it was a major international crisis which brought the UAVs back into the spotlight when US Predator UAVs were employed over Bosnia from July 1995 onwards. Another time, the US Department of Defence's UAV programmes got ever since a real boast thanks to the impressive performance of the Predator during the Bosnian crisis. According to Maj Gen Kenneth Israel, director of the Pentagon's Defence Airborne Reconnaissance Office (DARO), 'Predator has done a remarkable job. It helped the general impression about UAVs in the Services and in the Department in a very positive way. Because it's been so successful, there's been an awakening. It has sparked support for UAVs across the board and for our planned family of UAVs'.[15] Despite two early losses due to hostile fire and engine failure, Predator had amply proved the UAV's worth. Its ability to loiter and stare at particular areas, in order to pinpoint concealed targets and further assessing the damage to them once they've been hit, was decisive. Predator support operations in Bosnia also included humanitarian assistance monitoring, NATO troop protection, target location, search and rescue, before and after strike surveillance, peace accord monitoring and general peace-keeping support.[16] In addition, Predators were often retasked in flight, providing a real flexibility to the highest chain of command. Adverse weather was the principal limitation to Predator's ability to perform planned missions. However, improved in 1996 with a new synthetic aperture radar (SAR), Predator was successfully integrated into the complex command, control, communications, computers and intelligence (C41) architecture, and proved to be an essential asset to the Joint Force Commander, allowing him to increase his battlefield awareness and to focus his assets at the right place and time.

UAVS AND AIR POWER

'Air power is the most difficult of all forms of military force to measure, or even to express in precise terms'.

Sir Winston Churchill

The last conflicts have clearly outlined the increasing importance of unmanned aerial vehicles in air power, and doctrine has just started to take them into account. In that respect, the new edition of AP 3000 British Air Power Doctrine, defines air power as:

'The ability to project military force in air or space by or from a platform or missile. Air platforms could be any aircraft, helicopter or unmanned air vehicle'.[17]

Integration of UAVs and further doctrinal considerations of their employment are however still merging and need to be implemented. Albeit that UAVs have already proved their worth as intelligence, surveillance, target acquisition and reconnaissance (ISTAR) platforms, they have other potential capabilities that can be further exploited.

The characteristics of air power have been derived through history and experience, principally from a manned aircraft perspective. The unique ability to exploit the third dimension provides air power with its three primary strength of height, speed and reach.[18] However, technological limitations and a strong unwillingness to remove the man from the cockpit, constrained UAVs to be only relatively simple aircraft compared to their manned counter-parts. Nevertheless, the recent development of US high altitude long endurance (HALE) Global Hawk, able to loiter at 65,000 ft for 40 hours at 5,500 kms from its base, will most probably and definitely replace manned aircraft in high altitude reconnaissance missions. Indeed, crew can be a real limitation for long missions at very high altitude, due to human endurance and the requirement for specific life support equipment, which take an important place in the aircraft.

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The rescue of Capt O'Grady for instance, necessitated the issuing of several statements by Presidents Clinton himself, and provoked a rescue mission which involved the insertion of 43 marines into hostile territory, supported by some 40 aircraft. Employment of UAVs in a wider range of missions in place of manned aircraft

Air power's additional strengths, stemming from height, speed and reach, are recognised as ubiquity, flexibility, responsiveness and concentration.[19] These essential characteristics of air power have been better exploited by manned aircraft, provided that unmanned aircraft should not aim to replace manned aircraft in the future, but only strive to act by synergy as a force multiplier. Hence, UAVs could find a fundamental role in filling the gaps created by the inherent actual limitations of air power. Impermanence, limited payloads and fragility are today the most important restrictions on platforms using the third dimension.[20] UAVs can, to a certain extent, enhance the performance of manned aircraft endurance, yet increasing overall air presence over a theatre of operations. Indeed, reconnaissance UAVs such as Predator have already proved their worth by performing 24 hour coverage of the Bosnian theatre, and providing the Joint Force Commander with valuable real-time information at low cost and political risk. Other reasons are driving the recent development of UAVs and an increasing interest in them by most countries. UAVs should primarily replace manned aircraft in missions that are usually considered too 'dull, dirty, and dangerous'.[21] UAVs could perform these missions in a cost-effective way at a time when several air forces are in addition confronted with a shortage of aircrew.

