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**AN EXTENDED ROLE FOR UNMANNED AERIAL
VEHICLES IN THE ROYAL AUSTRALIAN AIR FORCE**

By

**Wing Commander Mark Lax and Wing Commander Barry
Sutherland**

About the Authors

Wing Commander Mark Lax joined the RAAF in 1974 and has had flying tours on C-130 and F-111 aircraft, and at the Aircraft Research and Development Unit. Prior to his latest posting on staff at the RAAF Air Power Studies Centre, he was the Commanding Officer of Base Squadron East Sale. During his time at the Centre, he was the editor of a number of publications on air power and is completing a history of No. 1 Squadron for publication. He is a graduate of the RAAF Academy, the RAAF Command and Staff Course and the RAF Aerosystems Course. He is currently attending USAF Air War College.

Wing Commander Barry Sutherland joined the RAAF in 1969 and has served in a variety of staff and base postings, mostly involved in air and ground training, including exchange duties with the RAF, Director of the RAAF Officers Training Schools and Commanding Officer of Base Squadron Williams. He has worked on a number of projects including electronic warfare operations, air base support, Tornado conversion training, and airmen education training. He is a graduate of the RAAF Advanced Staff Course and is currently on staff at the RAAF Air Power Studies Centre.

INTRODUCTION

Unmanned experimental aircraft have been under continuous development since the first British program early in World War I to produce remotely controlled pilotless aircraft to counter German airships and reduce aircrew casualties. Although operational derivatives of these unmanned aircraft have been used as reconnaissance and surveillance vehicles by the military over the last 35 years, there have been markedly low levels of expenditure to date on developing other uses for them. In the same period, however, the support, development and success of unmanned spacecraft have been significant compared with those of unmanned aircraft. For a number of valid reasons, manufacturers have chosen to continue along a cautious path of improvement to pilotless vehicles. As a result, these vehicles, now termed unmanned aerial vehicles (UAVs), have remained until recently relatively simple vehicles rather than the more complex vehicles required for offensive uses. With some limited exceptions, most vehicles up to about 1993 had limited range, were generally unarmed, had poor self-protection, and were employed mainly in direct support of surface forces.

Recent technological developments in propulsion systems, composite materials, multi-spectral stealth, guidance systems, and miniaturisation of sensor and weapon systems now allow relatively cheap UAVs to operate in a wide variety of roles, including those where they act as offensive weapons. But to date, most forces have shown little interest in pursuing this option - this is particularly true for air forces. The obvious question is - why? This paper will examine the composition of UAV systems, their past, present and projected developments, how they might be evaluated as alternatives to present systems, and the issues the ADF generally and the RAAF specifically must address in considering their employment in meeting Australia's unique defence requirements.

WHAT IS A UAV?

For the purposes of this paper, a UAV is defined as:

an aerial vehicle without an on-board human operator that uses aerodynamic forces to support its flight in a desired, non-ballistic path under autonomous or remote control to carry lethal or non-lethal payloads. The UAV can be expendable or recoverable.

Because there is a wide variety of UAVs with a broad range of capabilities, their arrangement into a classification system can be difficult. To understand the classification of UAVs, their development and how they can be evaluated in comparison to manned vehicles, an appreciation of the overall elements of a UAV system is first required.

UAV System Components

From the above definition, some general characteristics of UAVs can be identified. These characteristics are determined by the UAV design, construction, on-board and ground support systems which in turn are determined by five key operational

requirements: endurance, speed, radius of action, altitude and gross take-off weight. Examining the nature of UAVs by considering only the air vehicle and not the total package can be deceptive and over-simplify their operation. UAV systems can consist of the following elements:¹

- a. an airframe,
- b. a propulsion system,
- c. a control system,
- d. a launch and recovery system,
- e. a navigation and guidance system,
- f. a ground control station/mission support system,
- g. a payload,
- h. a data link and data storage system,
- i. a self protection system, and
- j. operating personnel.

Airframe

The required capabilities for a UAV, such as the operational ceiling, range, endurance, loiter and dash speeds, and payload determine its airframe dimensions, shape and construction materials. These airframe features in turn affect the UAV's ease of detection, destruction, repair and maintenance. UAV airframes can range from the simple, model-like 3.9 kilogram Pointer UAV capable of being carried dismantled on a soldier's back and launched by hand, to the 10,500 kilogram Global Hawk UAV. Shapes can range from the conventional rectangular box frame of the Israeli Aircraft Industries (IAI) Pioneer to the 'peanut shaped' Canadair CL-227 Sentinel vertical take-off and landing (VTOL) vehicle to the sleek DarkStar stealth UAV. Construction materials can range from metal or glass reinforced plastics to carbon fibre composites and radar absorbent materials.

