No. 66

UAVs/UCAVs – MISSIONS, CHALLENGES, AND STRATEGIC IMPLICATIONS FOR SMALL AND MEDIUM POWERS

Manjeet Singh Pardesi

Institute of Defence and Strategic Studies
Singapore

MAY 2004

With Compliments

The Institute of Defence and Strategic Studies (IDSS) was established in July 1996 as an autonomous research institute within the Nanyang Technological University. Its objectives are to:

- Conduct research on security, strategic and international issues.
- Provide general and graduate education in strategic studies, international relations, defence management and defence technology.
- Promote joint and exchange programmes with similar regional and international institutions; organise seminars/conferences on topics salient to the strategic and policy communities of the Asia-Pacific.

Research
Through its Working Paper Series, *IDSS Commentaries* and other publications, the Institute seeks to share its research findings with the strategic studies and defence policy communities. The Institute's researchers are also encouraged to publish their writings in refereed journals. The focus of research is on issues relating to the security and stability of the Asia-Pacific region and their implications for Singapore and other countries in the region. The Institute has also established the S. Rajaratnam Professorship in Strategic Studies (named after Singapore's first Foreign Minister), to bring distinguished scholars to participate in the work of the Institute. Previous holders of the Chair include Professors Stephen Walt (Harvard University), Jack Snyder (Columbia University), Wang Jisi (Chinese Academy of Social Sciences) and Alastair Iain Johnston (Harvard University). A Visiting Research Fellow Programme also enables overseas scholars to carry out related research in the Institute.

Teaching
The Institute provides educational opportunities at an advanced level to professionals from both the private and public sectors in Singapore and overseas through the Master of Science in Strategic Studies and Master of Science in International Relations programmes. These programmes are conducted full-time and part-time by an international faculty from July each year. The Institute also has a Doctorate programme in Strategic Studies/International Relations. In 2004, it will introduce a new Master of Science in International Political Economy programme. In addition to these graduate programmes, the Institute also teaches various modules in courses conducted by the SAFTI Military Institute, SAF Warrant Officers' School, Civil Defence Academy, Singapore Technologies College and the Defence, Home Affairs and Foreign Ministries. The Institute also runs a one-semester course on '*The International Relations of the Asia Pacific'* for undergraduates in NTU.

Networking
The Institute convenes workshops, seminars and colloquia on aspects of international relations and security development which are of contemporary and historical significance. Highlights of the Institute's activities include a regular Colloquium on Strategic Trends in the 21st Century, the annual Asia Pacific Programme for Senior Military Officers and the biennial Asia Pacific Security Conference (held in conjunction with Asian Aerospace). Institute staff participate in Track II security dialogues and scholarly conferences in the Asia-Pacific. The Institute has contacts and collaborations with many think-tanks and research institutes in Asia, Europe and the United States. The Institute has also participated in research projects funded by the Ford Foundation and the Sasakawa Peace Foundation. The Institute serves as the Secretariat for the Council for Security Cooperation in the Asia-Pacific (CSCAP), Singapore. Through these activities, the Institute aims to develop and nurture a network of researchers whose collaborative efforts will yield new insights into security issues of interest to Singapore and the region.

ABSTRACT

Unmanned Aerial Vehicles (armed and unarmed) are playing a crucial role in defense transformation by providing the military with a new platform that exploits advances in info-communications technologies, while playing a crucial role in the network-centric warfare concept. This paper studies various air missions (Intelligence, Surveillance, and Reconnaissance, Suppression of Enemy Air Defenses, Counterair etc.) to determine whether the UAVs represent a truly disruptive technology. This paper also studies the strategic implications of UAVs for small and medium powers. It concludes that the UAV is not a truly disruptive technology as there will always be missions that will require the manned aircraft. Their software complexity, automation and communications architecture makes them operationally unreliable for many missions and also considerably increases their cost by making them nearly as expensive as their manned counterpart. Advances in air defense systems and manned counterair aircraft considerably limit the utility of the unmanned platform for many air missions. This research concludes that the future is likely to see a mix of manned and unmanned aircraft networked with satellites performing complex air missions. The research also concludes that small and medium powers are likely to find UAVs useful in ISR roles only as the unmanned combat platform is still an unproven technology and is in its developmental stages. However, collaboration, licensed production, and joint marketing are areas that will allow small and medium powers (together perhaps with the United States) to come together for a joint effort.

****

BIOGRAPHY

Manjeet Singh Pardesi has been an Associate Research Fellow (Revolution in Military Affairs Programme) at the Institute of Defence and Strategic Studies, Singapore, since August 2003. He was initially trained as an Electrical and Electronic Engineer at the Nanyang Technological University, Singapore, where he studied on a Singapore Airlines/Neptune Orient Lines Scholarship. Thereafter, he pursued an MSc in Strategic Studies on a Singapore Technologies Engineering Scholarship at the Institute of Defence and Strategic Studies, Singapore. His research interests include Defence Technology (especially emerging technological trends and their potential for an RMA), the role of weapons of mass destruction in the 21st century, great power politics and India's foreign and security policy with an emphasis on Indo-US, Indo-China and India-ASEAN relations.

UAVs/UCAVs – MISSIONS, CHALLENGES, AND STRATEGIC IMPLICATIONS FOR SMALL AND MEDIUM POWERS

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.

Giulio Douhet

1. INTRODUCTION

The absorption of modern info-communications technologies (ICTs) has transformed the US military. This transformation has in turn changed the conduct of warfare in two ways – by enhancing platforms and by enabling network-centric warfare. Unmanned Aerial Vehicles (UAVs), armed and unarmed, are playing a crucial role in this revolution, as they provide the military with a new platform that exploits the advances in ICTs, and at the same time are integral to the network-centric warfare concept. Although interest in UAVs is as old as the history of manned aviation, UAVs started making news due to their military effectiveness in recent conflicts such as Iraq (2003) and Afghanistan (2001). The Afghanistan campaign highlighted the growing role of UAVs, because it was in Afghanistan that the UAVs actually started attacking targets in addition to performing their primary mission of intelligence gathering and guiding weapons to their target.[1]

This paper seeks to question whether the UAVs represent a truly disruptive technology. What will be the impact of UAVs on manned aircraft and how does the increased use of unmanned platforms alter the strategic landscape? To this end, this paper will examine various air operations – Intelligence, Surveillance, and Reconnaissance (ISR), Suppression of Enemy Air Defenses (SEAD), Counterair etc. – to establish the transformative impact of UAVs, if any. This research will also briefly discuss how Mini/Micro Aerial Vehicles (MAVs), which are a subset of UAVs are likely to be deployed on the battlefield. Additionally, this paper will analyze the US Department of Defense (DoD) commitment to

[1] See *US Drone Takes Combat Role* [Online]. (2002). Available: http://news.bbc.co.uk/1/hi/world/2404425.stm [2003, December 04], and *Spy Plane Hunting Bin Laden* [Online]. (2001). Available: http://news.bbc.co.uk/1/hi/world/americas/1670246.stm [2003, December 04].

UAVs through an assessment of its budgetary investments in UAVs compared to manned systems. This paper will go on to highlight the strategic implications of UAVs for small and medium powers. It will highlight the missions that are likely to be transformed with the introduction of UAVs and make a policy recommendation to these states with limited defense (and R&D) resources to invest only in these mission areas.

2. HISTORY

The US DoD defines an unmanned aerial vehicle 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. Ballistic or semiballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles."[2] While the idea of removing the pilot from the cockpit may be conceptually simple – the UAV presents an operational challenge, as it is a system designed to fly in a hostile environment. Conventional wisdom states that removing the pilot from the aircraft would mean that the extensive and expensive life-support equipment is not needed, thereby making the UAV more cost-effective. UAVs vary in size from systems that can be held in the palm of the hand to systems the size of commercial jet aircraft.

Even though the UAV concept seems somewhat revolutionary in nature, it is not new. Starting with the kite, the Chinese sought to achieve military advantage with devices held aloft by aerodynamic forces, as early as third century BC.[3] In Europe, kites were first used for military purposes in the Battle of Hastings in 1066.[4] The Americans first used unmanned aviation in combat when journalist William Eddy took hundreds of photographs during the Spanish-American War in 1898 from cameras suspended from a kite.[5] The first heavier than air, sustained, powered flight was achieved by a pilotless aircraft when Dr Samuel Pierpoint

---

[2] *DOD Dictionary of Military Terms* [Online]. (2003). Available: http://www.dtic.mil/doctrine/jel/doddict/data/u/05601.html [2003, December 04]. Unless stated otherwise, this research uses the phrase 'unmanned platform' to refer to UAVs and/or UCAVs, not cruise or ballistic missiles.

