Rise of the Robots? Western Unmanned Air Operations in Iraq and Afghanistan, 2001 to 2010

By Squadron Leader Joe Doyle

This article examines how military, unmanned aerial vehicles (UAVs) have developed since the 9/11 attacks on the US and the ensuring Global War on Terror. Their evolution into an established technology, competing with manned platforms in the world's foremost air forces has led analysts and practitioners alike to question whether a broad revolution in the application of military air power has taken place

In fact, military UAVs did *not* show themselves to be genuine competitors to conventional manned aircraft between 2001 and 2010. Success in mission areas where UAV utility was most evident was enabled by a counterinsurgency-dominated strategic context combined with a permissive air environment. Significant technical and conceptual limitations endured throughout the period. The limited and context-specific extent of this UAV "revolution" should warn against the premature replacement of manned capabilities in Western force structures and doctrine.

This article is adapted from an MA Dissertation, supervised by Professor Philip Sabin and originally submitted to the War Studies Department of King's College London in July 2011.

Introduction

We have already made a 100-year war-fighting leap-ahead with MQ-1 Predator, MQ-9 Reaper, and Global Hawk… [they] have fundamentally changed the nature of warfare.

- General (Ret'd) Barry McCaffrey, United States Army, October 2007.[1]

…remotely piloted planes won't be as effective in future wars as they are in Iraq and Afghanistan.

- General Roger Brady, Commander USAFE, July 2010.[2]

This article questions the extent to which the military unmanned aerial vehicle (UAV), for several decades a *developing* technology of potentially huge significance, matured in the aftermath of the 9/11 attacks on the US into an *established* technology that might compete with or even replace its manned contemporaries.[3] This question lies within a broader theme; whether or not a recent "rise of the robots" has constituted a broad revolution in warfare that will fundamentally change the nature of military air power, and perhaps even the role of the human being as a direct and vulnerable participant in military conflict.

The contradictory comments by Generals McCaffrey and Brady above illustrate the active contemporary debate that surrounds the integration of unmanned aerial vehicles (UAVs) into Western military air power. In the main, this discussion has assumed a predictive timeframe of roughly twenty years hence. The authors of the UK's 2009 *Future Air and Space Operational Concept* claimed that, by 2030, 'unmanned platforms will predominate in hostile environments with a requirement for persistence in contested air space, or in homeland resilience tasks'.[4] Western governments have implemented policies that suggest a belief in the imminency and viability of this near-term process of replacement. In 2009, US Secretary of Defence Robert Gates recommended a $2 billion increase in intelligence, surveillance and reconnaissance (ISR) funding, the centrepiece of which would be enhanced UAV operational capabilities and development.[5] Also during that year, the USAF trained more unmanned than manned pilots, and the US Air National Guard 174th Fighter Wing replaced its F-16 aircraft with Reaper.[6] The UK Strategic Defence and Security Review of 2010 announced the removal of Harrier and some Tornado aircraft from service, radically reducing the size of the UK's manned combat air forces.[7] Shortly afterwards, the British Defence Secretary announced plans to double the UK's Reaper force at an increased cost of £135 million, an increase achieved by the purchase of an additional five airframes with which to equip the reformed XIII Sqn at RAF Waddington.[8] [9]

The extent to which such decisions have been founded upon a sound understanding of contemporary operational experiences is not clear. A mid-decade US Government report criticised the Department of Defense for not having 'implemented a systematic approach to evaluating joint [UAV] performance on operational deployments', thereby hampering an understanding of ongoing trends and enduring problems, and perhaps taking industrial proponents of game-changing technological developments too closely at their word.[10] Nevertheless, it seems that advocates of change dominate official attitudes and continue to influence the decisions that will mould future Western air force structures. Beyond political and military discourse, academic observers have also taken differing viewpoints. For example, P W Singer's declarations of 'robotic' revolution are offset by the more measured assessments of Dr David Jordan and Ben Wilkins, who acknowledge the increased relevance of UAVs in the early 21st Century, but who also emphasise the continuing limitations of the technology and its employment.[11]

This article seeks to place an assessment of the military employment and utility of UAVs within the correct operational and air power perspectives, presenting a view that is similar to the Jordan/Wilkins position described above while extending the argument to strongly emphasise the contextual, along with the inherent, limitations that affect contemporary unmanned air operations. Military UAVs did *not* show themselves to be genuine competitors to conventional manned aircraft between 2001 and 2010. Success in mission areas where UAV utility was most evident was enabled by a counterinsurgency-dominated strategic context combined with a permissive air environment. Significant technical and conceptual limitations endured throughout the period. The limited and context-specific extent of this UAV "revolution" should warn against the premature replacement of manned capabilities in Western force structures and doctrine.

Scope

This article opens with a brief consideration of the relationship between the prevailing counterinsurgency-dominated strategic context and contemporary UAV employment between 2001 and 2010. The article then explores in detail the weaknesses and limitations that were evident in unmanned operations of the period. Here, previously published comparative accident rates are reassessed with the benefit of updated statistics that span the entire decade. Some of the underlying technical issues are then discussed, and Global Hawk provides a short, sharp case study that questions the technical viability of existing programmes of replacement. Issues associated with the paradoxical *manned* nature of unmanned warfare are considered. Finally, this article outlines the breadth of additional problems that endured throughout the period, before presenting a concluding summary.

Definitions and Exclusions

This article primarily restricts its focus to military operations in Iraq and Afghanistan during the period 2001 to 2010. UAVs have a much longer history than this; however, details of unmanned operations in earlier conflicts are only referenced when necessary to establish a suitable context. The 2011 conflict in Libya is also referenced only by exception; although it transformed the strategic context for a short time, and has rekindled a planning focus on contingency operations with a light "boots on the ground" footprint, the Western commitment in Afghanistan continues to dominate US and UK military activity and will likely do so until declared withdrawals are complete in the middle of this decade.

The term 'UAV' is used throughout this article in preference to 'UAS', 'UCAV', 'RPA' and other associated terms, in part due to the established place of this earlier term in existing literature, especially in the US and its armed forces, and partly as a simple stylistic choice and a useful simplification of inconsistent terminology.

This article considers only contemporary USAF-defined 'medium' and 'large' UAVs in Western air force employment: the MQ-1 Predator, MQ-9 Reaper and RQ-4 Global Hawk.[12] These fixed-wing platforms are the most established unmanned types with some degree of equivalency to traditional manned counterparts, and are therefore most suited to an exploration of the viability of near-term replacement. The contribution of rotary-wing platforms such as the MQ-8 to more recent operations is not explored.[13] Small 'throwbots' or primarily army-fielded surveillance UAVs are also outside the scope of the discussion.[14] Novel types such as the Lockheed Martin RQ-170 Sentinel are excluded from this study due to the extremely limited availability of information and their uncertain involvement in pre-2010 operations.[15] The 2011 loss of an RQ-170 in an incident claimed as sabotage by Iran, who presented a supposedly captured aircraft to the world's media, is referenced but not explored in detail due to the limited availability of unclassified data concerning that incident. Parallel CIA activity in Afghanistan and Pakistan is not considered; this article focuses instead on the employment of UAVs by conventional military air forces. An exploration of CIA-run 'drone' operations in Pakistan can be found in Colonel Andrew Roe's article in the Summer 2012 edition of Air Power Review.[16] Flight Lieutenant Kenny Fuchter also focused on extra-military counter-terrorist operations in an article in the Autumn/Winter 2012 edition of the same periodical.[17]

This article is perhaps inevitably dominated by discussions of American experience, a result of the availability of statistics, relative scales of military effort and the status of the US as technological leaders in the field of UAV development. The UK's involvement during this period, as an operator of Predator and Reaper aircraft, is difficult to measure statistically due to a lack of available unclassified data. The Italian experience with Predator in Iraq is acknowledged and discussed briefly, with specific reference to problems of command and control. The experiences of other states that may be assumed to fall within the political West, notably Israel, are excluded.