Propulsion System

UAV propulsion systems include conventional two-stroke, four-stroke and rotary internal combustion engines (with or without turbocharging), electric motors, rocket motors and turbojet engines. Thrust for some UAVs during ground launching may be augmented by catapults or rockets while some can be air launched to increase the effective range/endurance. Power can be provided by liquid fuels for most

¹ The most crude UAVs may not contain all of these systems. The German V1 'Buzz Bombs' of World War II had neither a sensor nor a data link/data storage (work was in hand to develop these), yet could still be classified as a UAV. Most modern systems have all elements but of varying degrees of complexity.

conventional engines, solid fuel for some rocket motors, and batteries for electric motors.² Although some UAVs with internal combustion engines use Avgas, the difficulties in obtaining and handling this fuel in the field have prompted research into engines that can use the more easily obtained and less dangerous fuel oil. Endurance, ceiling and payload are affected by the thrust available and the fuel capacity. The increased availability of small, lightweight and inexpensive turbojets, with turboprop and turboshaft derivatives, is expanding the roles for UAVs, including their use as decoys under the US miniature air-launched decoy (MALD) program.³ Experiments to extend endurance using new propulsion systems include the closed cycle piston engine, microwave power via a ground transmitter, and the solar-powered AeroVironment Pathfinder UAV, which is hoped to operate up to 75,000 feet.

Control System

UAVs can be operated using either control signals from a remote location (air or surface), or pre-programmed instructions, providing automatic or autonomous control. While some flying skills are required to manually and remotely control most UAVs effectively, some vehicles such as the British Phoenix now employ a flight control system (FCS) which does not require the controller to have flying skills. Although the controller launches the vehicle and the recovery is made by parachute, flight control during the mission is accomplished by the on-board FCS and navigation system.⁴ Although autonomously controlled vehicles are capable of performing their full mission profiles from take-off to landing without human intervention, changes can generally be made to mission profiles during flight by transmitting data from a remote location.

To control the UAV's attitude, airspeed and height, on-board sensors are required to collect and relay information either to the remote controller or the on-board FCS. Although most catastrophic losses of UAVs have been attributed to failure of guidance gyro or FCS components, technological improvements such as solid-state gyros and other solid state sensors are improving reliability and performance.⁵ An important recognition is that UAVs retain human control, albeit from outside, rather than from on-board the vehicle. Thus the operator is removed from the cockpit but not from the mission, an important feature not always recognised by those who would criticise the use of UAVs, even for basic reconnaissance missions.

Launch and Recovery System

A variety of systems exist for launching and recovering UAVs. Launch systems can be fixed or mobile and be as simple as bungee or pneumatic powered catapults to semi-prepared or fully paved runways, depending on the size and performance of the UAV. Larger UAVs such as those from the Teledyne Ryan Aeronautical (TRA) Firebee family can be air launched from aircraft such as the C130 while smaller

² The German Dornier company, in a novel approach, developed a rotary wing vehicle obtaining its electric power through a tethering cable.

³ 'Miniature Jet Engines Spawn Multiple Applications', *Jane's International Defense Review*, April 1996, pp 15-16.

⁴ Beat, Clifford, Bodman, John and Hewish, Mark, 'UAV development: the art of compromise', *International Defence Review*, May 1993, p 378.

⁵ *ibid.*, p 378.

vehicles, such as the TRA BQM-145A Medium Range UAV can be air launched from the F/A-18 Hornet. Recovery can be by parachute, either to the ground or for mid-air retrieval using a helicopter fitted with the US developed mid-air recovery system (MARS).

Smaller UAVs can be landed on a semi-prepared landing area with or without an arrestor system, or into a net. Larger UAVs such as the DarkStar require a paved runway with the appropriate navigation and landing aids. The requirements for launching and recovering a UAV may therefore have a significant effect on the ground support needed and the equipment required for deployments.

Navigation and Guidance System

Navigation and guidance systems are essential for UAVs operating out of line-of-sight and having limited or no human input after the start of the mission. Simple UAVs may be guided either directly by the controller maintaining visual contact or indirectly using a visual display relayed from the UAV to the controller by an on-board sensor for scene matching. Guidance for more complex vehicles may include inertial, global positioning system (GPS), long range aircraft navigation systems and terrain matching, possibly linked into a FCS.