[3] Han Hsin, a general in the late third century BC, needed a method for triangulating the distance for the tunnel his army was digging under a besieged city's walls and his engineers used a kite as reference. See Thomas P Ehrhard, "Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation" (Ph.D. dissertation, Johns Hopkins University, 2000), p. 653.

[4] Ibid., p.655.

[5] Ibid., p.656.

Langley launched his steam-powered aircraft over the Potomac River on May 06, 1896, for a flight lasting for over one minute.[6] After the Wright brothers first piloted, powered flight on December 17, 1903, unmanned aviation took a backseat compared to manned aviation.

During World War I, the US decided to make a contribution in the novel area of the flying bomb (known as cruise missile today).[7] As a result of technological immaturity and a declining defense budget after the war, the US scrapped the project in 1922.[8] The most important development for unmanned aviation during the interwar years was radio control. World War II saw the US Army Air Forces remotely control an aircraft under a program code-name Aphrodite.[9] The program was suspended, as none of the Aphrodite bombers were successful.[10] Post-World War II, the Ryan Aeronautical Company successfully developed two types of target drones – Q-1 and Q-2.[11]

In 1960, a U-2 reconnaissance plane piloted by Francis Gary Powers was shot down over Russia. This was followed by another American loss when an RB-47 on an electronic intelligence-gathering mission over the Barents Sea was shot down. Under great urgency, the US Air Force awarded Ryan Aeronautical two highly classified contracts code-named Red Wagon and Lucy Lee to demonstrate its drones for photo-reconnaissance missions. However, due to spiraling costs, both programs were terminated.[12] Two years later, in 1963, under a procurement concept called Big Safari, the US met its first success for unmanned reconnaissance aircraft. This led to the birth of Ryan 147 Lightning Bug, which flew a total of 3,435 operational reconnaissance UAV sorties during the Vietnam War between 1964 and 1975.[13] In 1971, the US demonstrated a historic first missile launch from a drone when the Lightning Bug modified BGM-34A was used to fire a guided air-to-surface missile against a

---

[6] Major Thomas G O'Reilly, "Uninhabited Air Vehicle – Critical Leverage System for our Nation's Defense in 2025" (Master's dissertation, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, US, 1999), pp. 9-10.

[7] UAVs and cruise missiles use related technology, however, the main difference between the two is that while the UAV is a reusable system, the cruise missile is not.

[8] See Lt Col Richard M Clark, "Uninhabited Combat Aerial Vehicles – Airpower by the People, For the People, But Not with the People" (CADRE Paper No. 8, College of Aerospace Doctrine Research and Education, Air University, Maxwell Air Force Base, Alabama, US, 2000), pp. 7-9.

[9] The most important unmanned systems to be used during the Second World War were V-1 and V-2 rockets. However, these were the precursors to modern day Intercontinental Ballistic Missiles, not UAVs.

[10] Clark, op. cit., pp. 10-11.

[11] Ibid., p. 12.

[12] Ibid., pp. 12-13.

[13] Ibid., pp. 13-20.

simulated SAM (surface-to-air missile) site. It achieved a direct hit.[14] Since this system was still under development, the first Unmanned Combat Aerial Vehicle (UCAV) played no part in the Vietnam conflict. After the war, by 1979, the various UAV/UCAV programs were shelved or canceled due to cuts in the defense budget.

Israel's successful use of UAVs during operations in Lebanon in 1982 rekindled American interest in this system.[15] US navy acquired the Pioneer UAV from Israel, which provided tactical level intelligence during Operation Desert Storm in 1991.[16] The ineffectiveness of the Tomahawk Land-Attack Missile (TLAM) attacks on Osama bin Laden's camps in Afghanistan, in retaliation for al-Qaeda sponsored US embassy bombings in Africa in August 1998 generated military interest in new roles for armed and unarmed UAVs.[17] During Operation Allied Force, UAVs performed numerous functions that included target identification, probing of Serbian air defenses, monitoring ethnic cleansing, bomb damage assessment, electronic intelligence operations, airborne communication relays and jamming of Serbian communications.[18]

In Afghanistan, the Predator UAV started performing 'armed reconnaissance' as mentioned earlier and the Global Hawk UAV made its debut in the skies over Afghanistan in 2001, even though it was an experimental system then.[19] In the recent Operation Iraqi Freedom, Global Hawk UAVs provided imagery of Iraqi Republican Guard divisions. The Predators continued their combat role by attacking high value targets in Iraq. Surveillance UAVs also helped US Special Forces in preventing Iraqis from launching any hidden Scud missiles.[20]

3. ROLES AND MISSIONS

---

[14] Ibid., pp. 23.
[15] Elizabeth Bone and Christopher Bolkcom. (2003). *Unmanned Aerial Vehicles: Background and Issues for Congress* [Online]. Available: www.fas.org/irp/crs/RL31872.pdf [2003, December 04], p.2.
[16] Ibid.
[17] Dennis M Gormley, "New Developments in unmanned air vehicles and land-attack cruise missiles", in *SIPRI Yearbook 2003 – Armaments, Disarmament and International Security* (Oxford: Oxford University Press, 2003), p. 416.
[18] Jim Garamone. (1999). *Predator Demonstrates worth over* Kosovo [Online]. Available: http://www.fas.org/irp/program/collect/docs/n19990921_991750.htm [2003, December 05]. Also see Andrew Krepinevich. (2003). *Operation Iraqi Freedom: A First Blush Assessment* [Online]. Available: http://www.csbaonline.org/4Publications/Archive/R.20030916.Operation_Iraqi_Fr/R.20030916.Operation_Iraqi_Fr.htm [2003, December 05].
[19] John McWethy. (2002). *Robo-Planes* [Online]. Available: http://abcnews.go.com/sections/wnt/DailyNews/roboplane020501.html [2003, December 05].
[20] Krepinevich, op. cit.

While there is a good deal of confidence in the underpinning technology of unmanned platforms, there is a great deal less certainty surrounding their roles and missions. UAVs/UCAVs are likely to play a key role in mission areas commonly categorized as "the dull, the dirty and the dangerous".[21] This section discusses some of the more important air missions (ISR, strike/SEAD, and Counterair) to determine if UAVs/UCAVs can replace manned platforms in some or all of these roles. This will be followed by a short analysis on the role of MAVs on the battlefield. It must be pointed out that the move towards unmanned platforms is not necessarily due to the inadequacy of manned aircraft. Rapid technological advancement over the past decade has led to a "technological push" in this direction. Moreover, since the end of the Cold War, the US has been attempting to replace manpower with technology, mostly because it retains strategic interests in every corner of the globe but is increasingly hesitant to commit its military personnel for several of these missions. The move towards the unmanned platform is a result of all these developments.

3.1 Intelligence, Surveillance, and Reconnaissance (ISR)

UAVs have been traditionally used as Intelligence, Surveillance, and Reconnaissance (ISR) assets, and their ability to do so is being boosted by the advances in sensor and modern info-communications technologies. For the US, ISR collection is a critical factor in achieving the Joint Vision 2020 operational concept of 'precision engagement'.[22]

During the Vietnam War, the photos provided by the Ryan 147 Lightning Bug revealed precise locations of SAM sites, enemy airfields, ship activity in Haiphong Harbor and battle damage assessment (BDA) provided intelligence that otherwise would have been obtained only if manned aircraft were sent in harm's way.[23] In Operation Desert Storm, the Pioneer UAV contributed to the tactical successes of the US Navy and Army by playing an important role in target designation, damage assessment and reconnaissance.[24]

---

[21] Office of the Secretary of Defense. (2002). *Unmanned Aerial Vehicles Roadmap 2002-2027* [Online]. Available: http://www.acq.osd.mil/usd/uav_roadmap.pdf [2003, December 08], p.iv. Dull missions include extended reconnaissance over a target area (i.e., coverage time beyond the capability of a manned sortie). Dirty missions include reconnoitering areas contaminated with radiological, chemical or biological agents. Dangerous missions include high-risk missions like SEAD with less need for supporting aircraft.

[22] See *Joint Vision 2020* [Online]. (2000). Available: http://www.dtic.mil/jointvision/jv2020.doc [2003, December 08], p.12.

[23] Clark, op. cit., pp.15-16.

[24] Clark, op. cit., pp.34-35.

In Afghanistan, Global Hawk was used for reconnaissance prior to the strikes and for post-strike BDA.[25] The Predator was used in Afghanistan to feed imagery to AC-130 special operation gunships and special operations teams on the ground.[26] Global Hawk accounted for only 5 per cent of intelligence sorties during Operation Iraqi Freedom but produced 50 per cent of the information on time-sensitive targets.[27] It is important to note that unmanned aerial vehicles retreated to their traditional role of reconnaissance in Iraq in spite of some successes in combat role in Afghanistan. In Afghanistan, barely a dozen UAVs launched 115 Hellfire missiles and laser-designated 525 targets. But in Iraq, where more than 56 larger UAVs and more than 60 smaller portable ones were used, UAVs launched only 62 Hellfires and designated only 146 targets. The main reasons were Iraqi winds and sandstorms (and the fact that these aircraft are much lighter than their manned counterpart) and the increased need for intelligence in the Iraqi campaign.[28] The growth of asymmetric warfare highlights the importance of unmanned ISR platforms.