UAVs and Counterinsurgency: A Good Fit

> *…the Iraq War … was actually the war that proved robots could be useful, which finally led them to be truly accepted… "This was the war where people said 'UAVs? Yes, give me more!'".*[18]

The post-9/11 Western military campaigns in Iraq and Afghanistan were fundamentally compatible with the limited capabilities of early 21st Century UAVs. The growth of unmanned participation in intelligence, surveillance and acquisition (ISA) and, to a lesser extent, attack missions was the result of context-specific mission requirements and in-theatre environmental realities. Specifically, the growing dominance of counterinsurgency tasks during extended conflict 'amongst the people', conducted within largely permissive airspace, suited the nascent capabilities of early 21st Century UAVs and also minimised the detrimental effects of defensive limitations.[19]

The primary and most attractive capability behind the increased desire among commanders for UAV employment was the novel 'persistent stare' capability enabled by long endurance. This capability '[mitigated] the negative air power characteristic of impermanence', and provided instead a form of 'virtual permanence' that gave the US and its allies 'the ability to deny the enemy a sanctuary both day and night'.[20] 'Persistent stare' coexisted alongside another new ability, the transmission of virtually real-time imagery directly into command headquarters and operations centres. This changed expectations among commanders, who 'no longer [wanted] pictures taken last week; they [wanted] streaming video with enough clarity and fidelity to anticipate the actions of the enemy'.[21] In effect, UAV video feeds offered a perceived solution to the enduring problem of the 'fog of war'.[22]

These novel capabilities proved to be a particularly "good fit" within an operational environment that emphasised ISA and precision attack missions. It was in these areas that unmanned platforms demonstrated their most significant absolute and relative growth. This generation of UAVs operated in an environment that was *not* dominated by high-end warfighting, which was truly evident only during the removal of Saddam Hussein's regime in Iraq in early 2003. There were no requirements beyond April 2003 to confront and destroy the military apparatus of an enemy state. Rather, 'low intensity conflict' tasks were required in support of ground forces, including 'providing overwatch [and] giving advanced warning of ambushes or obstacles along the route of a convoy'.[23] Close air support to troops in contact, frequently in populated areas, became a dominant feature of each campaign. Potential enemies and known high-value targets had to be carefully monitored and then if necessary precisely targeted. The precision of these strikes was important in the context of an increasingly casualty-intolerant counterinsurgency doctrine and international opinion.[24] The value contributed by 'persistent stare' and evolving targeting and precision strike capabilities was recognised in a mid-decade Jane's Defence study:

> It is in "Long War" related contingencies that [UAVs] have already most obviously demonstrated their value on the battlefield. [UAVs] have been immensely effective in providing tactical intelligence of terrorist and insurgent locations and movements and… have also performed strike missions against individuals and small groups.[25]

This beneficial compatibility between task and capability relied upon a key environmental enabling factor, and that was the permissive airspace environment that existed in both campaigns. Contemporary UAVs lack the means with which to avoid or defend against surface or air-to-air threats, due primarily to compromises in powerplant and payload that enable the long endurance so critical to 'persistent stare' and 'virtual permanence'.[26] General Philip Breedlove, the Vice Chief of Staff of the USAF, summarised this limitation in 2011:

> One has to remember that the current ISR fleet … is absolutely a permissive fleet… The Predator, the Reaper, the Global Hawk will not fly in contested [airspace] and will certainly not fly in denied airspace.[27]

This defensive inability was not critical in either Afghanistan or Iraq. While unguided and infra-red surface-to-air threats remained as fielded threats in each theatre, the most potent radar-guided and counter-air threats that might have prejudiced the effective employment of this generation of UAVs were absent during the extended COIN phases of each campaign. As a result, the defensive weaknesses of early 21st Century UAVs did not inhibit the synergy between unmanned capabilities and dominant counterinsurgency mission requirements. However, these permissive air environments were atypical and 'unusual in historical terms'.[28] The UK's *Future Character of Conflict* outlines an expectation that future battlespace, including the air environment, will be contested.[29] The utility of current generation UAVs in such an environment is likely to be compromised, as demonstrated by the US military's refusal to deploy Global Hawk into the Libyan theatre in early 2011 until integrated air defence systems, such as the long range SA-5, had been sufficiently degraded.[30]

The above-identified "good fit" was not exclusive. Afghanistan's complex terrain represents a challenge to the operation of even established aerospace technologies.[31] In addition, UAVs offered some contribution to missions beyond those most obviously associated with counterinsurgency operations. For example, a small number of Predators were briefly employed in the SEAD role in 2003 as decoys launched to tempt Iraqi air defence operators into engagements that would reveal the positions of their systems.[32] However, such missions represented only a minor and short-lived facet of the air power effort across the decade as a whole, and overall the "good fit" was clearly the dominant feature of the interaction between UAVs and operating environment. Any lessons inferred from a decade of unmanned air operations should therefore be understood as being of specific and quite narrow contextual provenance. Such lessons should be applied to processes of doctrinal and structural revision with an explicit awareness of this background, and without inappropriately broad assumptions of onward relevance.

Enduring Limitations

> *[Global Hawk] is not operationally effective for conducting near-continuous, persistent ISR as specified in the Air Force Concept of Employment.*

- Office of Director, Operational Test & Evaluation, May 2011.[33]

> *It is not the technology of the UCAV which presents the challenge, but its intellectual mastery.*

- AVM Professor Tony Mason, 2009.[34]

As outlined in the first section of this article, some UAV limitations were mitigated by the essentially favourable operational circumstances in Afghanistan and Iraq between 2001 and 2010. However, many key weaknesses and problems endured despite a permissive air environment and ISA-heavy operational requirements. Many of these have been explored in earlier studies, but it is useful to revisit some of this existing discussion with the benefit of drawing upon a full decade's worth of increasing UAV employment and operational experience. This article focuses on two main areas that question the near-term viability of UAVs as replacements for manned aircraft. The first of these explores the way in which implementation of novel technology remained a very significant challenge throughout the period. UAV accident rates fluctuated but remained high, with evident contributory problems of technological immaturity and poor reliability. A brief case study of Global Hawk offers a useful insight into the extent to which enduring technical issues question the true replacement potential of this generation of UAVs. The second area that is explored, echoing Professor Mason's statement above, is the paradoxically *manned* nature of UAV employment throughout the decade. UAV operations remained a very human affair in Afghanistan and Iraq, with ongoing uncertainties regarding command and control and the place of remote warriors in contemporary military ethos. Beyond these two specific themes, the sheer breadth and variety of the enduring limitations observed between 2001 and 2010 perhaps most undermines confidence in the viable near-term replacement of manned aircraft with unmanned equivalents.

