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Man versus Machine: The Future of the Manned Air Superiority Fighter and the Unmanned Air Vehicle (UAV)

Abstract

The first task in any military conflict remains the demanding and challenging task of achieving air superiority. Historically, the manned fighter aircraft has played an instrumental role in achieving this objective. However, faced with the political imperative for reduced casualties during military conflicts, lower costs and the advent of mature sensor systems, Unmanned Air Vehicles (UAVs) have now become feasible and desirable. In a manned fighter the decision-making ability is the single most vital role of the fighter pilot. The fighter pilot is however, the main limiting factor on aircraft manoeuvrability and may react in an unpredictable manner during times of combat stress. It is these weaknesses that have driven the increased use of UAV. However, there remains many challenges that the UAV must overcome before it could truly replace the manned fighter aircraft in the role of gaining and maintaining air superiority.

If you don't control the air, you'd better not go to war.

General Charles Horner

There is no substitute for a tactically devious human mind in a modern airplane.

Carlo Kopp Airpower Journal

The first task of any air force is to gain and maintain air superiority and the manned fighter has historically been instrumental in the achievement of this objective. However, recent military conflicts have seen a marked increase in the employment of Unmanned Air Vehicles (UAVs) and in some instances the Unmanned Combat Air Vehicles (UCAVs), which appears to be threatening the traditional role played by the manned fighter potentially signalling the demise of the latter in the modern battlefield. There are many definitions of UAV and UCAV, and for the purpose of this paper a UAV may be defined 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 be expendable or recoverable, and can carry a lethal or nonlethal payload.[1]

Until recently, the UAV has been optimised in passive air surveillance and reconnaissance roles.[2] However, faced with the political imperative for reduced casualties during military conflicts, lower costs and the advent of advanced sensor

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[1]UAV will be used when referring to a UCAV in this paper, as the definition of UAV includes the carriage of a lethal payload. Department of Defence Dictionary of Military Terms, http://www.dtic.mil/doctrine/jel/doddict/data/u/05624.html; Internet; accessed 7 December 2004.

[2]United States Foreign Affairs, Defense and Trade Division, Report for Congress, "Unmanned Air Vehicles; Background Issues for Congress" 25 April 2003, available from http://www.fas.org/irp/crs/RL31872.pdf; Internet; accessed 15 January 2005, 4.

systems, the use of the UAV in operations has now become feasible and desirable.[3] Accordingly, the demand and capability of the UAV have also sky rocketed. In 2001, the combat potential of the UAV was demonstrated with the well publicised successful attack by a modified United States Predator UAV, equipped with Hellfire air to surface missiles, against Taliban and al-Qa'ida leadership in Afghanistan.[4] A second, but less well known demonstration of the UAV's combat potential was during December 2002 when a United States Predator UAV, equipped with two Stinger Air to Air missiles, engaged an Iraqi MiG 25 manned fighter aircraft.[5] Although the UAV was eventually shot down by the MiG 25, this attack on a manned aircraft by a relatively low cost unmanned air vehicle was the first operational example of a 'first generation Unmanned Combat Air Vehicle (UCAV)' assuming the challenging role of achieving air superiority role. The United States is not alone in its pursuit of UAV related technologies. At present there are at least thirty-two nations known to be developing or manufacturing more than two hundred and fifty models of UAVs, with five European countries, Israel and the United States currently embarking on armed variants.[6]

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[3]Col Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[4]Assembly of Western European Union, The Interparliamentary European Security and Defence Assembly, "Unmanned Combat Air Vehicles and Military Aeronautics of the Future", Document A/1884 30 November 2004, available from http://www.assembly-weu.org/en/documents/sessions_ordinaires/rpt/2004/1884.html; Internet; accessed 12 January 2005, 7.

[5]*Ibid*., 8.

[6]United States Department of Defence, "UAV Roadmap 2002", available from, http://www.acq.osd.mil/usd/uav_roadmap.pdf; Internet; accessed 5 February 2005, 21.

Notwithstanding the ascendance of UAVs, this essay asserts that despite their technological feasibility, low cost and political appeal, the UAV would not replace the manned fighter aircraft in role of gaining and maintaining air superiority. To this end, the paramount requirement to gain and maintain air superiority in modern warfare will first be examined. The essential qualities required of a manned fighter to achieve air superiority will then be discussed, prior to an assessment of the opportunities and challenges that the UAV would have to surmount before it could truly replace the manned fighter. This essay will conclude that the manned fighter remains the only viable option for the challenging task of achieving air superiority in the forseeable future.

The annals of history is replete with lessons that demonstrate that a "degree of control of the air is of crucial importance not only to air operations but also to virtually all types of surface and sub-surface operations."[7] The United Kingdom recognises three levels of control of the air: favourable air situation, air superiority and air supremacy. Air superiority is defined as "that degree of dominance in the air battle of one force over another which permits the conduct of operations by the former at a given time and place without prohibitive interference by the opposing force."[8] The United States military considers air superiority as a core competency, and is "normally the first priority of US forces whenever the enemy possesses air and missile assets capable of

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[7]Directorate of Air Staff Ministry of Defence, *AP3000 British Air Power Doctrine*, (Norwich: Her Majesty's Stationary Office, Third Edition, 1999), 2.5.1.