UAVs face two competing systems for performing ISR missions – manned platforms and satellites. While providing a significant improvement in information collection capability over these competing systems, UAVs also pose some serious limitations.

Being large and manned aircraft, AWACS (Airborne Warning and Control System) and JSTARS (Joint Surveillance Target Attack Radar System) have limited maneuverability and self-defense. Unlike the loss of UAVs, loss of these expensive manned systems is likely to cause severe domestic political repercussions for the US. However, given the current state of technology, UAVs cannot completely replace AWACS and JSTARS manned aircraft in ISR missions. Advanced sensor technology is still under development and IT is not sufficiently developed to perform the battle management and command and control functions handled by AWACS and JSTARS personnel. The military is seeking sensors with high definition television (HDTV) standards[29], foliage penetration radar (FOPEN) with hyperspectral imagery, synthetic aperture radar (SAR) and moving target indication (MTI) mode to track

[25] John Persinos, "Unmanned Aerial Vehicles: On the Rise", *Aviation Today*, February 2002.
[26] Bone and Bolkcom, op. cit., p.14.
[27] Thomas Donnelly and Michael Vickers. (2003). *Iraq: Lessons Learned* [Online]. Available: http://www.aei.org/events/filter.,eventID.337/summary.asp [2003, December 08].
[28] Gail Kaufman, "Shot Fewer Missiles than in Afghanistan", *Defense News*, 08 December 2003.
[29] Predator is a medium altitude UAV that transmits video signals. To gain better situational awareness in the future, UAVs will need to fly higher. Higher altitude degrades video signals; hence migration to commercial HDTV standards is essential.

targets in all types of terrain throughout the spectrum of military operations.[30] Due to their inability to absorb data and reason (at least for the foreseeable future), UAVs cannot process and relay the same amount of data as a pilot in the cockpit (who can do so by learning, experiencing, and by intuition) and cannot maintain a 360-degree situational awareness (SA).

Manned missions provide high resolution data and are extremely flexible at adapting to multiple mission scenarios, however, their main limitation is their loiter time. UAVs on the other hand are capable of long loiter times; are smaller and hence stealthier than manned platforms; much less costly to procure, operate, and support; and avoid putting pilots at risk. However, fast jet-based tactical reconnaissance remains a much sought after, but scarce capability for UAVs.[31] The use of Global Hawk, Predator and JSTARS systems (i.e., both manned and unmanned platforms) was the key factor behind the shattering of the Republican Guard and the success of the SCUD suppression campaign in western Iraq during Operation Iraqi Freedom.[32] It is possible that in the future UAVs will be faster and more maneuverable, but it must be remembered that higher speed creates penalties for loiter time, one of the biggest assets of unmanned platforms.

UAVs have a major advantage over satellites in addition to being cheaper as it is easier to alter their flight paths and coverage. Moreover, they provide a comparatively cost-effective method of collecting ISR. UAVs also have an additional advantage of being able to fly closer to the target.[33] Operation Desert Storm highlighted the pivotal role that satellites will have in future conflicts, as space (due to the salience of satellites) became an area of strategic significance. However, the major drawback with UAVs as mentioned above is their lack of situational awareness. This shortcoming can be overcome by integrating UAVs with reconnaissance satellites. However, high data rates (bandwidths) are essential for real-time interactive command and control systems like flight controls, video reception and transmissions. UAVs are major consumers of bandwidth.[34] Since September 11, 2001, the

---

[30] Mark Hewish, "Unmanned, unblinking, undeterred", *Jane's International Defense Review*, 01 September 2002.

[31] A predator is a slow platform that takes 30 minutes to travel 50 nautical miles. UAVs offer a trade-off between speed and loiter time.

[32] Donnelly and Vickers, op. cit.

[33] UAVs within ten kilometers of an object can resolve to ten centimeters, and those within one kilometer to just one centimeter. See Michael O'Hanlon, *Technological Change and the Future of Warfare* (Washington, D.C.: Brookings Institution Press, 2000), p. 34.

[34] A video image of 300 by 300 pixels, and eight bits per pixel takes 720 kilobits to encode in a single frame. For smooth, continuous perception by a human operator this information needs to be refreshed at a rate of no

need has increased eight-fold due to the war in Afghanistan and the pursuit of terrorists in the region.[35] Stationing the mission control on a standoff aircraft (within line-of-sight) would decrease the dependency on satellites generated by stationing the mission control on the ground thousands of miles away. More autonomous UAVs will also require less bandwidth as more data will be processed on board.[36] It should also be remembered that since the UAVs fly in close proximity to the target, they would need to have a high signal-to-noise ratio (especially if they are flying far from their control station), thus increasing their possibility of detection.

The way forward is to integrate manned, unmanned, and satellite-based sensors to create a common operational picture of the battlefield. However, the spread of unintegrated information can be disastrous in a military campaign. Development of ICTs and software algorithms to fuse the data provided by the three platforms will be crucial to ISR operations in the future. A successful ISR mission must have a reliable, robust, secure and high-capacity communications infrastructure. The information collection system of the future is likely to be based on space-based assets providing wide area surveillance at a low level of resolution, but looking for cues that require detailed monitoring. This detailed monitoring will be performed by manned and unmanned vehicles.

3.2 Suppression of Enemy Air Defenses/Strike

US military strategy post embassy bombings in Africa focused on targeting Osama bin Laden and his training camps with TLAMs. This strategy did keep US troops out of harm, but it suffered from many operational limitations, the most important being the long delay between acquiring reliable intelligence on the precise location of time-sensitive targets (from the skies over Afghanistan) and the execution of an actual cruise missile attack (from ships in the

---

less than 30 times per second, i.e., the data transfer rate needed is 21.6 megabits per second. Present day commercial systems like *Globalstar* offer a data rate performance of 9.6 kilobits per second while the MILSTAR system offers a data rate of only 2.4 kilobits per second. Sophisticated compression algorithms may reduce the bandwidth requirements. See Major William K Lewis, "UCAV – The Next Generation Air Superiority Fighter" (Master's dissertation, School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, Alabama, US, 2002), pp. 44-46. It must be mentioned that many commercial satellite systems offer a higher data transfer rate, hence, it seems likely that in the future the US DoD will cooperate with the commercial satellite sector for data communication purposes.

[35] Bone and Bolkcom, op. cit., pp. 17-18.

[36] Bone and Bolkcom, op. cit., pp. 17-18. The Global Hawk is an autonomous rather than a remotely piloted vehicle. In spite of this, the UAV still requires multiple satellite and line-of-sight links for control, inflight mission re-routings, and the relay of sensor data.

Arabian Sea). The US was looking for an 'armed reconnaissance' platform to strike time-sensitive targets. Technological momentum led the US Air Force to fit two 45-kg, laser guided Hellfire-C missiles to the Predator UAV.[37] On 15 November 2001, two Hellfire missiles launched from a Predator killed Muhammad Atef, al-Qaeda's chief of military operations.[38] This was the first use of the Predator as a weapons platform. In another highly publicized event almost a year later, on 3 November 2002, a CIA-operated armed Predator flying over Yemen, with Yemen's approval, killed a top al-Qaeda operative, Ali Qaed Sinan al-Harthi, and his five companions traveling in the same car.[39] By performing successful "strike" missions, these incidents demonstrated the usefulness of armed UAVs in the global war against terrorism. These strike missions opened up a new debate on a possible new role for the armed UAVs – Suppression of Enemy Air Defenses (SEAD).

The US DoD defines SEAD as an "activity which neutralizes, destroys, or temporarily degrades surface-based enemy air defenses by destructive and/or disruptive means."[40] The Predator UAV was credited with two strikes in Operation Iraqi Freedom in March 2003 – one strike was against an anti-aircraft vehicle while the other was against a TV satellite dish in Baghdad.[41] The US is currently developing a new version of the armed Predator UAV, called Predator B, which will have the capability to carry eight Hellfire missiles instead of two.[42] The US is also developing newer platforms – UCAVs – that are being developed with a primary offensive mission of strike and SEAD.

To determine the efficacy of the unmanned platform in a SEAD role, the US will need to consider two rival challenges – the adoption of new counter-tactics by its opponents, and the development of new anti-air systems.