The principal case for UAVs remains above all that they save human lives. UAVs should therefore be employed as a priority on missions considered too hazardous for manned aircraft. Protection of human life, and particularly of aircrew, has now become a paramount concern for commanders, and can influence political and military strategy. In that respect, the essential desire to limit casualties may well be a centre of gravity in future conflicts, whereas media and public opinion now have a major impact on decision-makers. Gen Mohammed Farah Aidid with his guerrilla troops managed to seriously undermine US political objectives in Somalia in 1993, while inflicting less than two dozen US casualties. Therefore, change in the public's attitude towards an 'acceptable' level of casualties may well be the most important factor favouring the development of UAVs.[22] According to Maj Gen Jerry Harrison, former chief of the research and development laboratories of the US Army, the extremely low allied losses in the Gulf War 'set a standard that surprised many people. To replicate that in the future war translates into robotics'.[23] In addition, UAVs offer the great advantage of expandability. In Aug 1995, a Predator was completing a reconnaissance mission over Bosnia when it was shot down in the same area where USAF Capt Scott O'Grady's F-16 was downed two months earlier. Hardly a mention of its shoot-down was made in the world press.[24] The issue of downed aircrew retained as prisoners has always inflamed debate and public opinion over war and peace, and the real necessity to act. In other words, this is the classic public dilemma between 'something must be done' and the risk of friendly human losses in operations where no national main interests are at stake. The rescue of Capt O'Grady for instance, necessitated the issuing of several statements by Presidents Clinton himself, and provoked a rescue mission which involved the insertion of 43 marines into hostile territory, supported by some 40 aircraft.[25] Employment of UAVs in a wider range of missions in place of manned aircraft would therefore avoid the risk of losing aircrew as well as highly capable and valuable platforms, and reduce some of the political constraints that face military commanders in today's conflicts. In addition, it would provide a major advantage, that of cost.

UAVs are much less expensive than manned aircraft, and they have to be overall cost-effective platforms. Removing the crew from the cockpit allows a significant reduction in costs. In the last generation of manned aircraft, the cockpit design and pilot interface requires a considerable amount of resources and expensive electronic and computer devices. This, combined with pilot life support equipment, can represent almost 30 percent of the development and operational cost of the aircraft. In addition, the cost of aircrew flight training and aircraft maintenance is significant enough to further emphasise the interest in UAVs. Eliminating the cockpit of the aircraft leads to another great advantage, that is of reducing size and weight, therefore saving money while allowing a considerable increase in aircraft performance.

According to Chuck Heber, an unmanned air vehicle expert and head of the High Altitude Endurance UAV programs at the US Defence Advanced Research Projects Agency (DARPA): Deployable unmanned combat aerial vehicles (UCAV) are closer to becoming reality than many believe, and the need (for them) is clear

Notwithstanding progress in technology, manned aircraft are limited in terms of manoeuvrability and endurance by human physiological constraints. Conversely, UAVs are g-force limited only by structural engineering. UAVs' endurance depends on fuel supply, and its performance is not affected by time and consequent crew fatigue. More manoeuvrable, smaller, therefore less visible to sight and radar than manned aircraft, UAVs are more survivable. Employment of UAVs in a combat role is becoming more and more attractive and a challenging option for the future.

UAVS IN THE COMBAT ARENA

'In the development of air power, one has to look ahead and not backwards and figure out what is going to happen, not too much what has happened'.

William Mitchell

Could UAVs find a place in conflicts which will require more tempo, simultaneity and lethality in order to achieve success with a reduced number of losses? Could UAVs be more than a tactical ISTAR platform in the near future, although they have already proved to be a significant component of battle winning capability in this major reconnaissance role? According to Chuck Heber, an unmanned air vehicle expert and head of the High Altitude Endurance UAV programs at the US Defence Advanced Research Projects Agency (DARPA): 'Deployable unmanned combat aerial vehicles (UCAV) are closer to becoming reality than many believe, and the need (for them) is clear. There are missions we don't do today because of the risk, in peacetime as well as in wartime'.[26]

In any future conflict, offensive air actions will be paramount and represent an essential element of the overall military campaign. Modern weapons, with their power, range and accuracy will strive to destroy, or at least neutralise, enemy assets in the early days or even hours of the war. Such abilities are undoubtedly the key to victory or survival. In that respect, the primary mission of combat aerial vehicles will be to strike effectively and quickly at enemy formations. Furthermore, we have seen the overall importance of minimising collateral damage and civilian casualties in the target area, as well as saving lives among friendly aircrew. Yet whilst cruise missile can, to a certain extent, fulfil this offensive role, its limitations of cost, payload and accuracy suggest the need for a complementary system, similar in size and method of launch, but re-usable, dropping its warhead and coming back for a quick turnaround for another mission. Presently, UAVs are able to scan an area and to find enemy units. The next logical step will not only be to locate targets, but also to engage and destroy them.