The guidance system may also be linked to the payload to relay instructions for activation. For UAVs dependent on instructions relayed from a remote station, the guidance may be that required to allow the vehicle to fly from waypoint to waypoint. Vehicles requiring extreme guidance accuracy for autonomous take-offs and landings can use a Differential GPS. This modified GPS system is based on a ground station at a known datum providing differential corrections to the on-board GPS receiver for more accurate guidance. Accuracy of the order of two metres SEP⁶ can be achieved within a radius of approximately 800 kilometres of the reference receiver. UAVs employing autonomous or part autonomous control will have a mission computer as part of the overall navigation and guidance system.

Ground Control Station/Mission Support System

Like a manned aircraft, a UAV is dependent on a ground support infrastructure that varies in accordance with the comprehensiveness and complexity of the mission and the UAV's capability. Remote piloted vehicles (RPV) require a ground control station (GCS) for at least flight control while autonomous UAVs require a GCS for mission monitoring and changes. A mission support system (MSS) will also be required for planning and for receiving mission data transmitted from the vehicle. Sensors and weapons can also be controlled from the GCS. This support infrastructure adds considerably to the overall system cost, complexity, and to the amount of equipment transported as part of deploying UAVs.

⁶ Spherical Error Probable - a three-dimensional measure of accuracy, expressed as a radius, which represents a sphere into which 50 per cent of measurements fall.

Payload

The capability of a UAV is determined ultimately by its payload which, in the majority of present vehicles, consists of sensors. Sensors carried by UAVs vary in type and performance according to the role of the UAV and the mission requirements. A sensor stabilisation system is also required to eliminate platform movement from the imagery. Increases in computing power, coupled with reductions in the size, weight and power requirements of the sensors and their control systems, are progressively increasing the capabilities and uses of UAVs.

While UAV payloads have been predominantly sensors, experiments have been successfully conducted in launching weapons from UAVs. For example, two Mk 82 bombs have been released from a TRA Firebee, and a Maverick ASM has been fired from a TRA 234. Miniaturisation of weapons is improving the flexibility in employing UAVs with an increasing number of UAVs under development being considered for offensive roles. A list of payloads for various roles is shown in Table 1.

Table 1 - UAV Role and Possible Payloads

Recce & Surveillance	Infra-red (IR) Electro-optical (EO) EW Sensor Synthetic Aperture Radar (SAR)
Targeting	IR EO Radar EW Sensor Laser
Electronic Warfare	ESM Suite ECM Suite EPM Suite
Comms	Radio Microwave Relay Laser
Deception	Decoy ECM Suite
Offensive Operations	Warhead/ Kinetic Energy Penetrator EMP Weapon Directed Energy Weapon

Data Link and Data Storage System

Data links are required for communications between the UAV and the GCS/MSS. Data transmitted to the UAV may be for control of the platform, control of the payload or relay purposes. Data transmitted from the vehicle may relate to information collected by the sensors or to the performance parameters of the platform, the payload or relay. Linking can use high frequency (HF), very high frequency (VHF), ultra high frequency (UHF) or microwave bands. An advantage of HF data links is that they are not limited to line-of-sight transmissions. Past bandwidth and range limits which have restricted the use of HF links, however, are gradually being overcome.

While some UAVs use VHF data links, most use UHF or microwave links as these have sufficient bandwidths to carry real-time video signals. When sensor data cannot be transmitted by line-of-sight communications direct to the GCS, it can either be stored or transmitted in real-time via relays such as satellites, aircraft, other UAVs, ships and other ground stations. Data relayed via satellites requires the UAV to have an antenna system that is steerable and large enough for establishing the satellite links. As data links are regarded as one of the major weak points in UAVs, their design needs to be capable, reliable and robust.⁷ With the data linking being crucial to both control of the UAV and the retrieval of data collected, its susceptibility to jamming or corruption needs to be prevented by a protection system. While the ground to UAV link is usually a narrow beam of energy and hence difficult to jam, the UAV requires an omni-directional antenna which increases its vulnerability.

If the data is not transmitted in real-time, the UAV needs an on-board data storage system from which the information can be retrieved either through later transmission to a ground station, giving a near-real-time transmission capability, or on the ground at the completion of the mission. Data storage systems can be substantial, depending on the sensor, amount of data collected and its ease of compression. For example, a high quality, high definition photograph collected digitally through an electro-optical system may require up to one gigabyte of storage.⁸ Data compression techniques enable narrower bandwidths to be used for transmitting such data, allowing shorter transmission times and more mission data to be stored for a given storage capacity. Compressing the data, however, usually causes some loss of definition in the image depending on the system used. Compression ratios can range from as low as two to one to as high as one hundred to one. Where the data being collected exceeds the data transmission capacity with or without compression, a proportion of the images able to be accommodated by the capacity, such as one in forty, can instead be transmitted in real-time. The amount of quality loss regarded as acceptable will be a compromise between the degree of detail required in the imagery and the total area to be covered.