Today, the US relies exclusively on the F-16 and the Navy's EA-6B for defense suppression missions. The loss of a modern, expensive platform like the F-16 (and its pilot) will be a major political embarrassment for the US, in addition to being an economic loss. SEAD is an

---

[37] Gormley, op.cit., pp. 416-417.
[38] Ibid., p. 417.
[39] Ibid., p. 417.
[40] *DOD Dictionary of Military Terms* [Online]. (2003). Available: http://www.dtic.mil/doctrine/jel/doddict/data/s/05149.html [2003, December 10]. SEAD involves the suppression as well as destruction of enemy air defenses.
[41] Bone and Bolkcom, op. cit., p.14.
[42] Bone and Bolkcom, op. cit., p.14.

important mission as it helps in attaining 'air superiority'. The air forces can attack the heart of the enemy (i.e., perform the 'interdiction' mission) only after gaining command of the air. However, during Operation Desert Storm, the super-stealthy F-117 allowed the US to engage in 'parallel warfare'[43], i.e., it freed the US from rolling back enemy air defenses and enabled the F-117 aircraft to hit the heart of the enemy within the opening minutes of the conflict.[44] However, the Serbs learned from this conflict and adopted a "shoot and scoot" tactic by not deploying a determined air defense system. This enabled them to launch 700 missiles in the course of the 78-day conflict and caused enormous frustration to the US airmen.[45]

In addition to such tactics, the US is also likely to face "anti-access threat systems" like SAMs, cruise missiles, theater ballistic missiles, and other advanced air defense systems. The range of modern SAMs (estimated to be between 50 and 250 miles), is forcing the US to develop strategies and systems to reduce the risk to its airmen.[46] It must be highlighted that missiles launched from a distance from mobile SAM sites are difficult to detect, and that the high speed of newer missiles makes them more maneuverable.[47] This means that the friendly aircraft/UAVs will have a very narrow "escape zone" to avoid the SAMs. Unmanned jet engine G force limitations (±12G) do not significantly exceed those of the human pilot (between –3G and +9G) and hence do not substantially increase defensive capability against missiles.[48] It must be pointed out that the cost arithmetic further complicates the analysis and is not useful in determining the efficacy of UCAVs over current standoff systems like cruise missiles.[49] JDAMs employed by UCAVs may be cheap compared to the Tomahawk, but the

---

[43] 'Parallel warfare' is a non-linear war-fighting technique. In traditional 'series warfare', target sets are attacked in a linear sequence in a progressive march on to the enemy's nerve centers.

[44] The F-117 which flew only 2 percent of the total attack sorties, struck nearly 40% of the strategic targets. See Thomas A Keaney and Eliot A Cohen, *Revolution in Warfare? Air Power in the Persian Gulf*, (Annapolis: Naval Institute Press, 1995), pp. 189-193.

[45] See Gen John Jumper, "Global Strike Task Force", *Air Power Journal*, Spring 2001, p. 27.

[46] Countering "anti-access" threats implies a capability to operate from well outside an enemy's defenses. See John A Tirpak, "The Double Digit SAMs", *Air Force Magazine*, June 2001. Countries as diverse as China, Iran, Ukraine, Russia, and Croatia possess the Russian built double-digit S-300 SAMs.

[47] Most SAMs are faster than High-Speed Anti-Radiation Missiles (HARMs).

[48] Seated human beings lose consciousness if subjected to maneuvers harder than –3G or +10G. Nevertheless airframes and mechanical components can be designed to operate out to the ±20G envelope. See David Bookstaber. *Unmanned Aerial Combat Vehicles – What men do in aircraft and why machines can do it better* [Online]. Available: www.airpower.maxwell.af.mil/airchronicles/cc/ucav.pdf [2003, December 11]. Designing jet engines that could withstand 20Gs would require billions of dollars in development or would produce limited thrust-to-weight ratios (speed). Moreover, even if the engine technology allows the vehicle to withstand high G forces, the sensor technology is unlikely to allow the vehicle to maneuver in the proper direction at the proper time. See Ehrhard, op. cit., p. 574.

[49] Joint Direct Attack Munitions (JDAMs) employed by UCAVs have a unit cost of $21,000 compared to $600,000 for a Tomahawk cruise missile. This cost-per-kill contrast will favor UCAV use in many instances. See Col Robert E Chapman II, "Unmanned Combat Aerial Vehicles – Dawn of a New Age?", *Aerospace Power*

UCAV, which is an expensive recoverable platform, is likely to suffer considerable attrition due to its proximity to the target.

It must be noted that UAVs/UCAVs will play an important role in electronic attack missions, however, they will at best play a limited role only as the future use of Electromagnetic Pulse (EMP) weapons and Directed Energy (DE) weapons will increase the risk of self-jamming for the unmanned platform itself. The new S-400 SAM system with a range in excess of 250 miles would also render manned standoff jamming platforms useless.[50]

It makes sense to use low-cost UAVs and/or decoys to locate the positions of the SAM sites, which may be then be attacked as a part of a 'reactive' SEAD strategy. This together with UCAVs equipped with passive sensors (an extremely stealthy platform), represents an effective counter to mobile defenses. There are however, several constraints here that must be kept in mind – (1) the primitive nature of current target recognition programs means that a human operator must be kept in the loop to authorize the 'kill'[51], thereby, increasing the bandwidth requirements[52], and (2) integration with other ISR platforms is necessary to locate time sensitive targets.[53] These constraints put serious limitations on the use of unmanned combat platforms in 'reactive' SEAD missions. UCAVs are more likely to play an important role in 'pre-emptive' SEAD missions (where the exact locations of enemy SAM sites are known) as opposed to 'reactive' SEAD missions.[54] UCAVs, integrated with manned and unmanned assets like AWACS, F-16s, F-117s, Global Hawk, and communications satellites will play a role in future SEAD missions (reducing some risk to manned assets in this high threat environment), however, they will be one of many 'arrows in a quiver', and not a 'silver

---

Journal, Summer 2002. However, it must be remembered that UCAVs will need to fly closer to the target and that they are not inexpensive. The Joint Strike Fighter (JSF) will have a flyaway cost of $35 million and it is estimated that the DARPA/Boeing X-45 UCAV will cost about $25 million. See Bill Sweetman, "UCAVs grow fat on requirements", *Jane's International Defense Review*, 01 May 2003.

[50] Ibid., p. 27.

[51] Enemy command and control bunkers may shelter civilians or SAM missile systems may be located in urban areas, which if attacked by mistake will kill innocent civilians. It is unlikely that political and military authorities would leave the 'kill' decision to automated systems. In any case, automated systems are not yet sufficiently developed to identify and kill the whole range of possible targets.

[52] Bandwidths impose serious limitations on UCAVs in SEAD roles. The time for imagery transmission will depend on the bandwidth. Moreover, the time for human decisionmaking is a major unknown. These delays can prove fatal under the high threat SEAD environment.

[53] Also, the size of a deployed UCAV fleet is a major concern as it increases bandwidth requirements. Integration with satellites for data transmission will be essential for UCAV command and control.

[54] Thus, UCAVs are likely to provide a powerful "day one" force enabler by conducting pre-emptive SEAD missions, and are also likely to play an important role in low-intensity conflict and patrolling the skies over hostile territory.

bullet'. UAVs/UCAVs are nevertheless very suitable for strike missions, especially against a very heavily defended target due to their high level of stealth.

3.3 Counterair

In March 2003, Predator launched a Stinger air-to-air missile at an Iraqi MiG before the Iraqi aircraft shot it down.[55] This has led to the speculation that armed UAVs/UCAVs will play a role in counterair operations (and by extension as air superiority fighters in the future). The US DoD defines counterair as "a mission that integrates offensive and defensive operations to attain and maintain a desired degree of air superiority. Counterair missions are designed to destroy or negate enemy aircraft and missiles, both before and after launch,"[56] and defines air superiority as "that degree of dominance in the air battle of one force over another that permits the conduct of operations by the former and its related land, sea, and air forces at a given time and place without prohibitive interference by the opposing force."[57]

During Operation Desert Storm, coalition forces flew over 13,000 counterair missions, averaging 340 sorties daily, thus ensuring air superiority. The USAF F-15C, USN F-14A/D, and USN and USMC F/A-18 aircraft were the platforms instrumental in the command of the skies over Iraq.[58] The same air assets were available during Operation Allied Force for the function of counterair. Lockheed Martin's F-22 Raptor is likely to play the key role in America's air superiority efforts in the years ahead.[59] Stealth, maneuverability, and cost are the most important design pre-requisites for air superiority fighters of the future.[60] Whether or not a UCAV will replace the F-22 fighter (a manned platform) is a crucial question as American air superiority in a future conflict depends on the answer to this question. This is also a timely question since the decisions taken today will guide the research, development, production, and training of the new system (manned or unmanned replacement of the F-22

---

[55] David A Fulgham, "Predator's Progress", *Aviation Week and Space Technology*, 03 March 2003. Also see David A Fulgham, "Stinger Eyed for UAV Role", *Aviation Week and Space Technology*, 04 March 2002.