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UCAV missions are likely to consist of punitive strike missions, in which air forces are unwilling to risk a pilot's life, and deep strike or suppression of enemy air defence (SEAD) missions in support of manned offensive packages. Hence, UCAVs could operate alongside manned strike aircraft, and act as a 'first day of the war enabler'. Thanks to its long endurance capabilities, UCAVs could fly ahead of packages, knocking out enemy air defences, and stay around in order to suppress any threats that might pop up during the strike. UCAVs would then have the ability to loiter and maintain a persistent vigilance over the battlefield, whilst keeping enemy air defences suppressed. In addition, UCAVs could be able to provide an immediate strike capability against high value and time-critical targets, such as tactical ballistic missile launchers. Apart from performing this major role of SEAD, there is scope for UCAVs in OCA missions. Since airfields are more and more heavily defended, the path of strike aircraft remains quite predictable, and therefore runways present a dangerous target for manned aircraft. During the first weeks of the Gulf War, Britain lost 5 Tornados in low level airfields attacks in Iraq. Smaller, therefore stealthier and more manoeuvrable than manned aircraft, UCAVs could successfully penetrate enemy air defences, and deliver cheap bombs from low altitude on to runways. Attack of heavily defended fixed targets constitutes thereby a prime role for UCAVs in the next decade. Operating remotely unmanned combat platforms could then be the first day of the war aerial weapons performing missions that today would be considered suicidal.

However, to take the pilot out of the cockpit, means that UCAVs should have some hard evidence about significant affordability gains. The main desirable attributes of an UCAV are likely to be its affordability, lethality, survivability, supportability, deployability, flexibility and responsiveness. UAVs have the great advantage of reduced weight, drag and radar signature compared with their manned counter part, and above all are less expensive. Since the cost of an aircraft is roughly proportional to its size, Boeing officials have predicted that they can reduce the $30 million cost of the basic JSF to as little as $15 million by making it unmanned.[27] Inevitably, affordability is a main driver behind the desire to demonstrate that UCAVs can be operationally effective. DARPA is projecting an air vehicle unit cost less than one third that of a JSF, with reductions in operating and support costs of up to 80 percent compared to those of current fighter squadrons.[28] Anyhow, operational requirements for range and payloads will certainly determine aircraft size. To minimise range, UCAVs can either be

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air-launched or rocket-launched from a truck or an equivalent ground platform. In addition, payload can be reduced with the employment of small weapons, thus saving some precious space I the aircraft usually dedicated for onboard sensors and navigation systems. As a consequence, and in order to be an affordable cost-effective platform, UCAVs also have to be as autonomous as possible, pre-programmed on routes but still monitored by a ground or airborne operator.

The requirement to gain advantage over the enemy in the first hours of a conflict, by implementing the tenets of the manoeuvrist approach, leads air platforms to have a certain degree of lethality. The recent development and employment of air to ground missiles and precision guided bombs in piloted aircraft has been driven essentially by the need to enhance aircrew survivability. However, since cost is a prime factor for UCAVs, small unmanned aircraft could successfully take advantage of their low signature and high manoeuvrability by releasing cheap unguided weapons very close to the target, thereby ensuring the required level of accuracy.

Despite the many capabilities of today's UAVs, survivability remains a major concern for designers. Reduced radar cross section and noise level, combined with low infrared signature are among the current strengths; UAVs are still relatively slow aircraft and therefore more vulnerable than jets. On the other hand, slow speed allows ISTAR UAVs to increase their endurance for more time on station, and to loiter over a hostile area. However, due to their line of site guidance limitation, some UAVs can usually not use terrain to shield themselves from enemy fire. In addition, UAVs lack redundant and costly onboard flying systems unlike manned aircraft. The loss of a Predator UAV

Despite the many capabilities of today's UAVs, survivability remains a major concern for designers. Reduced radar cross section and noise level, combined with low infrared signature are among the current strength, UAVs are still relatively slow aircraft and therefore more vulnerable than jets over Bosnia to enemy light ground fire, while flying at 5,000 ft, is a recent example of UAVs' vulnerability. Thus, maturing technology should help to correct these shortcomings for UCAVs, by concentrating on recent proven techniques in stealth, bad weather sensor and weapons employment, making them harder to detect and kill. According to Lockheed Martin experts: 'UCAVs will be probably vulnerable to manned fighters within visual range. Beyond visual range there is no technical reason to believe that a UCAV could not hold its own against a manned fighter. In the longer terms it is conceivable that technology could even make it formidable within visual range'.[29] Without any crew acceleration limitation, a UCAV with a +/-10g capability could outfly many missiles, for missiles are usually designed with a factor of three over that of the target manned aircraft. An acceleration capability of +/-20g would make UCAVs superior to nearly all missiles. The challenge facing designers is obvious.