Self-Protection Systems

The smaller, cheaper tactical UAVs generally have no self-protection system; instead, they depend on their own inherent characteristics of small size, and low noise and

⁷ Beat, Clifford, Boatman, John and Hewish, Mark, *International Defense Review*, p 378.

⁸ An ordinary 203mm x 203mm picture has 1024x1024 pixels with each pixel constituting 16 bits, thereby giving a total of approximately 2.1 megabytes of data.

thermal emission signatures for protection. Larger UAVs, which cannot be regarded as easily expendable, may need to carry self-protection systems similar to those of manned aircraft, according to the hostility of the operating environment. These may include a radar warning receiver, ECM, towed decoys, flares and chaff. Without a pilot to provide situational awareness, more sensors are required by the UAV to detect and respond to threats, adding additional weight and thus reducing the useable payload. As most UAVs at some time will be required to operate in the same airspace as other friendly and unfriendly manned and unmanned aircraft, an identification friend or foe (IFF) system will be necessary to avoid friendly fire incidents.

Operating Personnel

The number of personnel required to operate UAVs varies according to the capability, complexity and mission profile. In terms of maintenance, the number of maintenance personnel can be expected to be comparable to that required for manned platforms of similar complexity. Likewise, the number of personnel required to receive and process imagery would be similar to that required by a manned aircraft performing a similar task. The major difference arises in controlling the UAV for the entire mission profile. At the 11th Reconnaissance Squadron established by the USAF in 1995, rated pilots are being used initially to control the unit's present Predator UAVs and for the future control of an anticipated acquisition of Global Hawks and DarkStars. This decision is based on accident rates to date being lower for UAVs controlled by rated pilots compared to those controlled by non-rated pilots.⁹ In the future, USAF officials believe that, with improved training, the control role may be transferred to enlisted personnel who are certified civil pilots.¹⁰

Using experienced Service-trained pilots to control UAVs increases their operating cost and therefore contributes to reducing their overall cost advantage. Yet with the cost of the more complex UAVs in the range of US\$3-10 million, vehicles cannot be treated as easily expendable. Effective training, combined with improved FCSs, offers greater opportunities to employ less highly trained controllers. At the same time, expert systems with software incorporating the skills of experienced aircrew and payload specialists could be developed for mission planning and mission control of platforms and payloads.

TYPES OF UAV

At present, there is no generally accepted classification system for UAVs. Potentially, UAVs can be classified in several ways, according to criteria such as the control system, sensor and mission. Two distinct groups result if the classification is based on the control system: the RPV and the autonomous UAV. While sharing features, their operation is quite different. An RPV follows the data link commands of a remote station to achieve a specific air mission while the autonomous UAV is usually pre-programmed to complete a specific mission. UAVs can be further classified based on whether they are either expendable (ie single mission, typically a missile) or

⁹ The term 'rated' is used by the USAF to denote 'qualified military aircrew' and is similar in context to the term 'General Duties' used by the RAAF to denote aircrew personnel.

¹⁰ Fulghum, David A., 'Air Force Prepares New UAV Acquisitions, Operations', *Aviation Week & Space Technology*, 27 November 1995, p 53.

recoverable to a particular friendly location, not necessarily an airfield (multi-mission). The modern air, land or sea launched cruise missile is in essence a sophisticated, autonomous, single-mission UAV. Another further sub-category is the target drone or decoy. Now known as unmanned aerial targets (UATs), they may be either remotely piloted or autonomously controlled, depending upon the nature of the task. Figure 1 shows the types of UAVs, based on a classification by control system and reusability.