Accident Rates

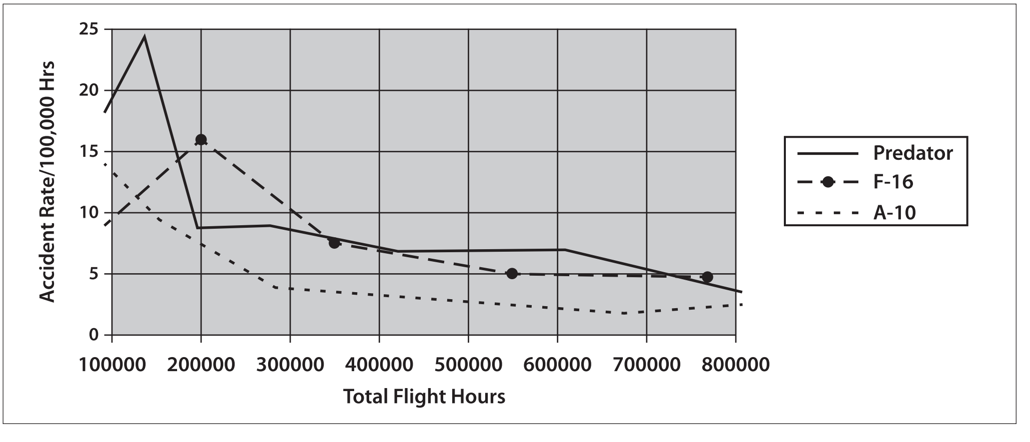
An early and enduring criticism of contemporary UAVs has been their high accident rates compared to manned aircraft. However, much of the established debate revolves around immature statistical data sets that show high loss rates among medium and large UAVs as they entered operational service. It is important to acknowledge the rapid pace with which UAV platforms and their operating procedures have developed, and now re-examine issues of accident rates and reliability with reference to more recent data.

The authors of the 2005 US Department of Defense *UAS Roadmap 2005-2030* compared the accident rates of early UAVs with the manned F-16 and U-2.[35] They concluded that, as of 2004, 'the mishap rates of the recent, larger [UAVs] track closely with that of the F-16 fleet at a comparable point in its career'.[36] The more recent USAF *UAS Flight Plan 2009 to 2047* also compared Predator and F-16 accident data, agreeing that UAV mishap rates were reducing but stressing that they remained absolutely higher than their manned equivalents.[37] *The Flight Plan* also referenced earlier reports that UAV reliability was a 'critical' factor, and stated that, as of the middle of the decade, inadequate resources had been expended in resolving 'root' reliability issues.[38] This analysis can now be extended by incorporating a greater number of manned and unmanned types and by expanding the period of analysis to the end of 2010. The results of such expanded analysis support the findings and emphasis of the *UAS Flight Plan* over those of the earlier *Road Map*. While year-on-year reduction trends in UAV accident rates remain comparable to those of a selection of manned jet aircraft at similar stages of their service history, the *absolute* accident rates that these trends represent remained intrinsically higher throughout the decade to 2010.

The expanded data adds the Reaper, Global Hawk, A-10 and F-22 to the sample of types that are compared, in addition to the earlier F-16, Predator and U-2 (the latter is considered here only briefly; relevant USAF records for this aircraft did not start until 1970, well into the U2's service history and so making meaningful equivalent comparison impossible). This data concentrates on the most meaningful measure of comparative accident rates, based upon annual accident rates plotted against accumulated flight hours, thereby continuing the methodology of the earlier *Road* Map and *Flight* Plan studies. Statistics are taken from official USAF accident data and refer to 'Class A' accidents, defined as those that cause 'a fatality or total permanent disability, loss of an aircraft, or property damage of $2 million or more'.[39] The data used in this section does not relate specifically to operations in Afghanistan and Iraq; clearly, the first ten years of service for many of these aircraft types predated 2001. While many of the UAV accidents in this period occurred during deployed operations, it is important to note that this data *excludes* combat losses.[40]

Comparative analysis up to the first 100,000 flight hour mark has already been published for Predator and F-16 in the *UAS Roadmap 2005-2030*.[41] The first set of data presented here extends this earlier study, modified to include the A-10 as a second manned type (which has proved much less accident-prone than the F-16, which has suffered by far the highest accident rate of any manned fighter/attack aircraft that remains within the active US inventory) and now incorporating statistics up to the end of 2010. By that date, the Predator had accumulated approximately 800,000 flight hours. A comparison of each of these aircraft between 100,000 hours and 800,000 hours service therefore gives a clear idea of annual accident rate trends as each aircraft type became increasingly established in service. The results are depicted in Figure 1.

Figure 1: Annual Accident Rate Trends 100,000 to 800,000 Hours: Predator, F-16 and A-10

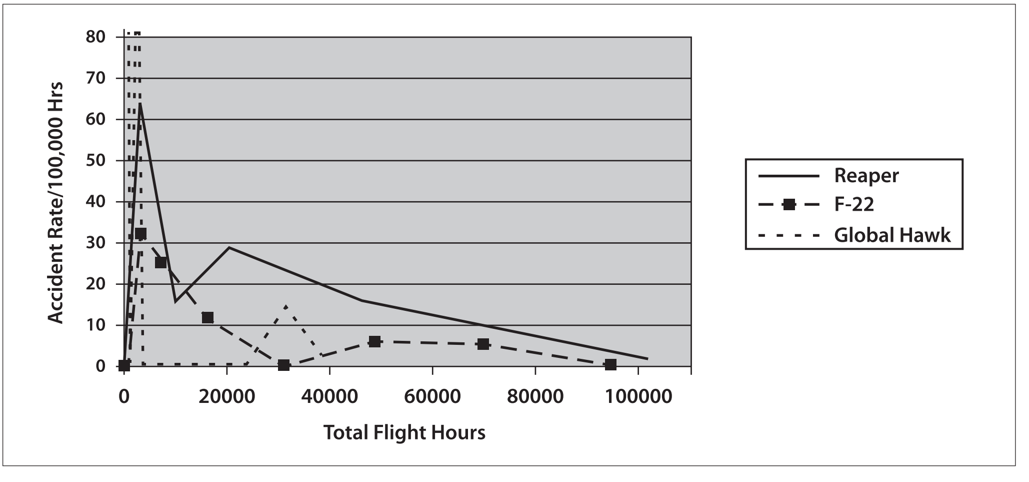


Source: USAF Air Force Safety Centre

This extension of scope essentially supports the findings of the earlier studies. The Predator accident rate continued to show a broadly similar reducing trend to each of the manned types. In fact, the reduction is of greater overall magnitude, having started from a position far higher than either of the manned types. This is noteworthy, as it suggests that UAV accident rates may indeed become comparable to those of manned aircraft as they mature in service. However, it would be easy to overstate the significance of this observation. The graph shows that *absolute* Predator accident rates remained higher than those of F-16 for most of the period overall, and they were significantly higher than the A-10 throughout. Again, the averaged accident rate taken across the entire period supports this, with Predator returning a mean rate of 7.4 accidents per 100,000 hours compared with 6.9 for F-16 and a much lower 3.6 for the A-10. The mean rates for the entire first 800,000 hour period (including the initial 100,000 hours analysed by the earlier *Road Map* study) were 9.3 for Predator, 8.1 for F-16 and 4.4 for the A-10.

It is also possible to now run a similar comparison involving more modern manned and unmanned aircraft types. An initial comparison between Reaper and F-22 is straightforward. The data shows that each aircraft had accumulated approximately 100,000 flight hours by 2010. The speed at which accident rates reduced is depicted graphically in Figure 2 below, with Global Hawk's lifetime total to the end of 2010 (approximately 40,000 flight hours) added for further comparison.