UCAV should also be easy to maintain and to deploy. Air-launch offers the option of minimum gear and personnel support, whilst the number of onboard controllers and control stations can be kept small. However, it is likely that an effective weapon payload will impose more ground support and even require UCAVs to be operated from a runway. According to DARPA, a SEAD/strike UCAV will probably have an empty weight of 3,600 kg or less and a payload of two 450 kg Joint Direct Attack Munitions (JDAM) or eight 110 kg small smart bombs, both using GPS navigation and guidance.[30] Such a vehicle would need to operate from a standard runway (8,000ft). On the other hand, on-board avionics should provide UCAVs with sufficient autonomous functions such as collision avoidance, self-defence and attack manoeuvring, plus the ability to self-diagnose problems and determine autonomously whether to return to base or terminate the flight.[31] Moreover, a future UCAV would have to operate in adverse climatic conditions and therefore should possess some adequate weather avoidance devices. Weather was indeed the principal limitation on Predator system capabilities over Bosnia. In-flight icing, high winds, precipitation and cloud cover restrained Predator's ability to perform some of its planned missions at medium altitude.

...UCAVs should be a flexible and responsive aerial platform. Advance in technology will allow full exploitation of the systems of systems architecture and information dominance

Finally, UCAVs should be a flexible and responsive aerial platform. Advance in technology will allow full exploitation of the systems of systems architecture and information dominance. Thus, reliance on off-board sensors in a control station would minimise the UCAVs' expensive sensor suit requirements. With its own sensors a UCAV could provide the precise location and range of a target to an operator who could them identify target, cue the weapon and authorise its release. The operator would also need to have the ability to manually control the UCAV's flight path in order to respond to real-time manoeuvring requirements or to change target at the last moment. In addition, ground or air operators should also be able to control simultaneously more than one UCAV.

Nevertheless, affordability and feasibility of the UCAV concept raises some key issues and further questions that are worth considering. They may restrain the enthusiasm of pilotless aircraft proponents, and also address some concerns that should be resolved in the future. First of all, the integration of UCAVs amongst manned aircraft remains a major issue, and will probably be the next challenge to overcome. The increasing number of unmanned platforms in the air is likely to generate some new difficulties. Airspace management and deconfliction may well constitute a severe limitation on the employment of unmanned platform among civilian aircraft in peace time. Since affordable UAVs should be as autonomous as possible to minimise their data-link vulnerability to electromagnetic perturbations and jamming, they would not be able to apply the safety regulations and aircraft separations that are required in civilian airspace. Furthermore, without a permanent radio control link with an operator, unmanned aerial armed platforms could not avoid mid-air collision or divert successfully in the case of technical problems. Overflight of civilians with a lethal payload will most probably be avoided as much as possible, in order to prevent any risk of loss of control or mechanical deficiency in an environment where Electronic Warfare (EW) capability is growing very rapidly throughout the world.

On the operational side, planning and integration of unmanned aircraft in the air campaign has already led to some adaptations. Cruise missiles reflect the present difficulties that military planners encounter in the allocation of airspace for unmanned aerial vehicles. Hence, UAVs and cruise missiles are usually deconflicted in time and/or space, in specific allocated airspace like Special Corridors (SC) or Restricted Operational Zones (ROZ). This airspace issue has some significant effects on the possibility of operator training. Only experience and training would provide the necessary background needed to develop and implement UCAV doctrine and enhance concepts of employment. As a consequence, the location of the two US Predator squadrons is currently the Nevada desert, away from airspace constraints, and close to the USAF Air Warfare Centre at Nellis Air Force Base.