[8]*Ibid*., 2.5.2.

threatening friendly forces."[9] Therefore, during military conflicts the United States and its Allies will seek to gain control of the air to provide the "flexibility and freedom of action central to a full range of military options."[10]

The importance of gaining air superiority cannot be understated. History has shown the advantages of gaining and maintaining air superiority, and the operational difficulties faced when air superiority is denied. During World War II, prior to the Normandy invasion, the Allies worked hard to achieve control of the air because "the experience gained from the landings in North Africa, Sicily and Salerno, combined with the American 'island-hopping' experiences in the Pacific, had proved that air power was a key requirement in any successful invasion."[11] Whilst air superiority did not defeat the Germans directly, it did allow the Allies freedom of action by allowing "further bombing operations and for the planned invasion of Europe."[12]

In the summer of 1940 the *Luftwaffe* endeavoured to defeat Royal Air Force Fighter Command in an attempt to gain and maintain air superiority over southeast England.[13] Hitler and his Generals recognised the importance of gaining air superiority

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[9]United States, Secretary of the Air Force, *US Air Force Doctrine Document 2.1.1,* (Headquarters Air Force Doctrine Center), Chapter 1, 1.

[10]Major William K Lewis, "UCAV-The Next Generation Air-Superiority Fighter", (Masters' thesis, The School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, June 2002) http://www.au.af.mil/au/awc/awcgate/saas/lewis.pdf; Internet; accessed 12 December 2004, V.

[11]United Kingdom, Royal Air Force Website, *Operation Overlord*, http://www.raf.mod.uk/dday/index.html; Internet; accessed 14 March 2005.

[12]Canada, National Sovereignty and Collective Security, *The Air Campaign over Germany*, http://www.saskschools.ca/curr_content/history20/index.html; Internet; accessed 7 February 2005.

[13]Major William F Andrews, "The Luftwaffe and the Battle for Air Superiority: Blue Print or Warning?", *UASF Air Power Journal*, Fall 1995, available from http://www.airpower.maxwell.af.mil/airchronicles/apj/andrews.pdf; Internet; accessed 16 December 2004, 4.

prior to attempting his planned invasion of England. Without air superiority the Germans knew that any invasion force would be seriously disrupted by the presence of the Royal Air Force. The *Luftwaffe's* doctrinal manuals had rightly acknowledged its importance and had "assigned first priority to winning air superiority."[14] However, following British bomber attacks on Berlin the *Luftwaffe*, seeking to erode the will of the British people, abruptly changed its focus to attack British towns and cities at the expense of decisively destroying the RAF's fighter bases and radar stations. The move away from RAF Fighter Command bases allowed the British a vital opportunity to rebuild and re-equip their depleted fighter squadrons. Within weeks, the RAF had recovered and prevented the *Luftwaffe* from achieving air superiority over southeast England. Without air superiority, Hitler knew that any invasion of Britain would be doomed to failure. As such, he cancelled "OPEARTION Sea-Lion indefinitely and eventually abandoned the plan altogether."[15]

While the Battle of Britain has illustrated the critical requirement to achieve air superiority and enable campaign objectives to be successfully attained, the 1991 Gulf War will again serve to amplify this point. During OPERATION Desert Storm the Allied air forces expanded considerable efforts to gain and maintain air superiority against Iraq, a country with the 6th largest air force in the world.[16] During the evening of 17 January 1991 Allied air forces launched a total of four hundred strike aircraft,

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[14]I. B. Holley Jr, *Case Studies in the Achievement of Air Superiority*, (Benjamin Franklin Cooling, US Government Printing Office Washington), 1991, 611.

[15]United Kingdom, Royal Air Force Website, *Battle of Britain – Phase 4 of the Battle*, http://www.raf.mod.uk/bob1940/phase4.html; Internet; accessed 14 March 2005.

[16]Directorate of Air Staff Ministry of Defence, *AP3000 British Air Power Doctrine*, (Norwich: Her Majesty's Stationary Office, Third Edition, 1999), 2.5.4.

supported by hundreds more, flying over one thousand three hundred combat sorties in the first twenty four hours of the air campaign.[17] Within nine days from the commencement of the air campaign more than one hundred and twenty Iraqi combat aircraft attempted to fly to Iran to escape destruction. Many of these Iraqi aircraft however, crashed or were engaged by Allied fighters. With air superiority achieved, the Allies were then able to commence bombing of Iraqi divisions in Iraq and Kuwait, thus creating the necessary conditions to facilitate the lightning quick ground offensive.[18]

The need to gain air superiority is just as applicable to contemporary military operations. More recently, the achievement of air superiority in Kosovo appeared to be effortless, with little to no loss of life.[19] However, the wrong lessons must not be drawn from these conflicts and it is vital that military planners continue to develop appropriate systems to defeat a sophisticated integrated air defense system capable of denying air superiority to friendly air forces.[20] The astute JTFC in future military operations must

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[17]Richard Hanlon, *Storm over Iraq, Air Power in the Gulf War*, (Washington and London Smithsonian Institution Press) 1992, 166.

[18]The Gulf War, *Air War –Operation Desert Storm*, http://www.indepthinfo.com/iraq/airwar.shtml; Internet; accessed 1 March 2005.

[19]Gen. John P. Jumper, "Leveraging 'Lessons Learned' with Tactical Operations," Speech to National Security Forum, Maxwell Air Force Base, available from http://www.findarticles.com/p/articles/mi_m0PDU/is_2003_May_27/ai_107122937; Internet; accessed 18 February 2005.