Figure 2: Annual Accident Rate Trends Over First 100,000 Hours: Reaper, F-22 and Global Hawk



Source: USAF Air Force Safety Centre

The erratic "spikes" on the far left hand side of the graph in Figure 2 show the effect of even a very small number of accidents on the apparent trends of aircraft with very low annual flight hour totals. Early criticism of high UAV accident rates may have been influenced by such "spikes". The longer term data is more representative of how accident rate trends settled as aircraft became established, and again these results, here for cutting edge platforms, effectively corroborate the findings of the *Road Map* and *Flight Plan* studies that compared the Predator, F-16 and U-2 over the same equivalent period of their service history. The Reaper exhibited a broadly comparable trend of accident rate reduction to that of F-22 over its first 100,000 flight hours. However, and as with Predator versus F-16 and A-10, Reaper tracked along a line that represented consistently higher *absolute* accident rates, reflected in total accident numbers of 11 during the first 100,000 flight hours compared to 6 for F-22. Thus Reaper remained significantly more likely to suffer Class A accidents than F-22, even as the average accident rates of both types reduced.

Reliability and Design: The *Why* Behind High Accident Rates

Accidents, of course, have causes. Summary causes of mishaps can be found in the results of official UAV accident investigations during the period, of which the USAF published fifty-two between 2001 and mid-2011.[42] Of these, at least thirty-four occurred in Afghanistan and Iraq. In thirty-three of the accidents malfunction or physical failure was identified as the primary cause of the accident. In seventeen cases human error was to blame. On two occasions the cause was attributed clearly to maintenance error.

To first consider the most prevalent group of causes, the thirty-three cases of malfunction and component failure revealed some of the design and operating limitations of this generation of UAVs. These included significant problems with engines and flight control systems and these persisted throughout the period. A September 2010 report into the crash of a Predator that suffered engine failure in Afghanistan noted that a decrease in vital engine oil levels 'frequently occurs in [Predators] due to the design of the oil system'.[43] Moreover, unmanned aircraft were susceptible to physical malfunctions caused by environmental conditions, with several crashes attributed to icing or flight in cloud. Susceptibility to such environmental influences did not have to result in aircraft loss to compromise mission effectiveness. Areas of poor weather that might have been penetrated by manned aircraft would limit the possible operating areas of a UAV, or even necessitate it to abort its mission, during operations in Afghanistan and Iraq.[44] Some of these issues were addressed by manufacturers and operators as the decade progressed. For example, modified systems added to later variants of Predator included 'weeping wing' chemical anti-icing technology, although in a further indication of limitation-driven compromise, this was often removed on operations to allow the carriage of more fuel or weapons.[45] Overall, however, general and airframe-specific problems of design and reliability continued to be evident in accident reports right up until 2010.

Human error, identified in seventeen of the accident reports as the primary cause, was frequently evident as basic errors in handling skills or airmanship that might as easily have occurred among crews of manned aircraft. However, a significant number of accidents were caused or exacerbated by design issues with the ergonomically-poor ground control stations from which the crews remotely operated the unmanned aircraft. One mid-decade accident occurred when a Predator pilot inadvertently shut down the engine instead of raising the gear, a result of a control system where the switches for both functions were virtually collocated and easily confused.[46] Still other accidents were attributed to poor situational awareness caused by a limited sensor field of view and a lack of perceptual cues when "flying", including losses incurred when attempting to land. These problems were acknowledged by the USAF to represent 'an inherent design flaw'.[47] Such issues present a significant challenge to future UAV operations, as the restoration or replication of such visual and tactile cues will require more advanced solutions than the relatively easy modification of switch positions within a ground-based "cockpit".[48] The evidence of unmanned operational performance over the past decade in these areas of design and reliability demonstrates the size of the task facing UAV developers if they are to meet some of the bolder forecasts regarding the extent to which their creations might replace traditional manned aircraft.

At the Technological Edge: Datalink Reliability and Security

The phrase 'lost link' is commonly encountered within accident report summaries and Predator operator testimony. Failure of these datalink systems, loss of signal and a subsequent inability to control the aircraft, was the primary cause of at least three of the investigated accidents, and was a contributory factor in several more. For example, the investigation into a Predator crash in Afghanistan in December 2003 while supporting Operation Enduring Freedom found that the datalink could not function at extreme aircraft attitudes, encountered in this instance during an attempted recovery from a stall.[49] Another Predator crashed in Afghanistan in January 2005 following a system freeze at its remote ground control station, and the subsequent loss of all satellite communications with the aircraft. Despite flying the 'lost link' profile for more than 12 hours, control could not be restored and the UAV was lost.[50] A failed datalink also brought about the demise of a Reaper that had to be shot down over Afghanistan in 2009 by a USAF F-15. Even a simple power surge at a ground control station would invariably mean a temporary loss of control of the associated UAVs.[51] Such fragility undermines forecasts that UAVs might undertake dynamic missions such as offensive counter-air and air defence, even in the mid-term.

It was not only the serviceability of UAV datalinks that appeared uncertain between 2001 and 2010. The possibility that UAV links may be jammed or severed, or that critical operating systems and networks may be compromised, was and remains a continuing concern.[52] AVM Professor Tony Mason pointed out in a recent RAF study that: 'any system which depends on electronic control is vulnerable to electronic disruption'.[53] General concerns of cyberattack seem increasingly well founded. In 2010 the Stuxnet virus attacked specific technologies that were largely associated with the Iranian nuclear programme.[54] Threats of this nature were referenced by US Deputy Secretary of Defence William Lynn in a cautionary 2010 debate on cyber warfare.[55] Specific questions of UAV datalink security, and of the information that is transmitted by them, were raised in response to one particular, and spectacular, occurrence in 2009. A US raid on Shiite militia in Iraq found evidence that the insurgents had been hacking into the real-time video feeds transmitted by Predator aircraft.[56] This imagery was transmitted via unencrypted signals, and the insurgents were able to tap into the video using simple, cheap commercial software. The US military subsequently admitted that this had been a known weakness since the 1990s, but it had been 'assumed [that] local adversaries wouldn't know how to exploit it'.[57] Finally, although this article deliberately avoids detailed discussion of the supposed Iranian downing of a RQ-170 in 2011 due to the ambiguous unclassified information that concerns that event, the very possibility that the aircraft was lost as a result of either failure or adversary "hacking" does little to inspire confidence in how robust these systems have become. These persistent uncertainties, associated with the reliability and security of the control technologies that are vital to UAV operations, question the assumption that near-term unmanned platforms might undertake missions truly critical to national defence. Significant advances will be required from the aerospace industry in this area, and it should be noted that the same industry has struggled to deliver the next generation of *manned* combat aircraft, the F-35, on time, under budget, and with all promised capabilities.[58]

Global Hawk and U-2: A Short Case Study in Replacement

> *Technology must deliver, not merely promise to deliver, the same level of competence in [UAVs] that we have learned to [expect] in manned aircraft.*[59]