[56] *DOD Dictionary of Military Terms* [Online]. (2003). Available: http://www.dtic.mil/doctrine/jel/doddict/data/c/01331.html [2003, December 16].

[57] *DOD Dictionary of Military Terms* [Online]. (2003). Available: http://www.dtic.mil/doctrine/jel/doddict/data/a/00293.html [2003, December 16]. SEAD is an important air superiority mission.

[58] Thomas A Keaney and Eliot A Cohen, *Gulf War Air Power Survey Summary Report* (Washington D.C.: US Government Printing Office, 1993), p. 56.

[59] Initial operational capability of one operational squadron of the F-22 fighter is slated for December 2005 when it replaces the F-15 Eagle that is over 25 years old. See *F-22 Raptor*, [Online]. (2000). Available: http://www.fas.org/man/dod-101/sys/ac/f-22.htm [2003, December 16].

[60] Stealth enhances survivability before engagement and maneuverability enhances survival while engaged.

fighter) over the next two decades (a period at the end of which the F-22 will most likely retire). Aerial combat is the most challenging mission for manned aircraft to perform and it is believed that missiles do not always kill the adversary (especially one equipped with significant counterair assets and capabilities like the MiG-29 Fulcrum and the Su-27 Flanker[61]), so close engagements are necessary.[62] Combat survivability remains the most significant limitation to UAV employment.[63] It has been mentioned in sections 3.1 and 3.2 that limitations imposed by line-of-sight data transfer requirements will enhance the role of satellite communications. However, the current American and allied satellite communications infrastructure is incapable of supporting any sizable number of UAVs or UCAVs. Global Hawk consumed five times the total bandwidth used by the entire US military in the Gulf.[64] Autonomous systems will reduce bandwidth requirements, however, it is unlikely that the UCAV will replace the manned aircraft in all operations as some politically sensitive targets will still need a human operator to make the "kill decision". Moreover, cognitive systems based on artificial intelligence (AI) are unlikely to replace the human completely, even though significant developments are likely to occur over the next two decades.

Stealth requirements dictate that the UCAV weapons be small and by extension, precise. The weaponization of the unmanned platform for air superiority missions is not likely to happen over the next two decades.[65] In the near future, the UCAV is not likely to have its own air-to-air weapons and is going to carry weapons like the Sidewinder missile and AMRAAM that already exist.[66] UAVs/UCAVs will be used predominantly to provide active sensors against highly lethal anti-aircraft weapons in support of inhabited vehicles.[67] UCAVs are unlikely to replace the manned aircraft for air combat missions in the policy relevant future. The future

---

[61] Other advanced air superiority fighters under development include the MiG 1.44MFI, the S-37 Berkut, and the Chinese built J-10 and J-12 aircraft. The proliferation of advanced S-300 and S-400 integrated air defense systems is also a serious concern for the Americans. Ballistic Missiles also pose a significant threat.
[62] The F-22 has been optimized for close air-to-air combat.
[63] The low altitude of tactical UAVs makes them susceptible to small arms fire. Strategic UAVs fly higher but at speeds observable by radar. Moreover, they may be within the range of modern SAMs. See Major Ronald L Banks, "The Integration of Unmanned Aerial Vehicles into the Function of Counterair" (Master's dissertation, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, US, 2000), p. 18.
[64] See Lt Col Kurt A Klausner, "Command and Control of the Air and Space Forces Requires Significant Attention to Bandwidth", *Air & Space Power Journal*, Winter 2002.
[65] Lewis, op. cit., p. 50. The small Stinger missile has minimal capability against manned aircraft and is a threat to friendly UAVs and helicopters. Directed energy weapons and lasers are ideal for use with UCAVs. However, initially they will require huge amount of power and will be too large to fit even on large commercial aircraft.
[66] Lewis, op. cit., p. 52.
[67] Manned platforms will mostly rely on passive sensors.

will see a mix of manned and unmanned platforms together with space weapons in counterair operations.

3.4 Mini/Micro-Aerial Vehicles

The United States is also heavily investing in a new class of unmanned platforms – Mini/Micro Aerial Vehicles (MAVs). MAVs are a subset of UAVs that are roughly two orders of magnitude smaller than manned systems (some as small as 6-inches). These compact lightweight air vehicles carrying miniature sensors play a key role in the war against terrorism.[68] While MAVs are more vulnerable to attack and loss due to their low altitude, this is compensated by the fact that they are extremely stealthy and very cheap. Their compact size and low weight will allow them to be carried by individual soldiers. The US Air Force is deploying MAVs for force protection in the shape of Lockheed Martin SentryEye.[69]

MAVs have tremendous potential for ISR operations. In the battlefield, they are likely to be operated by individual soldiers for local reconnaissance. MAVs integrated with a high-flying UAV will circumvent the need to develop foliage penetration sensors. They will also play an important role in urban operations where stealthy airborne assets closer to the ground may be required. In the sea, MAVs can also be deployed from ships to gather intelligence in order to prevent acts of maritime terrorism. They may also be fielded in a hostile environment to detect people with shoulder-fired missiles to attack aircraft. MAVs shall play an important role in real-time detection and analysis of a biological or a chemical agent in an infected environment. They are also likely to play an important role in humanitarian missions, e.g. searching for survivors amidst rubble from earthquakes.

Swarms of MAVs equipped with sensors and miniaturized warheads are theoretically capable of attacking high-value targets such as radars and launchers of SAM sites, i.e., they are likely to play an important role in SEAD missions in the future.[70] Global Positioning System (GPS) allows precise autonomous navigation and position reporting for MAVs, which are critical to

---

[68] Michael A Dornheim and Michael A Taverna, "War on Terrorism Boosts Deployment of Mini-UAVs", *Aviation Week & Space Technology*, 08 July 2002, and Mark Hewish, "Small, but well equipped", *Jane's International Defense Review*, 01 October 2002.
[69] Hewish, *Small, but well equipped*, op. cit.
[70] Ibid.

the military application of these technologies. Some of the limitations of this technology are its small range and high damage potential (especially due to the prevailing weather). Microelectromechanical systems (MEMS), micro-manufacturing and nanotechnology could provide an exponential leap in microminiaturization for weapons, sensors and platforms.[71]

4. FISCAL CHALLENGES

The US DoD is planning on investing around $10 billion in UAVs in the first decade of this century and plans to quadruple today's 90-aircraft inventory by then.[72] This invites comparison with the fact that the US Air Force has spent close to $20 billion on the F-22 air superiority fighter which will cost at least $100 million per aircraft to produce and will purchase close to 300 F-22s.[73] The US will also spend between $28 million to $38 million per aircraft on a new tactical fighter called the Joint Strike Fighter (JSF) and with the intention to purchase up to as many as 3,000 JSFs.[74] The total system cost of the Predator UAV, which is about $28.3 million, is about the same as a single seat F-16A.[75] Although the unmanned platform might be cheaper than its manned counterpart,[76] the UAV system on the whole is not always less expensive. Besides, it is estimated that the DARPA/Boeing X-45 UCAV will cost about $25 million (per unit).[77]

TABLE 1 Approximate costs of current and future manned and unmanned air platforms

Manned/Unmanned System	Cost
F-22 Raptor (per unit)	US$100 million
JSF (per unit)	US$28-38 million (depending upon specs.)
Predator System	~US$28 million
X-45 UCAV (per unit)	~US$25 million

[71] For the potential military applications of MAVs, see Timothy Coffey and John A Montgomery, "The Emergence of Mini UAVs for Military Applications", *Defense Horizons*, December 2002.
[72] David A Fulgham, "Pentagon Eyes Quadrupling UAV Force by 2010", *Aviation Week & Space Technology*, 17 February 2003.
[73] James Fallows. (2003). *Uncle Sam Buys an Airplane* [Online]. Available: http://www.theatlantic.com/issues/2002/06/fallows.htm [2003, December 26].
[74] Ibid.
[75] Lt Jeff Mustin. (2001). *Flesh and Blood: The Call for the Pilot in the Cockpit* [Online]. Available: http://www.airpower.maxwell.af.mil/airchronicles/cgo/mustin.html [2003, December 26]. It is important to think of UAVs/UCAVs as part of a system comprising the unmanned air vehicles (typically one to six), the sensor-shooter package, the control station (on ground or in the air), communications architecture, and other support equipment.
[76] A Predator UAV (single unit) costs around $4 million.
[77] Sweetman, op.cit., *UCAVs grow fat on requirements.*

It is clear from Table 1 that the unmanned platform does not necessarily offer the cost-effectiveness that it promises. Unmanned systems are "attritable", but not expendable, i.e., it is fine to lose them when the alternative to their loss is the manned aircraft. Expendability is not an option since these are not cheap systems. In addition, for the unmanned platform to replace the manned fighter, it must offer the same level of reliability as the manned platform (or exceed it). It should also be highlighted that UAVs are on an average lost at a much higher rate than manned aircraft.[78] DARPA, Boeing, and the US military are working together to develop a pure UCAV called the X-45 and its naval version UCAV-N, which are likely to play a major role in strike missions and electronic attacks in the future. These systems are likely to become operational in the 2008-2015 timeframe.[79] [80] Nevertheless, it is important to remember that these systems are still under development and would need to undergo extensive testing to prove their technological capability. Unless they are tried and tested in an actual operation (in small numbers at first), these systems are unlikely to challenge the manned platform in any significant way.