[20]Major William K Lewis, "UCAV-The Next Generation Air-Superiority Fighter", (Masters' thesis, The School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, June 2002) http://www.au.af.mil/au/awc/awcgate/saas/lewis.pdf; Internet; accessed 12 December 2004, 2.

do what is necessary to achieve air superiority and the success of any future "major air, land, or sea operation may depend on the degree of air superiority achieved."[21]

The key element in the achievement of air superiority has historically been the manned fighter aircraft. In 1940, during the Battle of Britain, Winston Churchill immortalised the efforts of RAF fighter pilots in a speech to the British parliament when he referred to them as "the few."

> "The gratitude of every home in our Island, in our Empire, and indeed throughout the world, except in the abodes of the guilty, goes out to the British airmen who, undaunted by odds, unwearied in their constant challenge and mortal danger, are turning the tide of the World War by their prowess and by their devotion. Never in the field of human conflict was so much owed by so many to so few."[22]

Whilst technologies, in the form of 4th and 5th generation manned fighters, continue to dominate the race for air superiority, there have been many occasions when superior fighter aircraft, and in superior numbers, have been defeated by inferior opponents.[23] This situation was apparent during the Korean War when Colonel John Boyd of the United States Air Force, recognized that the inferior American Sabre fighter aircraft had achieved a 10:1 kill ratio against the seemingly superior MiG-15 aircraft.[24] Boyd had identified that the American pilots were able to make crucial

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[21]United States, Secretary of the Air Force, *US Air Force Doctrine Document 2.1.1,* (Headquarters Air Force Doctrine Center), I.

[22]Wikipedia, The Free Encyclopaedia, http://en.wikipedia.org/wiki/So_much_owed_by_so_many_to_so_few; Internet; accessed; 12 January 2005.

[23]Mick Spick, *The Ace Factor*, (Airlife Publishing, Shrewsbury, England) 1988, III.

[24]Simon Anglim, "Boyds Loops, Ace Factors and Fighter Combat", *Royal Air Force Air Power Review*, Vol. 2, No. 2, 1999, 67.

decisions quicker than their Korean counterparts and "he devised the concept of observe, orientate, decide and act as a generic model for military decision making known as the 'OODA loop'."[25] In making these observations, Boyd had recognized that inferior technology could overcome superior ones if the pilot of the inferior aircraft could run his OODA loop more efficiently than the pilot of the superior aircraft. Therefore, it is the pilot's ability to assess his situation rather than the technology afforded by his aircraft that would provide him with the ultimate advantage.[26] The ability to assess rapidly changing three-dimensional information is known as situational awareness or SA.[27] Whilst all fighting men must have the ability to rapidly assess a changing and dynamic situation, the "highly fluid nature of fighter combat places at a premium here, the absence of extraneous factors such as terrain and the relatively small number of participants making its impact both greater and easier to assess."[28]

In the manned fighter it is the pilot who makes the tactical decisions, in a three-dimensional environment, based on the observed and rapidly changing situation. Making these decisions is the "single most vital role of the fighter pilot."[29] The airman's greatest strength is therefore, his ability to process, analyse and digest the

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[25]Directorate of Air Staff Ministry of Defence, *AP3000 British Air Power Doctrine*, (Norwich: Her Majesty's Stationary Office, Third Edition, 1999), 2.4.1.

[26]Simon Anglim, "Boyds Loops, Ace Factors and Fighter Combat", *Royal Air Force Air Power Review*, Vol. 2, No. 2, 1999, 68.

[27]Mick Spick, *The Ace Factor*, (Airlife Publishing, Shrewsbury, England) 1988, VI.

[28]Simon Anglim, "Boyds Loops, Ace Factors and Fighter Combat", *Royal Air Force Air Power Review*, Vol. 2, No. 2, 1999, 69.

[29]*Ibid*., 63.

information in 3-D and makes decisive decisions in a matter of seconds.[30] At present it is only human beings that can provide "the flexibility to adapt to rapidly changing circumstances and the ability to exploit these changes."[31] The demanding challenge of gaining and maintain air superiority dictates that no two missions will ever be the same and only humans have the "range of innovate thinking and flexible thinking necessary to solve complicated and unexpected problems."[32] Whilst it has been demonstrated that the human element "remains the critical factor that leads to success in war and in the exploitation of technology" the human is not without weakness.[33] It is these weaknesses that, since the beginning of air power history, have provided the stimulus to develop the UAV.

The UAV does not have the physical weaknesses inherent in human beings. The human body is not designed to "take 6, 8 or 12 times the normal force of gravity and its responses to this assault, from impaired vision to loss of consciousness, can prove fatal if they occur in the air."[34] To increase a human's resistance to gravity (G),

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[30]Roger Green, and others, *Human Factors for Pilots*, (Aldershot, Ashgate, 1991), 35.

[31]Major Robert C. Nolan II, "The Pilotless Air Force? A Look at Replacing Human Operators With Advanced Technology," (Masters thesis, The Research Department, Air and Staff College, March 1997), available from http://www.fas.org/irp/program/collect/docs/97-0530.pdf; Internet; accessed 12 January 2005, 15.