This question of the ability of the aerospace industry to deliver on capability promises can be explored with a brief consideration of Global Hawk as a specific and recent case study. Global Hawk has long been viewed as a replacement for, rather than merely a complement to, the U-2, and it was active in both Afghanistan and Iraq during the decade 2001 to 2010.[60] As of 2006, the capabilities of the two types were still not analogous, with the Global Hawk's strengths in range and endurance being offset by the U-2's better sensor suite and payload/power advantage.[61] The early Block 10 Global Hawk was subsequently criticised for low reliability rates in 2007, questioning the ability of the manufacturer, Northrop Grumman, to resolve myriad persistent technical issues.[62] As a result, by 2009 the Air Force had accepted a revised, delayed timeline for the planned process of replacement of the U-2, based on the need for further development to ensure that Global Hawk would more satisfactorily replace the U-2's capabilities.[63] The next 'Operational Test and Evaluation Report', carried out for the successor model of Global Hawk, the Block 30, was conducted between October and December 2010. It concluded that 'the RQ-4B Global Hawk Block 30 is not operationally suitable'.[64] The report cited 'frequent failures of mission-critical air vehicle components' as key factors that 'reduce takeoff reliability and increase mission abort rates'.[65] These failures were further exacerbated by shortages of critical spare parts, another criticism of the manufacturer's ability to deliver on promised capability. Global Hawk was also identified as being incompetent as a signals intelligence platform due to 'technical performance deficiencies and immature training, tactics, techniques, and procedures'.[66] In all, the Global Hawk could 'produce only 42 percent of the tasked ISR coverage time due to poor takeoff reliability, maintenance ground aborts, and high air abort rates'.[67] The somewhat meek USAF response to this report could only claim that Global Hawk aircraft had performed 'quite well' since August 2009.[68] This brief example clearly questions the suitability of even recently updated UAVs as replacements for manned aircraft, even when considering an example of a clear and intended programme of specific type-with-type replacement.

The Manned Aspects of Unmanned Air Warfare

> *It bears noting that Predator and Global Hawk are not unpiloted; their pilots are simply not aboard the aircraft.*[69]

The reference in the Global Hawk evaluation report to 'immature training, tactics, techniques, and procedures' reveals another important consideration that was highlighted by the experience of unmanned air operations between 2001 and 2010. The technological aura surrounding UAVs threatens to obscure the enduring *human* role in supposedly unmanned warfare. This is not in itself an especially novel observation. Nor is it linked only to UAVs, for an excessive focus on technology has long been an accusation aimed at Western warfare in general.[70] However, this is an important theme, and it has enormous relevance for ideas of the unmanned "replacement" of traditional air power. This article does not discuss hypothetical scenarios comparing "man in the loop" systems with developments in autonomy.[71] A consideration of the ethical issues surrounding such developments can be found in Wing Commander Nick Tucker-Lowe's article in the Autumn/Winter 2012 edition of Air Power Review.[72] Rather, the focus will remain upon on trends that could be observed in operations in Afghanistan and Iraq between 2001 and 2010, and two trends in particular were evidently problematic during that period. The first of these was the troubled integration of UAV capabilities into existing concepts and procedures of command and control. The second was the uncertain place of remote combatants within contemporary military organisations and ethos. In each case, the employment of UAVs either failed to overcome essential and enduring problems, or raised new issues that military organisations and their personnel were required to face.

To first address issues of command and control, the 'persistent stare' and associated real-time imagery that contemporary UAVs provided created a tendency towards a "long screwdriver" interference by commanders as far back as Operation Allied Force in 1999, and that tendency would become more apparent as UAV use increased after 2001.[73] P W Singer has labelled this phenomenon the 'Tactical General', in an apparent nod to the contrasting idea of the 'Strategic Corporal' previously suggested by Marine Corps General Charles Krulak.[74] Singer offers several illuminating anecdotes in support of this concept. During the initial stages of Operation Iraqi Freedom, General Tommy Franks was reported to frequently command UAV operators directly, effectively removing every mid- and low-level commander positioned in the chain between himself and the UAV crews, in contradiction to extant doctrine that promoted principles of delegated mission command.[75] One soldier described how his patrol in Afghanistan was interrupted so that a distant commander could discipline soldiers for untucking their shirts and removing their headwear, uniform violations that had been observed via a Predator video feed.[76] More significantly, the distant involvement of too many officers could lead to operational paralysis and conflicting tasking orders, demonstrating how the 'persistent stare' capability that was so beloved of contemporary commanders could in fact represent a drawback rather than a key advantage.[77]

Such command and control issues, in particular the paralysing impact of contradictory tasking imperatives, were also evident in the experiences of the small Italian Predator force that operated in Iraq from 2005. Problems included poor communications between the commanders of the air component and the overall joint task force, and competing pressures to fulfil both strategic and tactical tasking.[78] On occasion, direct approval from the Defence Chief of Staff in Rome was required to approve the transfer of Predator assets from tactical national missions to international strategic tasks.[79] Moreover, a lack of familiarity with the limitations of contemporary UAVs, notably in terms of the air power characteristics of speed and reach, led to inappropriate and wasted efforts to 'scramble' Predator aircraft in support of ground forces.[80] These experiences were in many ways an exaggeration of American problems, exacerbated by the complete novelty of UAV operations for Italian forces. Nonetheless, they further demonstrated the difficulties of integrating remote unmanned technologies, with real-time command visibility of tactical output, into the operating concepts and organisations of established air forces. These significant difficulties were prevalent even within a favourable context, in which UAVs represented participated in only a narrow range of missions, much less across the broad spectrum of military air power activities.

It was not only air power structures that struggled to incorporate novel and remotely operated unmanned aircraft. The integration into existing "manned" ethos of unmanned warfare, and the novelty of pilots and crews who continued to fight and kill while exposed to no virtually no risk to themselves, proved to be contentious and ambiguous as UAV operations expanded. Removing the human "weak link" may resolve problems such as air power's relative impermanence, but it is the man, and not the machine, that remains the vital element when considering the less tangible aspects of warfighting. This, again, is not an especially novel observation. Air Commodore Neville Parton asked in the introduction to a 2009 Royal Air Force study: 'Will the UAV operators be perceived as heroic by the troops they support on the ground, or dissociated technicians with no real understanding of the nature of warfare?'[81] However, one specific example serves this article's argument by casting still further doubt on the imminent readiness of Western air forces, and militaries in general, to undergo a significant process of "replacement" by which the man is first made truly remote, and is then potentially removed altogether, from air warfare.

Brigadier James Bashall commanded 1 Mechanised Brigade during the withdrawal of British troops from Basra city in 2007. While recounting his experiences at a Royal Air Force-sponsored conference in September 2010, he emphasised the critical importance of face-to-face involvement with British fast jet aircrew for both mutual operational understanding and unit morale, in effect allowing his men to put faces to what would otherwise be remote voices offering air support via radio.[82] In this, Brigadier Bashall suggested the intrinsic human nature of conflict, and the importance of bridging the traditional divide between those who operate on the ground and those who operate in the air, frequently from a distant location. Brigadier Bashall's anecdote hinted at an important interpersonal aspect of air-land cooperation, and one that was difficult to conduct even within the manned-aircraft dominated conflict in Iraq. Such interaction will surely be even more difficult in an era in which air power might be delivered primarily by remotely involved crews who remain in distant homeland locations. While this anecdote represents only a single example from the campaigns fought in Afghanistan and Iraq over the past decade, it demonstrates the continuing reliance of military forces upon camaraderie and reciprocal confidence that is enhanced by simple human proximity and personal interaction.[83] The consequences of removing these, upon operational understanding and raw fighting spirit, are unknown. Such enduringly human issues as those discussed above do not necessarily preclude a "rise of the robots" that replaces manned aircraft with unmanned equivalents. They do, however, demand that any such process be based on well-founded understanding that is based on experience, rather than a superficial appreciation of complex issues that is based on hypothetical forecasts, or hope.