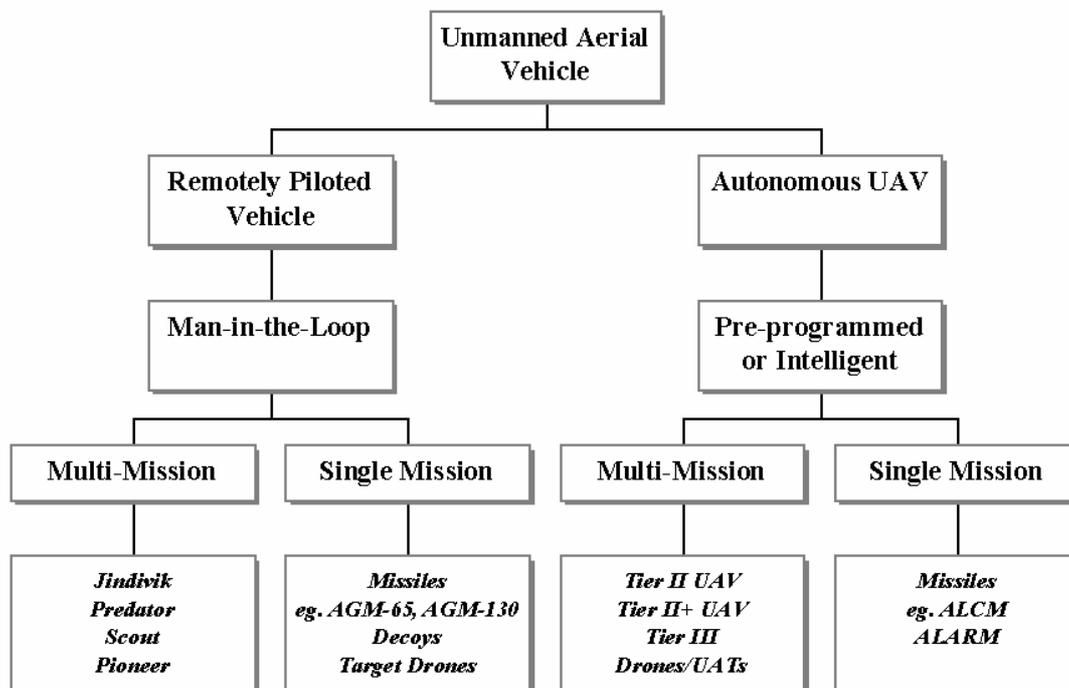


Figure 1 - UAV Classifications

Another classification system used by the US is based on the general capabilities of altitude, range and endurance. This system employs three broad categories of Tier I, Tier II or Tier III, with sub-categories such as Tier II Plus and Tier III Minus. Table 2 describes some features for those categories where information is currently available.

THE DEVELOPMENT OF UAVS

The UAV of today is the result of an evolutionary process that has ebbed and flowed throughout the history of military aviation. Instrumental in paving the way for UAVs was the development of radio and suitable servo mechanisms. After many unsuccessful attempts to develop UAVs during and after World War I, one of the first successes was the British 'Queen Bee'. This was a radio controlled pilotless version of the DH82a Tiger Moth, developed as a target drone for the Royal Navy between 1934 and 1943.

Table 2 - Tier Classification and Characteristics

Category	Designation	Max Alt	Radius	Speed	Endurance	Example
Tier I	Interim-Medium Altitude Endurance	Up to 15,000 ft	Up to 250 km	60-100 kts	5 - 24 hrs	Pioneer; Searcher
Tier II	Medium Altitude Endurance	3,000 ft to 25,000 ft	900 km	70 kts cruise	More than 24 hrs	Predator (Used in Bosnia)
Tier II Plus	High Altitude Endurance	65,000 ft max	Up to 5,000 km	350 kts cruise	Up to 42 hrs	Global Hawk (expected to fly Dec 96)
Tier III Minus	Low Observable-High Altitude Endurance	45,000 ft - 65,000 ft	800 km	300 kts cruise	Up to 12 hrs	DarkStar (enters service 1999)

The Development of UAVS

During World War II, German scientists led major developments in several radio controlled weapons, including the Henschel Hs 293 and Fritz X guided bombs, the Enzian rocket, and radio controlled aircraft filled with explosives. Despite their limited development, the Fritz X and Hs 293 were used predominantly in the Mediterranean with devastating effects against heavily armoured warships. Less sophisticated, and with a political rather than a military impact in mind, was the highly successful pulse jet propelled V1 'Buzz Bomb'. Capable of either air or surface launch, the success of the V1 was indirect in the disproportionate defence response by the Allies to counter it - a defence versus offence cost ratio of four to one.¹¹ During the same period, most of the limited UAV experiments conducted by the Allies were unsuccessful.