The minimum level of human control required in a UCAV is dependent upon data-link technology and capability. The operational frequency bandwidth is already fully exploited and there is a risk of interference combined with a high vulnerability to jamming. UCAV reliability and manned control capacity could therefore be decreased with the consequent risk of loss of control of a weaponised unmanned aircraft. If communication breaks down, is disrupted, sabotaged, or worse still, manipulated by the enemy, the UAV becomes useless or potentially self-destructive.[32]

The last important issue is weapon employment and the minimum degree of human control required. Human authorisation prior to weapon delivery is an absolutely critical element in the UCAV concept. It is, however, difficult to estimate the adequate level of situational awareness that an operator would require to authorise the release of a UCAV's weapons. To reproduce the level of situational awareness in a UCAV to a standard currently achieved by manned aircraft is therefore a major technological challenge. Notwithstanding a UCAV's on-board future sensors capabilities, it is unlikely that the ground or air operator would have the same accurate perception than a pilot may have in his aircraft regarding, for instance, the visual identification of a target or a threat. According to Rules of Engagement (ROEs), a UCAV's operator should, however, be able to identify positively a target prior to authorise the release of weapons. Without sufficient identification capability, a UCAV would add nothing more than a cruise missile, thereby lacking the required flexibility.

Finally, the legality of unmanned systems needs to be considered since they raise some moral and public concerns about automation and lethality

Finally, the legality of unmanned systems needs to be considered since they raise some moral and public concerns about automation and lethality. One can argue that unmanned vehicles are in a way not legal under the Geneva Convention's rules of war, because for instance a 'robot' would be unable to recognise a surrending person.[33] Furthermore, according to the fundamental concept of the Law of Armed Conflict (LOAC), UAVs would have to apply the principle of proportionality related to the relationship between military objectives and humanitarian concerns. Hence, an attack causing collateral damage, which could be considered excessive in relation tot he direct military advantage anticipated from it, should be banned. However, only an airman would be able to fully appreciate and judge the consequences of his actions regarding incidental loss of life and collateral damage. The general provisions of LOAC are incorporated in ROEs, which are becoming tighter, and therefore require constant evaluation of a situation, common sense and rational judgement, all human characteristics that automation can not artificially recreate. Rules of Engagement, the status and definition of combat unmanned aircraft in arms treaties should be clarified and amended in the near future and certainly prior to any operational employment of UCAVs.

TECHNICAL CHALLENGE AND THE IMPORTANCE OF THE HUMAN FACTOR

> *'It is not possession of technology, but its intellectual mastery, which will determine its significance in conflict'.*

AVM Tony Mason

International interest in the UCAV concept remains high, and the need for unmanned aerial platforms to support or replace manned aircraft in hazardous missions is real. According to US DARPA specialists, unmanned combat aircraft will, however, not go into battle in the near future.[34] Despite recent advances in aerospace technology, budget holders will have to be convinced that UCAVs can be built cheaply, operated reliably, and used effectively. More importantly, designers will have to face a strong scepticism about unmanned aircraft, fostered by previous expensive failures. 'They fly and they crash, but defence ministries keep on pouring cash into UAVs despite a litany of programme failures and embarrassing flops', argued *Flight International* journalist Douglas Barrie in 1997.[35] The current situation is more optimistic, recently boosted by the US Predator's success in Bosnia. In addition, air-vehicle technology is now relatively more mature. Nevertheless, some significant problems are darkening the UAV developers' sky, such as the data-link issue regarding jamming and other interference within frequencies.

Hence, the road to UAV glory has seen a few deaths by misadventure in the intervening years and is still being trodden by a number of walking wounded.[36] The Alliant Techsystems Outrider short range tactical UAV has suffered from both system integration and testing delays. The Israel Aircraft Industries (IAI) Pioneer short range UAV needs an improved engine. The IAI Hunter tactical UAV suffers from funding problems. The General Atomic Predator has a problem of asset availability. Lockeed Martin's Darkstar high-altitude endurance UAV crashed on its second flight, resulting in changes to some flight-control algorithms. The vehicle's landing gear is also being redesigned. Teledyne's Ryan Global Hawk UAV has a problem with software handling and integration.[37] Many designers, however, agree that there is an enormous gulf between deploying a UAV armed only with an electro-optic sensor package and a combat UAV carrying an offensive payload. Any delay in development, or due to a technical failure, is therefore likely to create a hostile environment for the UCAV concept, and for any other new unmanned programme in general. The Darkstar programme is more than a year behind schedule following the loss of the first vehicle. The Global Hawk programme, meanwhile, is at least six months late.[38] Experts worry about these delays, and have even considered ending production of the Darkstar stealth UAV, thus saving $600 million in acquisition costs and $400 million in operational and support costs.[39]