Niche Capabilities, Full-Spectrum Problems

Each of the technical and conceptual themes explored above represented a significant issue for UAV operations in Afghanistan and Iraq between 2001 and 2010. However, it is potentially the *breadth* of these issues, each apparent even within a context that was essentially favourable for UAV operations, that ought to give the greatest pause for thought. A rapid summary of some of the most significant additional limitations and areas of ambiguity that have not been discussed above gives an appreciation of their sheer quantity. Cost, long assumed to be a favourable aspect of removing men and support systems from aircraft, became an increasing issue as the decade progressed. The 2005 *UAS Roadmap* found that the per-pound payload costs of contemporary UAVs were higher than those anticipated for F-35, and by 2008 a sensor-laden Reaper was estimated to cost $18 million.[84] Increased data collection enabled by unmanned air operations created problems with both bandwidth and subsequent information exploitation.[85] In Afghanistan and its sister-theatre of border Pakistan, UAV activity was reliant on intelligence "cueing" derived from very human sources, and indeed at considerable human cost, as apparent in a revenge attack by a Taliban bomber against CIA operatives in Afghanistan in December 2009.[86]

Some studies have suggested that the increased distance from which war may now be waged increases the ease with which decisions to apply deadly force may be reached.[87] The negative implications of inflicting civilian casualties during the conduct of counterinsurgency operations have been made explicit within the guidance issued to Western forces in recent years, and example from Uruzgan Province in Afghanistan in 2009 revealed a serious number of failures in the judgement of unmanned operators.[88] While such failures are an ever-present risk for any participant in warfare, the official report of this incident highlighted specific failures in Predator operating and training procedures.[89] This article has not considered potential legal issues with the application of the Laws of Armed Conflict to remotely involved personnel of ambiguous combatant status, but the surrounding debate is detailed and many issues remain unresolved.[90]

Several reports have highlighted issues of fatigue and stress among UAV crews that were rooted in unrelenting operational tempo, disassociation from theatres of operations, and the mental challenges of remaining collocated with family while fighting a war of remotely inflicted violence.[91] Issues of training, tour length and career progression led to problems with morale, with the commander of the USAF Predator wing, in this case a former F-16 pilot, likening the completion of a UAV tour of duty to being 'a prisoner with a life sentence'.[92] The 2009 *UAS Flight Plan* recommended as a result that the USAF must 'assess and adjust [UAV] pilot development paths, to include incentive pay and career incentive pay issues' in order to guarantee future force efficiency and retain experienced personnel.[93] The *Flight Plan* further lamented personnel management problems that had been created by 'decisions that frequently are fragmented, reflect legacy culture, and limit innovation'.[94] Finally, domestic training activity remained, and remains, limited by problems that prevent the integration of UAVs into civilian airspace.[95] The sheer quantity of these limitations, all persistent as the decade progressed, is perhaps the most damning indictment of any proposal that unmanned aircraft stand ready to supplant, rather than supplement, their manned equivalents within Western air forces.

Conclusion: Replacements, or Pretenders to the Throne?

> *Robots in Iraq and Afghanistan today are sketching out the contours of what bodes to be a historic revolution in warfare… a process that will be of historic importance to the story of humanity itself.*
>
> - P W Singer, Wired for War, 2009.[96]

> *The more certain that people are of what the future holds, the more worried and critical a response they should receive.*
>
> - Professor Philip Sabin, 2010.[97]

Prior to the UK Strategic Defence and Security Review of 2010, British General Sir David Richards suggested that fleets of UAVs operating alongside light attack aircraft would represent reduced but acceptable capabilities with which to replace modern fast jets.[98] These remarks seemed to reflect an expectation of the enduring nature of recent conflict, that counterinsurgency and similarly waged 'wars amongst the people' would dominate the coming strategic landscape. However, General Richards did not acknowledge the favourable relationship between capability and context that defined unmanned air operations over the preceding decade, nor the limitations that had clearly endured. Moreover, many observers have increasingly stated, and indeed experience has shown, that future conflict may not resemble the COIN-dominated campaigns in Afghanistan or Iraq.[99] The successful air campaign over Libya in 2011 did not validate the type of capabilities mix that General Richards forecast and recommended.

The stated aim of this article was to contribute to existing debate by establishing a context-aware understanding of early 21st Century UAV operations. This article has shown that the most significant advances, made within the specific missions of ISA and, to a lesser extent, attack, were enabled by a favourable context that matched capabilities to requirements within a permissive environment. Individual problems and limitations endured, including intrinsically higher unmanned accident rates, myriad technical difficulties, industrial inability to deliver on capability promises, and conceptual issues that included the potential loss of critical "manned" aspects of joint warfighting processes and ethos. Ultimately, all of these factors combined to present at best a picture of a one-dimensional and imperfect "revolution" and, at worst, a poorly misunderstood phenomenon that threatens the West's established advantage in combat air power if it encourages premature and far-reaching force restructuring and doctrinal shifts.

Air power matters. It represents a key aspect of the West's defence against a variety of potential threats. It is therefore important that the strength of Western air forces should be at least preserved or, better, enhanced. To unquestioningly accept views that imply too wide a relevance to the counterinsurgency-bounded achievements of UAVs during the past decade would risk contributing to the creation of 'a bespoke counter-insurgency force with niche capabilities [that] won't provide policy-makers or political decision takers with a flexible military lever of power for the mid- to long-term', a warning issued by Air Chief Marshall Sir Steven Dalton in a statement prior to the 2010 Strategic Defence and Security Review.[100] The history of air power is full of sweeping, technology-induced and promise-led change. However, in order that the current debate is concluded with a beneficial outcome, it is crucial that the pace of change should be appropriate, and based upon observed, and not merely promised, development. It is right to innovate and to stretch for capability advantages. But it would be easy to overreach, and to change too much, and too soon, before capabilities are demonstrably worthy of confident adoption. There is a significant disconnect between what industry-promised future platforms *might* do, and what early generation UAVs *can* do, even within an essentially favourable context. As we move further into the second decade of an uncertain 21st Century, it is far from clear that the replacement of the manned aircraft should be close at hand.

Notes

1 General Barry R McCaffrey (Retd), *Memorandum for Colonel Mike Meese* (United States Military Academy, 2007), 5.

2 Air Force Times, "USAFE Chief: Don't Rely on UAVs", http://www.airforcetimes.com/news/2010/07/airforce_UAVs_073010/ [accessed 20 March 2011].

3 Sabin in Owen Barnes, ed., *Air Power: UAVs: The Wider Context* (Royal Air Force Directorate of Defence Studies, 2009), 108-109.

4 Defence Concepts and Doctrine Centre, *Future Air and Space Operational Concept 2009* (Ministry of Defence, 2009), 2-10.

5 US Department of Defense, "Secretary Gates Remarks at Maxwell-Gunter Air Force Base, Montgomery, Alabama, 21 April 2008", http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4214 [accessed 2 March 2011].