5. STRATEGIC IMPLICATIONS FOR SMALL AND MEDIUM POWERS

On the one hand, UAVs enable the United States to intervene militarily anywhere in the world whenever its interests are threatened (whether through ISR missions or in a combat capacity through surgical strikes, pre-emptive SEAD missions etc.) without putting its forces in harm's way. On the other hand, this possibility will drive certain nations to acquire armed UAVs and/or weapons of mass destruction (WMD) to oppose a US led intervention.[81] [82] It

[78] Predator cannot be launched in adverse weather including visible moisture. Moreover, a large number of crashes are due to human operator error. The crash rate of a Predator is an order of magnitude higher than the F-16. This rate will not be acceptable for multi-million dollar UCAV that costs as much as a manned fighter. See Sweetman, *UAVs Grow Fat on Requirements*.

[79] *Unmanned Combat Air Vehicle (X-45)*, [Online]. (No date). Available: http://www.boeing.com/phantom/ucav.html [2003, December 26].

[80] *UCAV-N Naval Unmanned Combat Air Vehicle*, [Online]. (No date). Available: http://www.boeing.com/defense-space/military/unmanned/ucav-n.html [2003, December 26].

[81] At least 40 countries have produced more than 600 different types of UAVs, many with ranges in excess of 300km. See Gormley, op. cit., p. 410.

[82] This notwithstanding, it is important for the strategic studies literature to study the implications of battlefield automation (especially societal implications from a moral perspective). Will the nature of war itself change when both belligerents fight with unmanned platforms, as this development is likely to change war into an economic transaction (an expensive video game) by removing the human from the equation? Unmanned technology is likely to give offensive forces a distinct advantage over defense. Will this increase the propensity for the belligerent equipped with unmanned platforms to attack its enemy especially if its enemy lacks these

must be emphasized that the greatest risk is posed by terrorist use of armed UAVs.[83] In the US missile defense system (especially those in the boost phase), UAVs are also likely to play an important role as interceptors to destroy ballistic missiles.[84] The proliferation of armed UAVs in the arsenals of its opponents is nonetheless going to complicate the cost-per-kill arithmetic for US missile defenses.[85] UAVs will also enable regional powers to bolster their power projection capabilities. India has raised its profile in the Indian Ocean Region by operationalizing its first full-fledged UAV base in Kochi where its Southern Naval Command is based. India also plans to set up UAV bases in Port Blair in the Andamans and Lakshadweep islands.[86]

What lessons should small and medium powers draw from the current and projected technological challenges and operational capabilities of UAVs/UCAVs? The extent to which small and medium powers can absorb high technology into their militaries depends on various factors. Singapore, with its well-educated workforce, knowledge-based economy, a sophisticated defense-industrial base, political stability and extensive ties with Western companies is well placed to absorb advanced technologies into its military forces.

It is in ISR missions where the use of UAVs is the most promising and it is precisely here where small and medium powers are advised to spend their resources and perhaps experiment with arming their UAVs. ISR capability will enable these states to gain "dominant battlespace knowledge" in a conflict, and their homeland security is further boosted when combined with an "armed reconnaissance" capability. They must bear in mind though that just developing these technologies is not enough; their successful integration into the services is an equally daunting and time-consuming task.[87] In addition to this, technological challenges especially bandwidth requirements and systems integration pose considerable hurdles. These states will need to invest in satellite technology to solve the bandwidth

advanced systems (since it will remove the human from the equation for the belligerent on the offense but not for the victim on the defense)?

[83] An unmanned aircraft's flight stability permits the effective release of biological agents along a line of contamination. Ibid., p. 413.

[84] *Unmanned Aerial Vehicles go through Major Expansion* (JINSA Online), [Online]. (2002). Available: http://www.jinsa.org/articles/articles.html/function/view/categoryid/164/documentid/1462/history/3,2360,656,164,1462 [2004, February 20].

[85] A Patriot PAC-3 missile costs $2-5 million compared to $50,000 for an aircraft adapted to become an armed UAV. Ibid., p. 411.

[86] Josy Joseph. (2003). *Navy to use UAVs to spy on sea-lanes* [Online]. Available: http://www.rediff.com/news/2003/jan/31uav.htm [2003, December 29].

[87] An important impediment to UAV integration is their operation by groups with minimal aviation expertise. Up to 20% of UAV losses are due to human error. See Bone and Bolkcom, op. cit., p.13.

limitation. UAVs are also likely to have numerous commercial applications that will interest small and medium powers, e.g., in telecommunications networks as relays, for crop spraying etc. This is good news for the defense sector, as it is likely that some of the research on unmanned technologies will be carried out by the commercial/university sector. Furthermore, many of the technologies involved (autopilot systems, satellite navigation and guidance systems, digital mapping technologies for mission planning, and collision avoidance systems etc.) are dual-use technologies.

The UCAV technology is still in its infancy and has not yet been demonstrated on the battlefield. The United States is perhaps the only country with enough resources to expend on this unproven (and thus far, unexperimented) technology. The high costs involved in experimenting with this immature technology means that small and medium powers should for the time being observe the trends in UCAV development in the US and not expend their limited resources pursuing it. It is important to remember that research and development costs continue to approximate double that of procurement costs.[88] Singapore realizes that its limited resources do not permit it to work the entire range of UAVs as compared to those undertaken by the US.[89] Singapore is working on a naval surveillance UAV named Lalee (low-altitude, long-enduring endurance). Presently in partnership with Singapore on the Lalee UAV, the European Aeronautic Defence and Space Company (EADS) has also shown a keen interest in other collaborative ventures with Singapore.[90] The US, France and Sweden have shown an interest in Lalee and are interested in collaborating with Singapore on it.[91]

Singapore's success in technologically sophisticated endeavors like *Bionix* makes it well positioned to enter into defense-industrial ventures (like collaboration, license production etc.) with other countries like Israel to meet the requirements of its armed forces and also to develop the export potential of the local defense industry.[92] Singapore's Defence Minister, Tony Tan, has in the past stated that Singapore will strengthen links with existing partners

[88] In 2003, the US spent $394 million on the procurement of the Global Hawk, the Predator, and the Shadow UAVs, but spent $805 million on UAV R&D costs. See Bone and Bolkcom, op. cit., p.6.
[89] Tan Peng Yam. (1999). *Harnessing Defense Technology – Singapore's Perspective* [Online]. Available: http://disam.osd.mil/pubs/INDEXES/journals/Journal_Index/v.21_3/Yam.pdf [2004, February 20].
[90] Felix Soh, "Pilotless attack jets by 2012", *The Straits Times*, 07 February 2002.
[91] Chan Kay Min, "Navy may use unmanned radar planes", *The Straits Times*, 11 May 2001.
[92] LTC Vijay Kumar, "Defence Collaboration: Policy Implications for Singapore", *Pointer* Vol. 27, No. 4 (October-December 2001).

and forge new ones as its defense technology needs increase.[93] Singapore is developing the Firefly UAV with Israeli technology. It is believed that Firefly is a high-altitude, high-speed reconnaissance platform, which can be converted into a cruise missile by fitting a warhead.[94] Singapore has in the past sold the Israeli UAV Blue Horizon to the Philippines. Singapore Technologies manufactured this UAV under contract with the Emit Aviation Consultancy of Israel.[95] Singapore Technologies is also working on several MAVs – Tailsitter, which is about the size of a golf bag, and the Sparrow, which is a palm-sized device. According to Tim Huxley, Singapore's investment in UAVs will also help Singapore with low-intensity concerns like monitoring of population and shipping movements to the south.[96]

In a nutshell, in spite of their size and budget constraints, UAVs are likely to find their way into the arsenals of small and medium powers. They will perform a central function in battlefield surveillance and even armed reconnaissance. MAVs with their potential to substantially transform urban operations and special operations missions will also interest small and medium powers. UAVs will also play a key homeland security role for these states. In addition to this, collaboration (especially in the area of research and development), licensed production and joint marketing are other areas that will allow small and medium powers (and maybe even some regional powers and the US) to come together for a joint effort.