After the end of World War II, however, continued development of some of the US weapons led to their successful employment in the Korean War, particularly the use of the Tarzon radio-controlled bomb against bridges. The 1950s also saw the emergence of technology to fulfil the strategic strike role by both manned and unmanned craft. Three classes of strategic air weapons emerged: the manned aircraft, the intercontinental ballistic missile (ICBM) and the air launched cruise missile (ALCM). The tug-of-war for dominance in the strategic air role had begun. The advent of nuclear weapons overcame the problem of ICBM inaccuracy in most cases¹² and, to the doyens of air power thinking at the time, the ICBM was the cost effective solution to the strategic strike mission. In Britain, the 1957 White Paper even went so far as to announce that the future RAF would be unlikely to require manned fighters or bombers. Although history has shown the fallacies of the Paper's predictions, its

¹¹ Armitage, Sir Michael, *Unmanned Aircraft*, Brassey's Air Power: Aircraft, Weapons Systems and Technology Series, Volume 3, Brassey's Defence Publishers London 1988, p 17.

¹² ICBM inaccuracy is due primarily to inertial guidance system errors and control errors associated with re-entry. The error magnitude is still in the order of 200m CEP, but surprisingly, even with nuclear warheads this is still too high for some applications. See Bunn et al in 'The Uncertainties of a Preemptive Nuclear Attack', *Scientific American Magazine*, November 1983, p 33.

major repercussion was to start a demise in the British manned aircraft industry, with some 42 major projects being cancelled.¹³ Meanwhile, the US, Soviets and others kept their various manned and unmanned aircraft options open.

US Experience in South-East Asia

By the early 1960s, RPVs were being used by the US to monitor missile developments in both the Soviet Union and Cuba. *Project Red Wagon* was established to determine the feasibility of reconnaissance UAVs, primarily as a result of the political embarrassment arising from the shooting down of an RB-47 and two U-2 spy planes.¹⁴ In Vietnam, the use of UAVs increased as the demand for US resources grew and the losses in US airmen and aircraft mounted. Although most vehicles used in theatre flew pre-programmed missions collecting photographic data which was stored until the end of the mission, they were also used innovatively for EW and other purposes. In the first flight of the newly developed TRA 147E UAV on an EW mission, the value of the information gained was graphically demonstrated. Despite being eventually shot down, the UAV transmitted details of the North Vietnamese SA-2 missile system. Such was the value of this intelligence that it was estimated to have covered the cost of the entire drone program, as well as saving scores of US aircraft and crews in later years.¹⁵ By 1973, the US had flown almost 3,500 UAV missions in South-East Asia for a combat loss rate of four per cent in support of photo, communications, electronic reconnaissance, ECM and decoy requirements. But the overall UAV program was shrouded in such secrecy that its success, which should have added much impetus to UAV development after the end of hostilities, went largely unnoticed.

Israeli Experience

Israel's earliest reported employment of UAVs was the operation of drones in the 1973 Yom Kippur war on the Syrian and Egyptian fronts as reconnaissance and surveillance platforms. They were also used as decoys to draw the fire of Arab SAMs and thus deplete their missile inventories. In 1982, innovative UAV developments led to the highly successful air operations over the Bekaa Valley in Lebanon. Israeli Scout and Mastiff mini-RPVs conducted reconnaissance and surveillance of Syrian airfields, SAM sites and troop movements. Reportedly, UAVs simulating the radar returns of Israeli aircraft preceded the main force to draw Syrian SAM fire and to stimulate the Syrian radars for strikes by Israeli anti-radiation missiles; UAVs were also reported to have electronically suppressed Syrian radars. The Israeli success was complete with only one aircraft lost against the Syrian loss of 86 combat aircraft and 18 SAM batteries. The watershed, however, was the provision to commanders, for the first time in war this century, of real-time video imagery of enemy dispositions beyond the line-of-sight.¹⁶

¹³ Derek Wood is most vitriolic in his condemnation of the Defence White Paper of April 1957 in his book *Project Cancelled*, Macdonald and Janes, London, 1975, pp vii, 152. There can be little doubt regarding the adverse, long term effect on British aircraft development and production capability.

¹⁴ The RB47 was shot down over the Barents Sea while on an ELINT mission. One U2 was lost over Cuba (pilot killed) and the other was Francis Gary Power's infamous capture in 1960. All losses had extreme political repercussions.

¹⁵ Armitage, *Unmanned Aircraft*, p 78.

¹⁶ *ibid.*, pp 82-86.

The 1991 Gulf War

RPVs and autonomous UAVs were used by both sides throughout the 1991 Gulf War, primarily as reconnaissance and surveillance platforms. The US, Britain and France deployed and made effective use of systems such as Pioneer, Pointer, Exdrone, Midge, Alpillies Mart and the Canadair CL-89, while the Iraqis used the Al Yamamah, Marakeb-1000, Sahreb-1 and Sahreb-2.