[32]Dr. Ross Pigue and Carol McCann. "Re-conceptualizing Command and Control", *Canadian Military Journal*, Vol. 3, No.1, Spring 2002, 53.

[33]Alvin Toffler and Heidi Toffler, *War and Anti-War*, (New York, N.Y. Little, Brown and Company, 1993), 75.

[34]Warren E. Leary, "National Science Health, High-Tech Suits Help Pilots Avoid Gravity's Perils," 22 August 2000, available from http://dustbunny.physics.indiana.edu/%7Edzierba/hp221_2000/NYT/NYT6.html; Internet; accessed 12 March 2005.

additional survival equipment has to be added to fighter aircraft. However, "even with G suits to keep blood from pooling in the lower extremities, seated human beings lose consciousness if subject to maneuvres harder than –3G or +10G."[35] Removing the man from the cockpit and eliminating the need for pilot support systems would not only reduce the weight and size of the aircraft but, more importantly, allow the aircraft to be manoeuvred well beyond the current imposed limits.[36] Nevertheless any possible benefit gained by removing the man from the cockpit and allowing a UAV to manoeuvre well beyond that of a manned fighter must be assessed against the increased structural integrity requirements which would without doubt lead to an increase in a UAV's overall size, weight and cost.

Another major limitation of the manned fighter aircraft is the difficulty in predicting how the 'man' will react under stressful conditions during operations. It can be shown that "under certain conditions of high stress, thinking becomes more rigid, more stereotyped, more emotional and less rational."[37] This might explain why pilots react differently when faced with the same combat conditions. Combat stress might also have been a factor in the recent unfortunate Blue-on-Blue engagement of Canadian soldiers by an American F-16 pilot in Afghanistan in April 2002. The pilot, despite being denied permission by his mission controller, continued to engage friendly forces

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[35]David Bookstaber, "Unmanned Combat Aerial Vehicles – What Men do In Aircraft and Why Machines Can Do It Better," available from http://www.airpower.maxwell.af.mil/airchronicles/cc/ucav.pdf; Internet; accessed 12 January 2005.

[36]Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[37]Simon Anglim, "Boyds Loops, Ace Factors and Fighter Combat", *Royal Air Force Air Power Review*, Vol. 2, No. 2, 1999, 75.

resulting in the loss of four lives.[38] Another unfortunate incident where combat stress might have played a crucial factor "is the 1994 friendly forces' shoot down of two Blackhawk helicopters over Iraq during Operation Provide Comfort."[39] During this incident both pilots misidentified the helicopters as 'hostile' despite onboard and off-board sensors indicating that the helicopters were friendly. Whilst it can never be proven that 'combat stress' was the main reason for these unfortunate incidents, they do serve to highlight the weakness of human judgment under combat conditions, something that remotely piloted (without the fear of combat) or autonomous UAVs would not be as prone to.

Notwithstanding the potential for human errors in the cockpit there continues to be a growing demand by the public to minimize friendly casualties during military conflicts.[40] The sight of downed coalition aircrew that had been tortured by Iraqis on world television during the 1991 Gulf War had a negative impact on public relations and morale.[41] Consequently, the Kosovo campaign in 1999, coalition aircraft, despite having gained air superiority, operated above 15,000 feet to minimize the threat posed

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[38]Tobey Harden, "Four Canadians Killed by US Bomb," Daily Telegraph, http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2002/04/19/wcana19.xml; Internet; accessed 11 January 2005.

[39]United States General Accounting Office, Report to the Secretary of Defense, "Combat Identification Systems," available from http://www.gao.gov/new.items/d01632.pdf; Internet; accessed 12 January 2005.

[40]John A Tirpak, "UCAVs Move Toward Feasibility," *Journal of the Air Force Association*, Vol. 82, No. 3, March 1999, available from http://www.afa.org/magazine/march1999/0399ucavs.asp; Internet; accessed 12 January 2005.

[41]David Bookstaber, "Unmanned Combat Aerial Vehicles – What Men do In Aircraft and Why Machines Can Do It Better," available from http://www.airpower.maxwell.af.mil/airchronicles/cc/ucav.pdf; Internet; accessed 12 January 2005.

to NATO pilots by the Yugoslav air defence system.[42] The effect of losing a highly trained airman during combat operations cannot be understated. However, despite the growing public demand for a casualty free military operation, there is no system or UAV that is able to demonstrate the required level of mental agility and the ability to "anticipate an opponents actions when both combatants are moving simultaneously at several hundred miles an hour, and to recognise and seize opportunities for aggressive action, which may be fleeting indeed."[43] Until UAVs can demonstrate the ability to think and react like humans, there will always be a requirement for the fighter pilot in a manned aircraft, in the important role of gaining and maintaining air superiority.

The employment of unmanned machines for military purposes is not a new one. Since 1991 UAVs have established themselves as key enablers on the modern technology dominated battlefield.[44] Their increased use can be attributed to many factors such as lower cost, little risk of casualties and political acceptability. In contrast, the cost of the manned air superiority fighter has sky rocketed in the last decade. The enormous costs of fighter programmes in both the United States and in Europe have compelled governments to reduce the numbers of fighter aircraft ordered. The reduction in aircraft numbers is alarming, as evident in the F-22 Raptor

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[42]United Kingdom, Ministry of Defence, "Kosovo – Lessons Learned from the Crises," available from http://www.kosovo.mod.uk/lessons/contents.htm; Internet; accessed; 12 January 2005, Chapter 7.12.