6. CONCLUSION

The unmanned aerial vehicle is an innovative weapon system that avoids placing a pilot in harm's way, but it is not a truly disruptive technology as there will always be missions that will require the manned aircraft. Likewise, the unmanned platform has lesser flexibility, greater vulnerability and cannot analyze its environment. It is clear that many advanced unmanned platforms are as expensive as manned aircraft and their high cost makes them attritable, not expendable. Their software complexity, automation and communications

---

[93] "Defence technology to be Singapore's cutting edge: defence minister", *Agence France Presse*, 06 September 2000.

[94] *Singapore sets the pace*, [Online]. (2001). Available: http://www.global-defence.com/2001/RSpart3b.html [2004, February 20].

[95] "Philippines to acquire Israeli UAV Spy Plane for Use in Basilan", *The Philippine Star*, 25 July 2001. Courtesy Arms Trade Newswire [Online]. Available: http://www.clw.org/atop/newswire/nw072701.html [2004, February 20].

[96] Tim Huxley. *Singapore and the Revolution in Military Affairs* [Online]. Available: http://jciss.llnl.gov/IT_RMA/Huxley_Final.pdf [2004, February 20].

architecture makes them operationally unreliable for many missions. Thus far, communications technology has limited the effectiveness of the unmanned platform, especially its armed counterpart.

UAVs also face considerable challenge from competing systems like satellites and TLAMs. Satellites not only provide better situational awareness, but also avoid international norms for violating national/sovereign airspace and are thus far invulnerable to shoot down. TLAMs have proven superior in weapon delivery roles. However, many dull, dirty and dangerous missions will see an increased role for the unmanned platform.

UAVs are going to perform the critical ISR mission in future military operations where they are likely to perform tactical missions together with their manned counterpart upon obtaining cues from satellites. UCAVs and armed UAVs shall also perform strike and pre-emptive SEAD missions in the future, but are not likely to perform reactive SEAD missions due to the proliferation of sophisticated IADS worldwide. They are also likely to play an important but limited role in electronic attack missions. The proliferation of sophisticated counterair assets makes them unsuitable for counterair missions and communications and automotive technology limitations together with political ones (the authorization to fire) reduces their usefulness for combat missions. It is unlikely for the unmanned platform to make significant inroads into the force application role in the policy relevant future.[97]

Small and medium powers are likely to find UAVs useful in ISR roles only as the unmanned combat platform is still an unproven technology and is in its developmental stages. However, their potential for homeland security and commercial applications will give them prominence in the years ahead. The defense-industrial sector is likely to see an influx of new players from the commercial sector, as advances in the unmanned technologies are likely to have important commercial applications.

However, it is important to remember that unmanned platforms can never replace the manned aircraft, as the unmanned platform is just a machine that takes cues from the environment and follows a pre-defined set of instructions to react, i.e., it cannot analyze its environment. Even

[97] Advances in nanotechnology can boost the role of the unmanned platform (MAVs) in a combat mission. However, it must be remembered that advances in other new systems such as kinetic energy weapons and directed energy weapons will reduce the combat effectiveness of manned as well as unmanned aviation.

AI systems can at best only improve existing technology; they can never supplant the human under the uncertainties and rapid changes of war.

BIBLIOGRAPHY

1. "Defence technology to be Singapore's cutting edge: defence minister", *Agence France Presse*, 06 September 2000.
2. "Philippines to acquire Israeli UAV Spy Plane for Use in Basilan", *The Philippine Star*, 25 July 2001. Courtesy Arms Trade Newswire [Online]. Available: http://www.clw.org/atop/newswire/nw072701.html [2004, February 20].
3. Bone, Elizabeth and Christopher Bolkcom. *Unmanned Aerial Vehicles: Background and Issues for Congress* [Online]. Available: www.fas.org/irp/crs/RL31872.pdf [2003, December 04].
4. Bookstaber, David. *Unmanned Aerial Combat Vehicles – What men do in aircraft and why machines can do it better* [Online]. Available: www.airpower.maxwell.af.mil/airchronicles/cc/ucav.pdf [2003, December 11].
5. Chan, Kay Min, "Navy may use unmanned radar planes", *The Straits Times*, 11 May 2001.
6. Coffey, Timothy and John A Montgomery, "The Emergence of Mini UAVs for Military Applications", *Defense Horizons*, December 2002.
7. Col Chapman II, Robert E. "Unmanned Combat Aerial Vehicles – Dawn of a New Age?", *Aerospace Power Journal*, Summer 2002.
8. *DOD Dictionary of Military Terms* [Online]. (2003). Available: http://www.dtic.mil/doctrine/jel/doddict/data/u/05601.html [2003, December 04].
9. Donnelly, Thomas and Michael Vickers. *Iraq: Lessons Learned* [Online]. Available: http://www.aei.org/events/filter.,eventID.337/summary.asp [2003, December 08].
10. Dornheim, Michael A and Michael A Taverna, "War on Terrorism Boosts Deployment of Mini-UAVs", *Aviation Week & Space Technology*, 08 July 2002.
11. Ehrhard, Thomas P. *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation*. Ph.D. dissertation, Johns Hopkins University, 2000.
12. *F-22 Raptor*, [Online]. (2000). Available: http://www.fas.org/man/dod-101/sys/ac/f-22.htm [2003, December 16].

13. Fallows, James. *Uncle Sam Buys an Airplane* [Online]. Available: http://www.theatlantic.com/issues/2002/06/fallows.htm [2003, December 26].

14. Fulgham David A. "Predator's Progress", *Aviation Week and Space Technology*, 03 March 2003.

15. Fulgham, David A. "Pentagon Eyes Quadrupling UAV Force by 2010", *Aviation Week & Space Technology*, 17 February 2003.

16. Fulgham, David A. "Stinger Eyed for UAV Role", *Aviation Week and Space Technology*, 04 March 2002.

17. Garamone, Jim. *Predator Demonstrates worth over* Kosovo [Online]. Available: http://www.fas.org/irp/program/collect/docs/n19990921_991750.htm [2003, December 05].

18. Gen Jumper, John. "Global Strike Task Force", *Air Power Journal*, Spring 2001, p. 27.

19. Hewish, Mark. "Small, but well equipped", *Jane's International Defense Review*, 01 October 2002.

20. Hewish, Mark. "Unmanned, unblinking, undeterred", *Jane's International Defense Review*, 01 September 2002.

21. Huxley, Tim. *Singapore and the Revolution in Military Affairs* [Online]. Available: http://jciss.llnl.gov/IT_RMA/Huxley_Final.pdf [2004, February 20].

22. *Joint Vision 2020* [Online]. (2000). Available: http://www.dtic.mil/jointvision/jv2020.doc [2003, December 08].

23. Joseph, Josy. *Navy to use UAVs to spy on sea-lanes* [Online]. Available: http://www.rediff.com/news/2003/jan/31uav.htm [2003, December 29].

24. Kaufman, Gail. "Shot Fewer Missiles than in Afghanistan", *Defense News*, 08 December 2003.

25. Keaney, Thomas A and Eliot A Cohen. *Gulf War Air Power Survey Summary Report* (Washington D.C.: US Government Printing Office, 1993).

26. Keaney, Thomas A and Eliot A Cohen. *Revolution in Warfare? Air Power in the Persian Gulf*. Annapolis: Naval Institute Press, 1995.

27. Krepinevich, Andrew. *Operation Iraqi Freedom: A First Blush Assessment* [Online]. Available: http://www.csbaonline.org/4Publications/Archive/R.20030916.Operation_Iraqi_Fr/R.20030916.Operation_Iraqi_Fr.htm [2003, December 05].

28. Lt Col Clark, Richard M. *Uninhabited Combat Aerial Vehicles – Airpower by the People, For the People, But Not with the People.* CADRE Paper No. 8, College of Aerospace

Doctrine Research and Education, Air University, Maxwell Air Force Base, Alabama, US, 2000.