Significant advances in technology, however, should be considered as a valid planning assumption over the next 15 years, and will probably enable UAV designers to overcome some of the present technical difficulties. Indeed, growth of information technology seems quite limitless, and future information-based systems will be far more developed than those currently available. Data fusion rates will probably be 100,000 times faster and more accurate than today, whilst data storage capabilities will be at least 10,000 times greater due to component miniaturisation.[40] Computer, communications and sensor technologies are now becoming available in packages small enough to be genuinely applicable to sophisticated UAVs.[41] New airfoils and lightweight materials would also make possible the construction of an airframe able to loiter for many hours. Meanwhile miniaturised sensors and avionics, and efficient heavy fuel engines would greatly enhance current UAV performance. Structural configuration and surface characteristics would also reduce radar signature through the use of advanced materials and treatments. Furthermore, stealth technology, already mastered in recent manned fighters and the Darkstar UAV, will undoubtedly be used widely in any new UCAV design. Thus, according to some specialists, the UCAV concept could probably be a two-axis unstable aircraft with no vertical tail, employing thrust vectoring and fly-by flight controls using electric actuators.[42] An affordable UCAV also needs to be much more autonomous than the auto-pilot equipped remotely piloted vehicle of the past. We can expect that with recent improvements in miniature solid state gyros and sensors, UCAVs would be more reliable in terms of flight control. As a consequence, they could be pre-programmed to fly from way-point using Global

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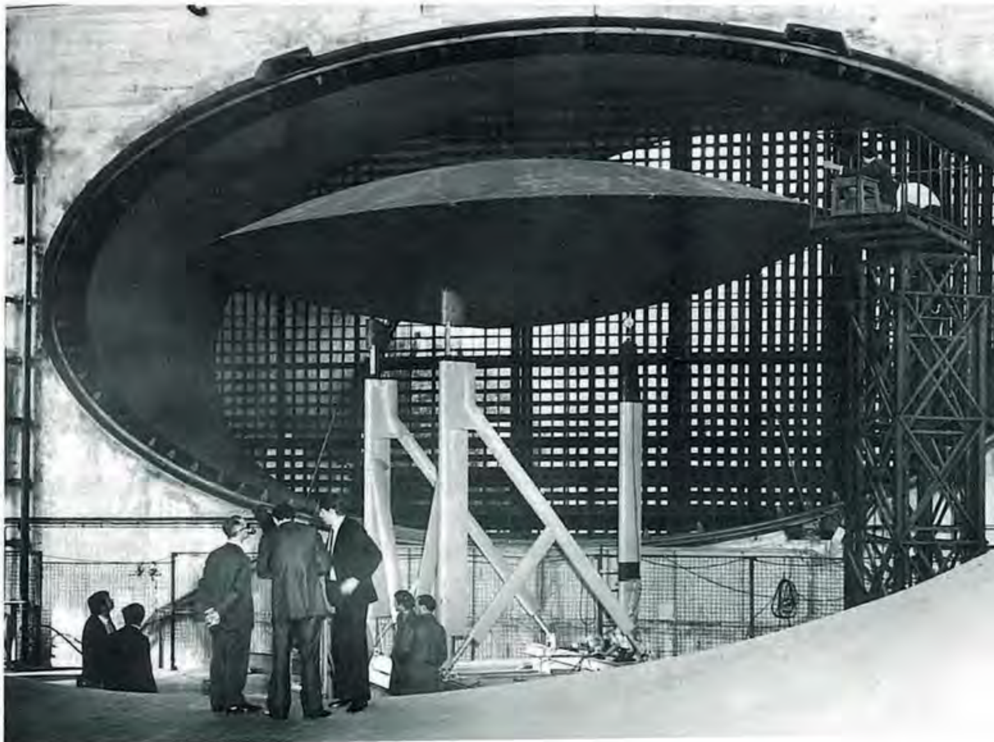

Position Satellite (GPS) navigation, and to change altitude automatically. This could help to minimise the vulnerable line of sight support infrastructure and personnel required by today's UAVs. Hence, computer processors and software, data links, ground or future air control stations, launch and recovery devices, and logistics support network will also benefit from the latest improvements in technology.

If changing technology and the human dimension of conflict[43] are likely to shape future wars, the human element remains the overall critical factor that leads to success in war through the exploitation of technology.[44] According to the USAF AFM 1-1 document, 'Technology only helps people to win wars'. Human physical limitations to g-loading and the increasing pressure to minimise, or even suppress, aircrew casualties are today's main reasons which may lead to removal of the pilot from the cockpit. Accordingly, the man in an aircraft can not be replaced totally by technology, even with the most sophisticated devices and foreseeable capabilities. The human in a combat aircraft is indeed doing much more than flying the aircraft and controlling the weapon and navigation system. Only human intelligence has the capacity to adapt to the changing, and sometimes very unexpected, circumstances of combat missions. Flexibility and adaptability are by essence human qualities but are also inherent air power strengths. Human presence in the battlespace confers levels of flexibility, unpredictability and judgement which machines are unable to match. Programmers would probably not be smart enough to anticipate every change in battlefield circumstances.[45] In addition, one can wonder how the finest software will estimate the uncertainty of conflict, enemy's intentions, and all the factors that Clausewitz has described as 'the fog of war'. Furthermore, if war is changing with new technologies, enabling the development of more sophisticated and accurate weapons, one key factor always remains constant in war, the Clausewitzian idea of 'friction'.