[43]Simon Anglim, "Boyds Loops, Ace Factors and Fighter Combat", *Royal Air Force Air Power Review*, Vol. 2, No. 2, 1999, 64.

[44]Assembly of Western European Union, The Interparliamentary European Security and Defence Assembly, "Unmanned Combat Air Vehicles and Military Aeronautics of the Future," Document A/1884 30 November 2004, available from http://www.assembly-weu.org/en/documents/sessions_ordinaires/rpt/2004/1884.html; Internet; accessed 12 January 2005, 6.

programme; America's 21st century air superiority fighter. The initial aircraft order for the F-22 Raptor, was estimated at 750. However, faced with soaring unit costs, currently estimated at $187.3 million (USD) per unit, the Department of Defense has now reduced the order to a maximum of 295 aircraft.[45] It is therefore, not surprising then that Governments, faced with disproportionate unit costs for new manned fighters, have embraced the opportunity to acquire a relatively low cost alternative, the UAV.[46] In comparison, the United States X-45 SEAD/Strike UAV, due to fly in 2010, is expected to cost only $10-15 million (USD) per unit.[47] The cost benefits of the UAV therefore, appear to be extremely appealing on paper compared to that of commensurate manned air superiority fighters. However, the UAV cost per unit for the X-45 does not include the requirement for a ground support system. Comparatively, the system price, including a ground station and four air vehicles, for a United States Predator, "a medium-altitude, long-endurance UAV, roughly half the size of an Air Force F-16 fighter" is considerably higher at $30 million (USD) but has a limited operational capability.[48] Moreover, the growing cost of UAV Research and

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[45]Globalsecurity.org, "F-22 Raptor Cost," http://www.globalsecurity.org/military/systems/aircraft/f-22-cost.htm; Internet; accessed 12 January 2005.

[46]Assembly of Western European Union, The Interparliamentary European Security and Defence Assembly, "Unmanned Combat Air Vehicles and Military Aeronautics of the Future," Document A/1884 30 November 2004, available from http://www.assembly-weu.org/en/documents/sessions_ordinaires/rpt/2004/1884.html; Internet; accessed 12 January 2005, 7.

[47]Globalsecurity.org, "X-45UCAV," http://www.globalsecurity.org/military/systems/aircraft/x-45.htm; Internet; accessed 12 January 2005.

[48]UAV cost can either be defined by unit cost of an individual air vehicle, or by system cost. System cost could include one to six air vehicles, the sensor package, the ground control station, and various support equipment. United States Foreign Affairs, Defense and Trade Division, Report for Congress, "Unmanned Air Vehicles; Background Issues for Congress" 25 April 2003, available from http://www.fas.org/irp/crs/RL31872.pdf; Internet; accessed 15 January 2005, CRS 10,22.

Development (R&D) and increased unit and system prices has also raised questions on whether the UAV would remain an expendable asset. The United States high altitude reconnaissance UAV Global Hawk is a good example of a UAV that has potentially become "un-expendable" due to a unit cost of up to $73 million (USD).[49] If, due to cost, the UAV is no longer expendable, then there might also be future additional costs involved in re-equipping them to make them more survivable in a combat environment.[50] Without enhanced survivability, future UAVs might be inappropriate to fulfill the demanding and challenging air superiority role currently undertaken by manned fighters. Nevertheless, there is no doubt that future UAVs will have strong potential to deliver life cycle savings over the manned fighter; the magnitude of these savings should not however, be used in isolation to solely justify their requirement.

The lower cost of the UAV has been a major driving factor in their development and operational employment. Despite their increased utilization since the 1991 Gulf War, the use of UAVs in non-surveillance roles have been limited by technology.[51] Nonetheless, the technological challenges that previously confined UAVs to the passive surveillance and reconnaissance roles have now been overcome. According to the United States Defense Advanced Research Projects Agency (DARPA) there are

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[49]United States Foreign Affairs, Defense and Trade Division, Report for Congress, "Unmanned Air Vehicles; Background Issues for Congress", 25 April 2003, available from http://www.fas.org/irp/crs/RL31872.pdf; Internet; accessed 15 January 2005, CRS-35.

[50]*Ibid*., CRS-13.

[51]Major William K. Lewis, "UCAV-The Next Generation Air-Superiority Fighter", (Masters' thesis, The School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, June 2002) http://www.au.af.mil/au/awc/awcgate/saas/lewis.pdf; Internet accessed 12 December 2004, V.

currently "no technological miracles needed to make a U[C]AV work."[52] It envisaged that future UAVs would be manufactured using the latest composite materials and incorporate proven stealth technologies. The UAV will be "G force limited by structural engineering, [and] not the ability of the pilot's heart to provide his head with blood under the strain" therefore, greatly increasing its ability to perform defensive and offensive manoeuvres beyond that of manned fighters.[53] The combination of low observable technology and greater manoeuvrability would allow the UAV to remain undetected and employ its weapons first, thus vastly increasing its capability envelope.[54] Manoeuvrability and stealth are two keys elements of the manned air superiority fighter, and it is likely that in both cases the UAV would out perform the manned fighter. The key technological challenge is to provide onboard sensors that would allow the UAV to semi-automatically or automatically, detect and engage airborne threats. In practice, there should be no difference between the sensors on manned aircraft and the sensors on UAVs.[55] Without an onboard radar and Infra-Red Search and Track System (IRSTS) to provide a detection capability and self-protection sensors to enhance its survivability, the UAV would be totally unsuitable for the air

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[52]Lt Col. Anthony J. Lazarskie USAF, "Legal Implications of the Uninhibited Combat Air Vehicle," *Air and Space Power Chronicles*, 27 March 2001, available from, http://www.airpower.maxwell.af.mil/airchronicles/cc/lazarski.html; Internet; accessed 4 February 2005.