Coalition tactical reconnaissance UAVs flew a total of 530 missions *for Operation Desert Shield and Operation Desert Storm*, logging 1,700 hours aloft. For this total effort, approximately 28 vehicles were damaged, including 12 which were destroyed. Of the 40 Pioneer UAVs employed by the US, 60 per cent sustained combat damage, but 75 per cent of these were deemed repairable.¹⁷ Of all the vehicles lost, only two appear to be attributed to combat related action.¹⁸ This low loss rate was most likely due to the small size of the UAVs and the Iraqi mind-set that they posed little or no threat.

Although the UAVs employed had limited payload, range and role flexibility, they again demonstrated their usefulness in a major war scenario. By providing affordable, real-time or near-real-time intelligence direct to the commander on the spot, they were a key element of the intelligence and reconnaissance systems available to the US-led Coalition Forces. A major outcome of the Gulf War was the emergence of an operational concept for obtaining theatre-wide reconnaissance and intelligence coverage on a 24 hour basis over hostile areas under all environmental conditions with minimum risk to human life. Reinforcing this concept, the Vice Chairman of the US Joint Chiefs of Staff, Admiral William Owens, recently proposed:

A notional future 'system of systems' that links reconnaissance satellites and UAVs in surveillance of a 200 nautical miles by 200 nautical mile battle area.¹⁹

Post-Gulf War, preventing the loss of human life in combat has become a primary concern of advanced nations in conflicts, other than their direct defence. As UAVs can at least partially fulfil this political and humanitarian imperative, a niche role for them may have finally been carved.

Bosnia

The most recent, significant use of UAVs has been with the UN peacekeeping effort in the former Yugoslavia. In 1992, the United Nations sanctioned the use of NATO air forces to provide air cover over Bosnia, to support the ground forces stationed throughout the country, to monitor and to enforce sanctions, and to provide relief to besieged Bosnian communities. Reconnaissance and intelligence support for this mission was required on a 24 hour, seven day a week basis.

In the period preceding a general cease-fire in late November 1995, NATO forces had to maintain a high level of vigilance and a clear picture of events on the ground.

¹⁷ Witt, Mike, 'Unmanned Eyes in the Sky', *Asian Defence Journal* 7/93, p 21.

¹⁸ See Waters, Gary, *Gulf Lesson One: The Value of Air Power*, APSC, Canberra, 1992, p 183.

¹⁹ *Jane's Defence Weekly*, 5 August 1995, p 32.

Numerous sophisticated reconnaissance and surveillance systems were used, including satellites, high-altitude U-2 and TR-1 reconnaissance aircraft, and UAVs. Owing to the constant threat of SAMs and anti-aircraft artillery (AAA), UAVs were introduced for tactical reconnaissance and the monitoring of opposing factions, as well as the later location of unmarked graves suspected as resulting from alleged war crimes.

Although still at the test and evaluation stage, at least five General Atomics Predator UAVs were deployed in mid-July 1995 to Albania and Croatia to support UN peacekeepers in some of the more hazardous reconnaissance missions. Within a month, two Predators had been lost: one reportedly due to ground fire while on a low altitude tactical reconnaissance mission at 1,500 feet altitude (25,000 feet capable); the other due to engine trouble, possibly caused by ground fire, requiring its deliberate crashing by the controller to prevent capture. While these losses sparked a review of Predator employment, they were not withdrawn because the information they provided was considered essential and could not otherwise be obtained. The loss of these UAVs, which went largely unnoticed by the world press, can be contrasted to attention given to those manned aircraft lost in the conflict.²⁰

LESSONS FOR AUSTRALIA

Although the combat experience in using UAVs is extremely limited in comparison to that of manned aircraft, some lessons can be derived for use by Australia. Perhaps the most striking lesson is that UAVs have been most successful where a specific requirement has been identified that might best be satisfied by a UAV system, followed by a program instituted with a commitment to develop or acquire the necessary technology. Closely associated with this system development or acquisition has been the development of a successful concept of operation for the UAV. This is illustrated by the German weapons of World War II, the US drones in Vietnam and the Israeli mini-RPVs in the Bekaa Valley. All were developed initially for specific roles and were improved gradually with experience for other roles, using the lessons learnt to generate technological improvements; particularly, they complemented the use of manned aircraft instead of competing with them. In most cases, however, developments up until about 1990 were hampered by inadequate demand, technological restrictions in the size, weight and performance of on-board systems and payloads, secrecy, and a failure to recognise the potential for exploitation in concepts of operations.