In aircraft today, the pilot is acting more and more as a decision-maker, using his own judgement and experience provided by training and skill to respond to constantly changing situations, and to obtain sufficient situational awareness. As discussed earlier, ROEs are likely to be more strict and tight conflicts, thereby limiting the employment of air assets. The variety and complexity of new missions across the whole spectrum of air power is already requiring more initiative and critical, rapid decisions from aircrew. Despite redundancy in sophisticated electronic devices, identification of friend or foe in the air often relies in the last resort on human eyes. In addition, the overall importance of minimising collateral damage also requires positive target identification, and therefore a high level of control over weapon release. Today, this can only be achieved effectively by a man onboard the aircraft, who is able to take into account all the political and moral constraints associated with new kinds of crises and other low intensity conflicts.

Finally, there is still strong feeling in air forces about 'pilot prestige', and it is more likely that airmen will embrace UAV technology in the future only through necessity. The need for a cultural change within western air forces regarding UAVs is obvious although it will probably take some time before it becomes a reality. Hence UAVs, and moreover UCAVs, should be affordable, reliable, and cost-effective platforms if they are to be employed in support of manned aircraft, and may be one day replacing them.

Removing the pilot from the cockpit, and therefore from the front line of the battlefield, may also be interpreted by the enemy as a message. The question is whether it would be a message of strength, stemming from high technology and asymmetric tactics, or a message of determination to avoid human casualties, which in turn could be interpreted as a lack of total commitment and weakness.

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RECOMMENDATIONS FOR THE FUTURE

Still confining ourselves to the narrow limits of human foresight, we can nevertheless state, with complete certainty, that probable future wars will be radically different in character from those of the past'.

Giulio Douhet

It is almost impossible to predict what form a war will take in the near future. However, according to the proponents of the Revolution in Military Affairs (RMA), technologies of the information age should allow air power to be employed to its maximum efficiency with speed, precision and minimum human cost. Therefore, present and future potential attributes of UAVs would suggest that unmanned platforms are more and more likely to be employed in future conflicts.

Compared to the 1991 Persian Gulf War, the recent four day US and UK air campaign over Iraq in 1998 (Operation 'Desert Fox') has clearly highlighted the increasing importance of today's most frequently employed weapon-carrying unmanned platform, the Tomahawk cruise missile. In 70 hours of air strike, 415 US cruise missiles were launched from air and sea, whilst during the five week Gulf War air campaign only 291 of them were fired. Meanwhile, manned aircraft flew 650 sorties during Desert Fox, 622 of which were carried out by US aircraft.[46] What is more worrying for the future, regarding UAV employment, is what was discovered inside an Iraqi hangar after air strikes. Among the aircraft destroyed were some pilotless L-29 'drones of death' developed to carry out chemical or bacteriological missions. Although cruise missile strikes achieved a reasonable success during this operation without risk of pilot loss or capture, the $500,000 to $1 million per missile cost, combined with the actual target penetration and speed limitations of Tomahawk missile, still present significant restrictions on the massive use of these weapons by other countries. In other words, considering the 65 Tomahawk cruise missiles purchased by the UK for the Royal Navy,[47] we can assume that in the near future the USA will probably be the only power able to conduct unmanned air strikes of this scale. In that respect, and as developed earlier in this essay, there is a niche for cost-effective reusable UCAVs in specific missions. Anyhow, it is most probable that UCAV will be first developed in the USA, despite a world-wide growing interest for unmanned platforms. Such a technical

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process will, however, require time and a high level of confidence and funds from budget holders. Nonetheless, the US DARPA believes that a combat version of a UAV could be ready to enter the fleet in the 2010 timeframe, and the US Department of Defence (DoD) will finance a $120 Million programme to see whether a pilotless combat aircraft is technically feasible.[48]