[53]Steven Shaker and Alan Wise, *War Without Men* (New York, N.Y., Pergamon-Brassey's), 1988, 4.

[54]Major William K. Lewis, "UCAV-The Next Generation Air-Superiority Fighter", (Masters' thesis, The School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, June 2002) http://www.au.af.mil/au/awc/awcgate/saas/lewis.pdf; Internet; accessed 12 December 2004, 21.

[55]United States Department of Defence, "UAV Roadmap 2002", available from, http://www.acq.osd.mil/usd/uav_roadmap.pdf; Internet; accessed 5 February 2005, 87.

superiority role.[56] Undoubtedly, current and future technologies will continue to enhance future generations of UAVs. However, the key to success is "whether someone can integrate these technologies into a reliable platform" and "that will take considerable effort."[57]

With available technology, the "benefits and promise offered by UAVs in surveillance, targeting and attack have captured the attention of senior military leaders", civilian officials and the public alike.[58] Not only can UAVs increase the possibility of success by leveraging stealth technology, the unit cost is also considerably lower compared to manned fighters. However, the foremost reason for the increased use of UAVs during the last decade could be attributed to its ability to be deployed at high altitudes, for long durations into heavily defended areas without risk to the pilot.[59] With zero risk of human casualties, there would be little public or political outcry when a UAV is shot down or crashes. During a six month period in Iraq and Afghanistan, a total of seven Predator UAVs were shot down with very little

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[56]Peter R. Worch, "UAV Technologies and Combat Operations," United States Scientific Advisory Board, available from http://www.fas.org/man/dod-101/sys/ac/docs/ucav96/chap5.pdf; Internet; accessed 12 March 2005, 5-2.

[57]John A Tirpak, "UCAVs Move Toward Feasibility," *Journal of the Air Force Association*, Vol. 82, No. 3, March 1999, available from http://www.afa.org/magazine/march1999/0399ucavs.asp; Internet; accessed 12 January 2005.

[58]United States, Defense Science Board Study, "Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles," available from http://www.acq.osd.mil/dsb/reports/uav.pdf; Internet; accessed 12 January 2005.

[59]Col (Sel) Bruce W. Carmichael and others, United States Air Force Research Paper, "Strikestar 2025,"August 1996, available from https://research.maxwell.af.mil/papers/ay1996/spacecast/vol3ch13.pdf; Internet; accessed 2 February 2005, 2.

media scrutiny or public criticism.[60] Additionally, without the need to recover the pilot from a downed UAV there is no need to conduct extremely challenging and expensive Combat Search and Rescue (CSAR) Missions thereby averting the risk of further casualties.[61] Whilst the UAV offers considerable cost savings over the manned fighter and they minimize the risk to life, the "current UAV accident rate (the rate at which the aircraft are lost or damaged) is 100 times that of manned aircraft."[62] Faced with a significantly increased accident rate compared to that of manned fighters and an increasing price tag, the UAV is at risk of becoming too expensive to lose and future military commanders might be reluctant to deploy them for dangerous missions; the very reason they were designed for.[63]

Although the UAV offers many potential advantages, there are also significant challenges must be overcome before it could adequately replace the manned fighter for the air superiority role. The most significant test for the UAV is "whether these vehicles can provide the same level of adaptive decision making and responsiveness to

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[60]Globalsecurity.org, *RQ-1 Predator MAE UAV*, http://www.globalsecurity.org/intell/systems/predator.htm; Internet; accessed 12 January 2005.

[61]Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[62]United States Foreign Affairs, Defense and Trade Division, Report for Congress, "Unmanned Air Vehicles; Background Issues for Congress," 25 April 2003, available from http://www.fas.org/irp/crs/RL31872.pdf; Internet; accessed 15 January 2005, I.

[63]*Ibid*., CRS-12.

mission changes that manned aircraft provide."[64] The ability for a machine to react in a human like manner is often referred to as Artificial Intelligence (AI).[65] AI is the vital ingredient for any future UAVs as it removes the need for streaming video and high-bandwidth communication requirements.[66] Without advanced levels of AI, the UAV would still have to rely heavily on communications with its ground system and ground/sea based human operators. The challenging task of developing a UAV with true AI cannot be underestimated. A pilot engaged in close visual combat is continually assessing the situation, cycling through OODA loops, to ensure that the aircraft is manoeuvred into an advantageous position vis-à-vis his enemy. The ability to replicate this level of adaptive decision-making in a UAV would continue to remain a towering technological feat. For instance, the X-45 Joint UAV, the most technology advanced UAV, will still not have onboard AI. However, the X-45 operator station will have AI, to assist the "the operator in the assessment of the battlefield situation and in his decision to authorise UAV weapons release".[67] Even with this it is unlikely that the remotely controlled UAV could achieve the same level of SA required to achieve

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[64]Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[65]Assembly of Western European Union, The Interparliamentary European Security and Defence Assembly, "Unmanned Combat Air Vehicles and Military Aeronautics of the Future", Document A/1884 30 November 2004, available from http://www.assembly-weu.org/en/documents/sessions_ordinaires/rpt/2004/1884.html; Internet; accessed 12 January 2005, 9.