[6] Speednews, "Is the US Military in the Twilight Years of Manned, Fixed-Wing Procurement?", http://www.speednews.com/CMS.aspx?pn=Wayne_Plucker&pid=3210&psec=GUEST [accessed 25 February 2011]; 174th Fighter Wing, ANG, "'Conversion' Photographs and Captions", http://www.174fw.ang.af.mil/photos/mediagallery.asp?galleryID=6661 [accessed 20 February 2011].
[7] HM Government, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review* (HM Government, 2010), 26.
[8] BBC, "RAF Reaper Drones to be Remotely Controlled from UK", http://www.bbc.co.uk/news/uk-13392373 [accessed 14 May 2011].
[9] The Guardian, "UK to Double Number of Drones in Afghanistan", http://www.guardian.co.uk/world/2012/oct/22/uk-double-drones-afghanistan [accessed 6 Nov 2012].
[10] US Government Accountability Office (GAO), *Unmanned Aircraft Systems: DoD Needs to More Effectively Promote Interoperability and Improve Performance Assessments* (US GAO, 2005), 18.
[11] P.W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (London: Penguin, 2009), 430-431; Jordan and Wilkins in Barnes, ed., *Air Power: UAVs*, 42.
[12] United States Air Force, *Unmanned Aircraft Systems Flight Plan 2009-2047* (Headquarters USAF, 2009), 38-40.
[13] Navy Times, "Fire Scout UAVs Bound for Afghanistan", http://www.navytimes.com/news/2011/04/defense-fire-scout-uavs-bound-for-afghanistan-042111/ [accessed 4 May 2011].
[14] Singer, *Wired for War*, 364.
[15] Small Wars Journal, "Bin Laden Mission Signals the End for the Predator Drone", http://smallwarsjournal.com/blog/2011/05/bin-laden-mission-signals-the/ [accessed 4 June 2011].
[16] Lieutenant Colonel Andrew Roe, " 'Bugsplat' and Fallible Humans: the Hi-Tech U.S. Drone Campaign over North-West Pakistan", Air Power Review 15 no. 2 (2012): 65-82.
[17] Flight Lieutenant Kenny Fuchter, "The First Drone War: Air Power for Strategic Effect", *Air Power Review* 15 no. 3 (2012): 17-34.
[18] Singer, *Wired for War*, 216-217.
[19] Rupert Smith, *The Utility of Force* (London: Penguin, 2006).
[20] Barnes, ed., *Air Power: UAVs*, 2; Jordan in David Jordan and James Kiras, eds., *Understanding Modern Warfare* (Cambridge, 2008), 212; Benjamin Lambeth, *Air Power Against Terror: America's Conduct of Operation Enduring Freedom* (RAND, 2005), xxx.
[21] USA Today, "Insurgents Benefit from Drone Shortage", http://www.usatoday.com/news/world/iraq/2008-03-24-UAV_N.htm [accessed 10 February 2011].
[22] Singer, *Wired for War*, 185; Carl von Clausewitz, *On War* (Oxford, 2007), 64.
[23] Jordan and Wilkins in Barnes, ed., *Air Power: UAVs*, 41.
[24] Human Rights Watch, *"Troops in Contact": Airstrikes and Civilian Deaths in Afghanistan* (Human Rights Watch, 2008), 2-7; Headquarters, Department of the Army (2006), *FM 3-24: Counterinsurgency* (US Army, 2006), E-1.
[25] Tate Nurkin and Seth Drewry, *UAS: Unmanned, Unbound: Exploring Future Operational Concepts for Unmanned Aerial Systems* (Jane's Strategic Advisory Services, 2006), 30.
[26] Sabin in Barnes, ed., *Air Power: UAVs*, 107.

[27] Air Force Magazine, "The Reaper Harvest", http://www.airforce-magazine.com/MagazineArchive/Pages/2011/April%202011/0411reaper.aspx [Accessed 2 May 2011].
[28] Colonel Chris Chambliss, "MQ-1 Predator and MQ-9 Reaper Unmanned Aircraft Systems: At a Crossroads", *Air and Space Power Journal (Spanish Edition)*, 22 no. 4 (2008), 34-38.
[29] Defence Concepts and Doctrine Centre, *Future Character of Conflict* (Ministry of Defence, 2010), 22-23.
[30] US DoD, "DoD News Briefing with Vice Admiral Gortney from the Pentagon on Libya Operation Odyssey Dawn March 19, 2011", http://www.defense.gov/transcripts/transcript.aspx?transcriptid=4786 [accessed 10 April 2011].
[31] See USAF, "Executive Summary of Aircraft Accident Investigation, F-15E T/N 90-0231, Bagram Airfield Afghanistan, 18 July 2009", http://usaf.aib.law.af.mil/F-15E_AOR_18Jul09.pdf [accessed 10 March 2011].
[32] Anthony Cordesman, *The Iraq War: Strategy, Tactics and Military Lessons* (CSIS, 2003), 337.
[33] Office of Director, Operational Test & Evaluation , *RQ-4B Global Hawk Block 30 Operational Test and Evaluation Report* (US Department of Defense, 2011), i.
[34] Mason in Barnes, ed., *Air Power: UAVs*, 123.
[35] United States Department of Defense, *Unmanned Air Systems Roadmap 2005-2030* (Office of the Secretary of Defence, 2005), 53, 55.
[36] Ibid., 53.
[37] United States Air Force, *Unmanned Aircraft Systems Flight Plan 2009-2047* (Headquarters USAF, 2009), 81.
[38] Ibid.
[39] USAF, "USAF Accident Investigation Boards Information", http://usaf.aib.law.af.mil/AIB_Info.html [accessed 10 March 2011].
[40] Email exchange with USAF Air Force Safety Centre, April 2011.
[41] US DoD, *UAS Roadmap*, 55.
[42] USAF, "United States Air Force Class A Aerospace Mishaps", http://usaf.aib.law.af.mil/ [accessed 25 November 2010, updated 15 June 2011].
[43] USAF, "Executive Summary of Aircraft Accident Investigation, MQ-1B, T/N 00-3072, Creech Air Force Base, Nevada,19 September 2010", http://usaf.aib.law.af.mil/ExecSum2010/MQ1B_19%20Sep%2010.pdf [accessed 13 March 2011].
[44] US GAO, *Unmanned Aircraft Systems 2005*, 16-17.
[45] Matt Martin, *Predator: The Remote-Control Air War Over Iraq and Afghanistan* (Minneapolis: Zenith Press, 2010), 62.
[46] USAF, "Executive Summary of Aircraft Accident Investigation, MQ-1B, S/N 99-3055, Creech AFB, Nevada, 3 August 2006", http://usaf.aib.law.af.mil/MQ-1B_Creech_3Aug06.pdf [accessed 10 March 2011].
[47] USAF, "Executive Summary of Aircraft Accident Investigation, MQ-1B, S/N 03-3104, Kandahar Air Base, Afghanistan, 26 March 2007", http://usaf.aib.law.af.mil/MQ-1B_AOR_26Mar07.pdf [accessed 10 March 2011].
[48] Aviation International News, "New UAV Control System May Cut Predator Losses", http://www.ainonline.com/news/single-news-page/article/new-uav-control-system-may-cut-