29. Lt Col Klausner, Kurt A. "Command and Control of the Air and Space Forces Requires Significant Attention to Bandwidth", *Air & Space Power Journal*, Winter 2002.
30. Lt Mustin, Jeff. *Flesh and Blood: The Call for the Pilot in the Cockpit* [Online]. Available: http://www.airpower.maxwell.af.mil/airchronicles/cgo/mustin.html [2003, December 26].
31. LTC Kumar, Vijay. "Defence Collaboration: Policy Implications for Singapore", *Pointer* Vol. 27, No. 4 (October-December 2001).
32. Major Banks, Ronald L. *The Integration of Unmanned Aerial Vehicles into the Function of Counterair*. Master's dissertation, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, US, 2000.
33. Major Lewis, William K. *UCAV – The Next Generation Air Superiority Fighter*. Master's dissertation, School of Advanced Air Power Studies, Air University, Maxwell Air Force Base, Alabama, US, 2002.
34. Major O'Reilly, Thomas G. *Uninhabited Air Vehicle – Critical Leverage System for our Nation's Defense in 2025*. Master's dissertation, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama, US, 1999.
35. McWethy, John. *Robo-Planes* [Online]. Available: http://abcnews.go.com/sections/wnt/DailyNews/roboplane020501.html [2003, December 05].
36. O'Hanlon, Michael. *Technological Change and the Future of Warfare*. Washington, D.C.: Brookings Institution Press, 2000.
37. Persinos, John, "Unmanned Aerial Vehicles: On the Rise", *Aviation Today*, February 2002.
38. *Singapore sets the pace*, [Online]. (2001). Available: http://www.global-defence.com/2001/RSpart3b.html [2004, February 20].
39. *SIPRI Yearbook 2003 – Armaments, Disarmament and International Security*. Oxford: Oxford University Press, 2003.
40. Soh, Felix. "Pilotless attack jets by 2012", *The Straits Times*, 07 February 2002.
41. *Spy Plane Hunting Bin Laden* [Online]. (2001). Available: http://news.bbc.co.uk/1/hi/world/americas/1670246.stm [2003, December 04].
42. Sweetman, Bill. "UCAVs grow fat on requirements", *Jane's International Defense Review*, 01 May 2003.

43. Tan, Peng Yam. (1999). *Harnessing Defense Technology – Singapore's Perspective* [Online]. Available: http://disam.osd.mil/pubs/INDEXES/journals/Journal_Index/v.21_3/Yam.pdf [2004, February 20].
44. Tirpak, John A. "The Double Digit SAMs", *Air Force Magazine*, June 2001.
45. *UCAV-N Naval Unmanned Combat Air Vehicle*, [Online]. (No date). Available: http://www.boeing.com/defense-space/military/unmanned/ucav-n.html [2003, December 26].
46. *Unmanned Aerial Vehicles go through Major Expansion* (JINSA Online), [Online]. (2002). Available: http://www.jinsa.org/articles/articles.html/function/view/categoryid/164/documentid/1462/history/3,2360,656,164,1462 [2004, February 20].
47. *Unmanned Aerial Vehicles Roadmap 2002-2027* [Online]. Available: http://www.acq.osd.mil/usd/uav_roadmap.pdf [2003, December 08].
48. *Unmanned Combat Air Vehicle (X-45)*, [Online]. (No date). Available: http://www.boeing.com/phantom/ucav.html [2003, December 26].
49. *US Drone Takes Combat Role* [Online]. (2002). Available: http://news.bbc.co.uk/1/hi/world/2404425.stm [2003, December 04].

IDSS Working Paper Series

16. Crisis and Transformation: ASEAN in the New Era (2001)
Etel Solingen

17. Human Security: East Versus West? (2001)
Amitav Acharya

18. Asian Developing Countries and the Next Round of WTO Negotiations (2001)
Barry Desker

19. Multilateralism, Neo-liberalism and Security in Asia: The Role of the Asia Pacific Economic Co-operation Forum (2001)
Ian Taylor

20. Humanitarian Intervention and Peacekeeping as Issues for Asia-Pacific Security (2001)
Derek McDougall

21. Comprehensive Security: The South Asian Case (2002)
S.D. Muni

22. The Evolution of China's Maritime Combat Doctrines and Models: 1949-2001 (2002)
You Ji

23. The Concept of Security Before and After September 11 (2002)
    a. The Contested Concept of Security
       Steve Smith
    b. Security and Security Studies After September 11: Some Preliminary Reflections
       Amitav Acharya

24. Democratisation In South Korea And Taiwan: The Effect Of Social Division On Inter-Korean and Cross-Strait Relations (2002)
Chien-peng (C.P.) Chung

25. Understanding Financial Globalisation (2002)
Andrew Walter

26. 911, American Praetorian Unilateralism and the Impact on State-Society Relations in Southeast Asia (2002)
Kumar Ramakrishna

27. Great Power Politics in Contemporary East Asia: Negotiating Multipolarity or Hegemony? (2002)
Tan See Seng

28. What Fear Hath Wrought: Missile Hysteria and The Writing of "America" (2002)
Tan See Seng

29. International Responses to Terrorism: The Limits and Possibilities of Legal Control of Terrorism by Regional Arrangement with Particular Reference to Asean (2002)
Ong Yen Nee

30. Reconceptualizing the PLA Navy in Post – Mao China: Functions, Warfare, Arms, and Organization (2002)
Nan Li

31. Attempting Developmental Regionalism Through AFTA: The Domestics Politics – Domestic Capital Nexus (2002)
Helen E S Nesadurai

32. 11 September and China: Opportunities, Challenges, and Warfighting (2002)
Nan Li

33. Islam and Society in Southeast Asia after September 11 (2002)
Barry Desker

34. Hegemonic Constraints: The Implications of September 11 For American Power (2002)
Evelyn Goh

35. Not Yet All Aboard…But Already All At Sea Over Container Security Initiative (2002)
Irvin Lim

36. Financial Liberalization and Prudential Regulation in East Asia: Still Perverse? (2002)
Andrew Walter

37. Indonesia and The Washington Consensus (2002)
Premjith Sadasivan

38. The Political Economy of FDI Location: Why Don't Political Checks and Balances and Treaty Constraints Matter? (2002)
Andrew Walter

39. The Securitization of Transnational Crime in ASEAN (2002)
Ralf Emmers

40. Liquidity Support and The Financial Crisis: The Indonesian Experience (2002)
J Soedradjad Djiwandono

41. A UK Perspective on Defence Equipment Acquisition (2003)
David Kirkpatrick

42. Regionalisation of Peace in Asia: Experiences and Prospects of ASEAN, ARF and UN Partnership (2003)
Mely C. Anthony

43. The WTO In 2003: Structural Shifts, State-Of-Play And Prospects For The Doha Round (2003)
Razeen Sally

44. Seeking Security In The Dragon's Shadow : China and Southeast Asia In The Emerging Asian Order (2003)
Amitav Acharya

45. Deconstructing Political Islam In Malaysia: UMNO'S Response To PAS' Religio-Political Dialectic (2003)
Joseph Liow

46. The War On Terror And The Future of Indonesian Democracy (2003)
Tatik S. Hafidz

47. Examining The Role of Foreign Assistance in Security Sector Reforms: The Indonesian Case (2003)
Eduardo Lachica

48. Sovereignty and The Politics of Identity in International Relations (2003)
Adrian Kuah

49. Deconstructing *Jihad*; Southeast Asian Contexts (2003)
Patricia Martinez

50. The Correlates of Nationalism in Beijing Public Opinion (2003)
Alastair Iain Johnston

51. In Search of Suitable Positions' in the Asia Pacific: Negotiating the US-China Relationship and Regional Security (2003)
Evelyn Goh

52. American Unilaterism, Foreign Economic Policy and the 'Securitisation' of Globalisation (2003)
Richard Higgott

53. Fireball on the Water: Naval Force Protection-Projection, Coast Guarding, Customs Border Security & Multilateral Cooperation in Rolling Back the Global Waves of Terror from the Sea (2003)
Irvin Lim

54. Revisiting Responses To Power Preponderance: Going Beyond The Balancing-Bandwagoning Dichotomy (2003)
Chong Ja Ian

55. Pre-emption and Prevention: An Ethical and Legal Critique of the Bush Doctrine and Anticipatory Use of Force In Defence of the State (2003)
Malcolm Brailey

56. The Indo-Chinese Enlargement of ASEAN: Implications for Regional Economic Integration (2003)
Helen E S Nesadurai

57. The Advent of a New Way of War: Theory and Practice of Effects Based Operation (2003)
Joshua Ho

58. Critical Mass: Weighing in on *Force* Transformation & *Speed Kills* Post-Operation Iraqi Freedom (2004)
Irvin Lim

59. Force Modernisation Trends in Southeast Asia (2004)
Andrew Tan

60. Testing Alternative Responses to Power Preponderance: Buffering, Binding, Bonding and Beleaguering in the Real World (2004)
Chong Ja Ian

61. Outlook on the Indonesian Parliamentary Election 2004 (2004)
Irman G. Lanti

62. Globalization and Non-Traditional Security Issues: A Study of Human and Drug Trafficking in East Asia (2004)
Ralf Emmers

63. Outlook for Malaysia's 11th General Election (2004)
Joseph Liow

64. Not *Many* Jobs Take a Whole Army: Special Operations Forces and The Revolution in Military Affairs. (2004)
Malcolm Brailey

65. Technological Globalisation and Regional Security in East Asia (2004)
J.D. Kenneth Boutin

66. UAVs/UCAVS – Missions, Challenges, and Strategic Implications for Small and Medium Powers (2004)
Manjeet Singh Pardesi