[66]Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[67]Airforce-Technologies.com, "X-45 J-UCAV Joint Unmanned Combat Air System," *USA*, http://www.airforce-technology.com/projects/x-45-ucav/; Internet; accessed 12 January 2005.

air superiority as in manned fighters. The development of AI will require vast processing capabilities and the technological hurdles that must be overcome before the UAV possesses sufficient AI, to enable autonomous operations, might be some time away. Without onboard AI providing the UAV with a capability to make adaptive decisions, the UAV would be limited to a support role, with the manned fighter performing the more onerous task of maintaining air superiority. Nevertheless, even without AI, a second challenge for the UAV is to integrate them to work with existing manned platforms and adhere to Rules of Engagement (ROE).

The majority of current UAVs are operated in isolation to manned aircraft. Given the increased use of the UAV, it is vital that they are seamlessly integrated to complement manned aircraft on military operations and during peacetime training missions.[68] UAVs have already demonstrated safe navigation systems and reliable flight control systems, including automatic take-off and landings; however, at present it cannot provide "a collision avoidance capability equal to that of a human pilot."[69] The inability to take collision avoidance action might limit the UAV, in peacetime, to military or restricted airspace. As an example of the restrictions placed on UAVs, it currently takes between 60-90 days for UAVs to be granted flight permission in the United States National Air Space (NAS).[70] Whilst this might prevent some short-notice UAV operations in peacetime, the problem would be exacerbated during military

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[68]John A Tirpak, "UCAVs Move Toward Feasibility," *Journal of the Air Force Association*, Vol. 82, No. 3, March 1999, available from http://www.afa.org/magazine/march1999/0399ucavs.asp; Internet; accessed 12 January 2005.

[69]WorldSecurity-Index.com, "UAV Safety," http://www.worldsecurity-index.com/pressdet.php?id=608; Internet; accessed 18 March 2005.

[70]UAV National Industry Team (UNITE), Frequently Asked Questions, http://www.unite.aero/unite_custom/faq.html; Internet; accessed 18 March 2005.

operations as UAVs might be prevented from fully integrating with other manned strike aircraft. A recent report by the United States Defense Science Board recommended that it would be "absolutely critical that the DoD develop Detect, See and Avoid (DSA) requirement for all classes of UAVs that they intend to deploy in the NAS and International airspace . . . so as to permit safe flight of UAVs in mixed manned and unmanned formations."[71] Failure to fully integrate UAVs with manned fighters will seriously restrict the ability of the JTFC to employ airpower in a timely and efficient manner and could lead to additional restrictions being imposed on essential combat engagement orders (Rules of Engagement (ROE)).[72]

The use of force during military operations is currently regulated and governed by national directives issued as ROE. ROEs are issued to ensure that any application of force is appropriate to the area of operations, and are responsibly discharged by the military without causing unnecessary suffering and collateral damage. ROEs are not unique to air forces. Any failure to adhere to the ROE might lead to the increased possibility of friendly fire incidents (Blue-on-Blue) and unnecessary collateral damage. At present during air superiority missions, it is the pilot who has to ensure that his decisions remain within the published ROEs. Pilots are also fully aware that they will

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[71]United States, Defense Science Board Study, "Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles," available from http://www.acq.osd.mil/dsb/reports/uav.pdf; Internet; accessed 12 January 2005.

[72]ROE are "directives issued by competent military authority which delineate the circumstances and limitations under which United States forces initiate and/or continue combat engagement with other forces encountered" (JP 1-02). Effective operations require the establishment and promulgation of easily understood ROE. United States, Secretary of the Air Force, *US Air Force Doctrine Document 2.1.1,* (Headquarters Air Force Doctrine Center), 2.1.1.

be ultimately responsible for any decisions taken by them.[73] For UAV operations to take place alongside manned fighter aircraft, the possibility that the UAV could engage and shoot down a friendly air asset must be negated.[74] As AI, required to allow UAVs to autonomously engage targets independently has not yet arrived, there remains a requirement for weapon release to be confirmed and authorised via man-in-the-loop. If in the future AI technology does allow autonomous UAV operations and independent weapons release, there remains an unanswered question of who would be legally accountable if the UAV engaged a friendly asset or caused extensive collateral damage.[75] The command and control of UAVs will therefore be a great challenge. Without an effective command and control architecture, UAVs are unlikely to be authorised to employ deadly force, and thus would be ill suited for the air superiority role.[76]

A key requirement for effective command and control is the ability to communicate with UAVs whenever they are deployed on military operations around the world. At present UAVs are controlled by a variety of methods including UHF and satellite communications. For strategic UAVs however, the "only means of

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[73]Lt Col. Anthony J. Lazarskie USAF, "Legal Implications of the Uninhibited Combat Air Vehicle," *Air and Space Power Chronicles*, 27 March 2001, available from, http://www.airpower.maxwell.af.mil/airchronicles/cc/lazarski.html; Internet; accessed 4 February 2005.