predator-losses-8631/?no_cache=1&cHash=5d0b225fc7 [accessed 26 April 2011].
49 USAF, "Executive Summary of Aircraft Accident Investigation, RQ-1L 'Predator' S/N 97-3036 at a Deployed Location on 11 December 2003", http://usaf.aib.law.af.mil/RQ-1_AOR_11Dec03.pdf [accessed 2 April 2011].
50 USAF, "Executive Summary of Aircraft Accident Investigation, MQ-1L at a Deployed Location on 20 January 2005", http://usaf.aib.law.af.mil/MQ-1L%2014%20Jan2005.pdf [accessed 11 March 2011].
51 Esquire, "We've Seen the Future, and it's Unmanned", http://www.esquire.com/features/unmanned-aircraft-1109-3 [accessed 3 February 2011].
52 Defense News, "Future UAVs Must Be Hardened: USAF Officers", http://www.defensenews.com/story.php?i=6285209 [accessed 10 May 2011].
53 Mason in Barnes, ed., *Air Power: UAVs*, 119.
54 Symantec, *W32.Stuxnet Dossier Version 1.4* (Symantec Corporation, 2011), 2.
55 Foreign Affairs, "The Pentagon's New Cyberstrategy', http://www.foreignaffairs.com/discussions/news-and-events/foreign-affairs-live-the-pentagons-new-cyberstrategy [accessed 4 May 2011].
56 Wall Street Journal, "The Wall Street Journal: Insurgents Hack US Drones", http://online.wsj.com/article/SB126102247889095011.html?mod=WSJ_hpp_MIDDLETopStories [accessed 26 November 2010].
57 Ibid.
58 US Government Accountability Office (GAO), *Joint Strike Fighter: Additional Costs and Delays Risk Not Meeting Warfighter Requirements on Time* (US GAO, 2010).
59 Air Force Times, "USAFE Chief: Don't Rely on UAVs", http://www.airforcetimes.com/news/2010/07/airforce_UAVs_073010/ [accessed 20 March 2011].
60 Thomas Erhard, *Air Force UAVs: The Secret History* (The Mitchell Institue/AFA, 2010), 56.
61 Spacewar.com, "Unmanned Drones Slated To Replace U-2", http://www.spacewar.com/reports/Unmmaned_Drones_Slated_To_Replace_U_2.html [accessed 26 April 2011]; Defense Tech, "USAF not Ready to Retire the U-2", http://defensetech.org/2008/08/27/usaf-not-ready-to-retire-the-u-2/ [accessed 25 April 2011].
62 Office of Director, Operational Test & Evaluation, *Global Hawk High Altitude Endurance Unmanned Aerial Vehicle, RQ-4 Report Summary* (US Department of Defense, 2007).
63 Air Force Magazine, "12 Miles High, Changing Course", http://www.airforce-magazine.com/MagazineArchive/Pages/2009/February%202009/0209course.aspx [accessed 2 June 2011].
64 Office of DOT&E, *RQ-4B Global Hawk Block 30*, vi.
65 Ibid.
66 Ibid., iii-iv.
67 Ibid., ii.
68 USAF, "Global Hawk Block 30 Initial Operational Test and Evaluation Results", http://www.airforce-magazine.com/SiteCollectionDocuments/Reports/2011/June%202011/Day13/RQ4_Blk30_IOTE.pdf
[accessed 26 June 2011}.
69 Lambeth, *Air Power Against Terror*, 361.

[70] Cox in Barnes, ed., *Air Power: UAVs*, 94.
[71] Singer, *Wired for War*, 123-134.
[72] Wing Commander Nick Tucker-Lowe, "RPAS and the Ethical Landscape of Contemporary Conflict", *Air Power Review* 15 no. 3 (2012): 1-16.
[73] Jordan and Wilkins in Barnes, ed., *Air Power: UAVs*, 38.
[74] Singer, *Wired for War*, 349-350; Charles Krulak, "The Strategic Corporal: Leadership in the Three Block War", Marines Magazine January 1999, http://www.au.af.mil/au/awc/awcgate/usmc/strategic_corporal.htm [accessed 10 January 2011].
[75] Singer, *Wired for War*, 351.
[76] Ibid., 350.
[77] Ibid., 352-3.
[78] Colonel Ludovico Chianese, "Predator Command and Control: An Italian Perspective", *Air and Space Power Journal*, 21 No 3 (USAF, 2007), http://www.au.af.mil/au/cadre/aspj/airchronicles/apj/apj07/fal07/chianese.html [accessed 20 Sep 2010].
[79] Ibid.
[80] Ibid.
[81] Barnes, ed., *Air Power: UAVs*, 5.
[82] Brigadier James Bashall, "Operational Perspective of a 'Customer' of Air Power" (lecture, JSCSC, September 30, 2010).
[83] Singer, *Wired for War*, 335.
[84] US DoD, *UAS Roadmap*, 61; Strategy Page, "The Rise of the Droids (Conversion of USAF 174th Fighter Wing from F16 to MQ-9)", http://www.strategypage.com/htmw/htairfo/articles/20080811.aspx, [accessed 18 September 2010].
[85] US GAO, *Unmanned Aircraft Systems 2005*, 14-15; New York Times, "Military Is Awash in Data From Drones", http://www.nytimes.com/2010/01/11/business/11drone.html [accessed 12 March 2011].
[86] *The Secret War on Terror: Episode 2*, BBC broadcast, March 11, 2011. Outline available: http://www.bbc.co.uk/programmes/b00zt4b2.
[87] Steinar Sanderød, "The Use of Air Power Today: Have New Ethical Challenges Occurred?" in *Power, Insurgency and the "War on Terror"*, ed. Joel Hayward (Royal Air Force Centre for Air Power Studies, 2010), 230-232; Cox in Barnes, ed., *Air Power: UAVs*, 94.
[88] Human Rights Watch, "*Troops in Contact*": *Airstrikes and Civilian Deaths in Afghanistan* (Human Rights Watch, 2008), 2-7; Headquarters, Department of the Army, *FM 3-24: Counterinsurgency* (US Army, 2006), E-1.
[89] Major General Timothy McHale and General Stanley McChrystal, *Executive Summary for AR 15-6 Investigation, 21 February 2010 CIVCAS Incident in Uruzgan Province* (Headquarters US-FOR Afghanistan, 2010).
[90] Mardell in Barnes, ed., *Air Power: UAVs*, 68-85; Defence Concepts and Doctrine Centre, *JDN 2/11: The UK Approach to Unmanned Aircraft Systems* (Ministry of Defence, 2011), 5-1 to 5-12.
[91] Anthony Tvaryanas, *A Resurvey of Shift Work-Related Fatigue in MQ-1 Predator Unmanned Aircraft System Crewmembers* (Naval Postgraduate School: Monterey, California, 2008); Time Magazine, "Long Distance Warriors", http://www.time.com/time/magazine/article/0,9171,

1137653-2,00.html [accessed 15 December 2010].
[92] Centre for Strategic and Budgetary Assessments (2009), *An Air Force Strategy for the Long Haul* (CSBA).Centre for Strategic and Budgetary Assessments (2009), pp60-62; Los Angeles Times, "Battle Breaks Out Over the Predator", http://articles.latimes.com/2008/mar/21/nation/na-predators21/2 [accessed 20 February 2011].
[93] USAF, *UAS Flight Plan*, 30, 49.
[94] Ibid., p59.
[95] US Government Accountability Office (GAO), *Unmanned Air Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses Within the National Airspace System* (US GAO, 2008), 3.
[96] Singer, *Wired for War*, 430-431.
[97] Philip Sabin, *The Current and Future Utility of Air & Space Power* (RAFCAPS Discussion Paper No 1, 2010), 6.
[98] General Sir David Richards (2010), "Future Conflict and Its Prevention: People and the Information Age" (speech, IISS, 18 January 2010).
[99] David Ucko, *Counterinsurgency and its Discontents: Assessing the Value of a Divisive Concept* (German Institute for International and Security Affairs, 2011), 5-6.
[100] Air Chief Marshal Sir Stephen Dalton (2010), "Dominant Air Power in the Information Age: The Comparative Advantage of Air and Space Power in Future Conflict" (speech, IISS, 15 February 2010).