In Britain, the Royal Air Force is intending to replace its Tornado GR4 attack aircraft by 2018, under a programme called 'Future Offensive Air System' (FOAS). The name of the project changed from the original 'Future Offensive Aircraft' to reflect a broader range of potential platforms including manned aircraft, UCAVs, and conventional air-launched cruise missiles (CALCM). The programme's requirements cover a wide area of missions. FOAS would be able to conduct air interdiction and offensive counter air operations at long range and all altitudes, as well as secondary missions of anti-surface warfare, suppression of enemy air defences and tactical reconnaissance.[49]

Unlike air superiority missions, which can be effectively achieved by single seat aircraft (eg: F-22, Typhoon Eurofighter, Rafale), all weather and all altitudes air to surface missions have often required the presence of two crew men in the aircraft (F-15E, Tornado, M2000D). In the FOAS UCAV concept, technology will therefore have to replace two human brains, skills and experience, while doing more complex and unpredictable missions. According to Air Chief Marshal Sir John Allison, Commander-in-chief of Royal Air Force Strike Command: 'The problems are massive, and Britain is unlikely to opt for uninhabited combat air vehicles to meet its next generation strike aircraft requirement'.[50] Instead, he predicted: 'it would be the 'deep penetration attack aircraft beyond FOAS' where UCAV most likely would come into its own'.[51] This means to try to predict what will happen in year 2030! In addition, the inertia of weapons procurement in most of the European countries dictates that we already know what kind of platform the armed forces will depend on in 2020.

The future of manned aircraft in the Air Force is therefore not threatened for the next 25 years or so. Furthermore, unlike the US which can afford specialised expensive aircraft such as stealth fighter F-117 and B-2 strategic bomber, European air forces will still have to do all the spectrum of air power missions with fewer aircraft. For this reason, emphasis will certainly continue to be on swing role and versatile manned jets which offer all the flexibility required. In the meantime, cruise missiles will most probably take on more importance in tomorrow's missions as well as UAVs. Matra-BAe Dynamics has already developed the Storm Shadow/Apache CALCM to be launched from Rafale and Tornado. Other studies are focusing on CALCM possibly being carried and deployed a large military or even converted civil transport aircraft.[52] Hence, it is likely that future air missions will involve a force mix of manned aircraft, UAVs and CALCMs. UAVs will undoubtedly expand their role in combat missions, but will always remain nothing more than a force multiplier, and not yet replace manned aircraft.

> *'The first battles of the future will be held in the air, and the results of those battles will either determine who shall win the war or have a very marked influence on it'.*

William Mitchell

The 20th century saw the birth of air power with its overwhelming importance in the conduct of warfare. It has also been the preserve of manned aircraft, which proved to be the most flexible platforms to deliver air power across the whole spectrum of conflicts. However, ever since the first aircraft was used in combat its potential vulnerability was appreciated, together with its inherence consequences of aircrew losses and cost. In the meantime, UAVs have remained relatively simple aircraft with limited range, and generally unarmed. They have been employed mainly in support of ground forces in the reconnaissance role, providing though that they were cost effective platforms.

By the turn of a new millennium, technology is now advancing at such a pace that UAVs may be considered as ideally suited to the new hostile environment of high density lethal weapons, precision strikes, and minimum human losses. Combat UAVs are therefore a very attractive option in countries where people are becoming more and more averse to human suffering and reluctant to spend a lot of money on new defence projects. Hence, significant affordability gains in the UCAV concept will remain the major factor in taking the pilot out of the cockpit. Whatever future conflicts might look like the fog of war, uncertainty and friction would always require the presence of a human brain in the loop, to make right decisions at the right time. Therefore, manned aircraft will certainly continue to offer the best compromise in term of flexibility and efficiency to deliver air power in the next decades. Uninhabited combat aerial vehicles will, however, play a significant role as a force multiplier, by replacing and supporting manned aircraft in specific missions such as SEAD and other attacks on heavily defended targets. Acting in this role as a 'first day of the war enabler', UCAVs would definitely, like cruise missiles, hugely enhance the capabilities of air forces whilst saving human lives. As for ISTAR UAVs, such as Predator, it is nevertheless likely that we will have to wait until the US develops, tests, and moreover uses UCAVs in operations, before the scepticism of most European decision makers and other budget providers might be dispelled. This at least postpones a potential European UCAV to the post-FOAS generation of aircraft.

NOTES

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8 *Op Cit* Sir Michael Armitage, p.65.

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29 *Ibid* p.32.

30 *Idem*.

31 *Idem*.

32 *Op Cit* Alvin and Heidi Toffler, p.114.

33 *Op Cit* Steven M Shaker and Alan R Wise, p.171.

34 *Op Cit* Graham Warwick, p.36.

35 *Op Cit* Douglas Barrie, p.58.

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