[74]Cliff Lawson, "UCAVs May Find Niche in 21st Century," available from http://www.fas.org/man/dod-101/sys/ac/docs/980625-ucav.htm; Internet; accessed 12 January 2005.

[75]Lt Col. Anthony J. Lazarskie USAF, "Legal Implications of the Uninhibited Combat Air Vehicle," *Air and Space Power Chronicles*, 27 March 2001, available from, http://www.airpower.maxwell.af.mil/airchronicles/cc/lazarski.html; Internet; accessed 4 February 2005.

[76]Lt Col R. Clark USAF, "Uninhabited Combat Air Vehicles – Airpower By The People, For The People But Not With The People," College of Aerospace Doctrine, Research and Education, available from https://research.au.af.mil/papers/ay2000/cadre/clark.pdf; Internet; accessed 12 January 2005, 50.

communication is through satellite communications."[77] Therefore, given the potential for increased UAV employment in future military operations, a significant increase in communication bandwidth will be required.[78] The bandwidth required to support modern military operations is alarming and demand growth outstrips supply. For instance, the United States was "supporting one-tenth the number of forces deployed during Desert Storm with eight times the commercial SATCOM bandwidth."[79] If the satellite bandwidth is not available in theatre, there might be occasions when the JTFC is unable to employ UAVs without restrictions. Another significant challenge for the future employment of UAVs is the requirement for a robust communication system that is jam resistant.[80] Without a secure anti-jam communication system, the network might become corrupted and unusable. Any future UAV communication and control system must therefore be survivable and resilient to network attacks. The possibility of a UAV being jammed or controlled by a hostile third party could have potentially disastrous implications. Therefore, any system that is deployed must be extensively tested to ensure that UAVs can be operated without being restricted by bandwidth restrictions

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[77]Maj Ronald L. Banks, USAF, "The Integration of Unmanned Aerial Vehicles into the Function of Counterair," Research Report to Air Command and Staff College, available from, https://research.au.af.mil/papers/ay2000/acsc/00-021.pdf; Internet; accessed 12 January 2005, 19.

[78]Lt Col Kurt A. Klausner, UASF, "Command and

and robust enough against network attacks.[81] Whilst manned fighters and air traffic control systems are equally susceptible to being 'jammed' the effect is manifested in an increase of operator workload. However, if a UAV is 'jammed' it may lead to mission failure, and possible loss of the air vehicle, which might ultimately mean the loss of air superiority.[82]

In conclusion the requirement to gain and maintain air superiority will remain the first task of any prudent military commander. Whilst air superiority has never won any wars, it has undoubtedly set the conditions for other elements to achieve overall campaign objectives. Without air superiority, the ability to conduct military operations without interference from hostile forces would be severely restricted. During World War II the Germans failed to gain air superiority over south-east England and paid the ultimate price by being forced, due to the fear of failure, to cancel their planned invasion across the English Channel.

The manned fighter has historically fulfilled the task of gaining and maintaining air superiority. Whilst technology has often been the critical combat multiplier, there have been many occasions when pilots flying inferior machines defeated technologically superior aircraft. The decisive factor in many of these airborne engagements was the ability of the pilot to out-think his opponent. This ability for

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[81]Robert E Chapman, "Unmanned Combat Air Vehicles; Dawn of a New Age", Aerospace Power Journal Summer 2002; available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj02/sum02/chapman.html; Internet; accessed 4 February 2005.

[82]United States Department of Defence, "UAV Roadmap 2002", available from, http://www.acq.osd.mil/usd/uav_roadmap.pdf; Internet; accessed 5 February 2005, 163.

Situational Awareness (SA) has often bridged the technology gap and remains the dominant factor of the manned fighter in the air superiority role. Nevertheless human beings are not designed to operate under extreme G conditions and could potentially react in an unpredictable manner during times of combat stress. Despite these weaknesses, the pilot remains the only 'machine' capable of dynamic decision making. As such, the manned fighter remains the most reliable "weapon" in the difficult task of gaining and maintaining air superiority.

The use of UAVs in military operations is not a recent phenomenon. However, advances in technology have made UAVs indispensable in recent military conflicts such as the Gulf War and Kosovo. Another major reason for the increased use of UAVs is the political imperative for reduced casualties during conflicts. The UAV is often used by the JTFC in places were the risk of human casualties is high. Moreover, due to its low unit cost, the UAV is expendable. Nevertheless, as the UAV is employed in more challenging environments, its unit cost could be expected to rise as additional protective measures are retrofitted to enhance its survivability.

Despite these advantages the UAV has to overcome many more technological hurdles before it could truly replace the manned fighter in the air superiority mission. The key technological challenge is the incorporation of AI onboard the UAV to permit autonomous operations. Without AI, UAVs would have great difficulty in integrating with manned fighters and adhering to stipulated Rules of Engagement (ROE). The lack of AI could also limit the capability envelope of UAVs as they have to communicate with ground stations. This is a weak link in the UAV system. Not only must bandwidth be available, the link must also be jam resistant. These are critical

prerequisites before the UAV can truly replace the manned fighter in the air superiority role. There is no doubt that UAVs will continue to play a major and sometimes-vital role in future sophisticated military operations. However, despite their technological feasibility, low cost and political appeal, the UAV would not be capable of replacing manned fighter aircraft in the role of gaining and maintaining air superiority.

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