While Israel is often recognised for its innovative applications of UAVs in the Bekaa Valley, these uses could be interpreted as tactical adaptations of the strategic employment of US UAVs in Vietnam. A large part of the US failure to exploit its UAV successes in Vietnam may be attributed not only to program secrecy but also to the inadequate recording of the UAV lessons in their air power doctrine. Although the operation of UAVs in the Gulf War and Bosnia has not differed significantly from

²⁰ In early June 1995, Captain Scott O'Grady was shot down in his F-16 in central Bosnia, probably by an SA-6. The event had sufficient impact to raise the level of debate on the Bosnian issue in the US Congress, including discussion on lifting arms sanctions against the Bosnian Government.

that of the earlier conflicts described, sufficient interest has now been generated to warrant their inclusion in the force structure of many countries, thus raising the level of demand for industry. Coupled with this increased demand have been the improvements bestowed by better technology and the availability of commercial-off-the-shelf (COTS) components for building platform and payload systems, thus lowering the developmental and operating costs.

The primary lesson for Australia is that UAVs are already proven platforms for aerial reconnaissance and surveillance, and that their capabilities are expanding. Another lesson is that experience is a powerful developmental tool and that continued delays in Australia gaining UAV experience will hamper their development and adaptation for Australia's unique circumstances. However, this experience should be gained only where a need exists for a UAV capability satisfying a requirement. Once that experience is gained, however, examination can be more authoritatively made for expanded uses. At this stage of their development, UAVs should be viewed as a means of complementing and enhancing current capabilities, rather than as a total replacement. Finally, these lessons, requirements and the potential exploitation should be incorporated into doctrine where they are applicable.

CURRENT UAV SYSTEMS

UAVs are an established part of modern warfare with many countries employing them operationally, primarily for reconnaissance and surveillance but also for decoys, electronic combat, communications relay and, to a limited extent, attack. Countries already using or evaluating the use of UAVs include the United States, Britain, France, Israel, Canada, Japan, South Africa, Singapore, Russia, Poland, Finland, Syria, China, India, Spain, Morocco, Egypt, Portugal, Italy, Syria, Iraq, Bulgaria, Czech Republic, Argentina, Brazil, Greece, Belgium, Holland, Switzerland, Germany and Australia. Notable among these users for having combat experience with UAVs are the United States, Britain, France, Israel and South Africa.

As a result of the Bosnian experience, US planners are now openly proposing the use of UAVs over the Korean Peninsula, the Persian Gulf region, and over Central and South America for the war against illegal drug trafficking. Already, UAVs are being used in the war against drugs within the US. The key arguments for expanding the use of UAVs is that they are cheaper than satellites, are far more flexible, can be operated below cloud cover when some satellites may be blind to the ground picture, and can often provide the imagery detail not available from satellites. Weather at this stage still restricts the operation of most UAVs and, in certain circumstances, they may need to rely on satellites or other relay vehicles for the transfer of data.

Current Platform Developments

Over 60 UAV systems are presently available or are under full-scale development for the global market, with most systems being the smaller, simpler vehicles employed at the tactical level.²¹ The latest Tier II-Plus and Tier III Minus UAVs being developed in the US for operational deployment in the post-2000 time frame, however, have the

²¹ *Jane's Defense Weekly*, 12 August 1995, p 38.

size and complexity of some manned aircraft but have far greater endurance. For example, the Tier II Plus Global Hawk high-altitude UAV scheduled to fly in late 1996 has a wingspan of over 35 metres, a length of 13.5 metres and a weight of 10,500 kilograms. A vehicle with Global Hawk's capability could launch from Learmonth and fly a circuit between there and Cape York two and a half times, with a surveillance coverage of 137,196 square kilometres or 1,900 spot targets per 24 hour period.²²

Tier III systems will be similar in size to Tier II Plus but will be stealthy and are planned to remain aloft for up to three months. Another capable but more survivable UAV system, developed by Lockheed Martin Company's 'Skunk Works', is the Tier III Minus DarkStar. Unveiled on 1 June 1995 and successfully test flown on 29 March 1996, this UAV incorporates many B-2 design features and is especially configured to avoid intercept by fighters which are considered its greatest threat.²³ But with both Global Hawk and DarkStar each having an estimated cost of US\$10 million, they cannot be considered readily expendable. Among other developments in high altitude, long endurance platforms is a UAV being developed as a 'poor man's satellite' by the Skynet Communications Network. Using a turbofan engine, the Skynet vehicle is planned to cruise at 65,000 feet for 36-48 hours; if, however, a concept of using microwave energy beamed from the ground to drive electric motors is successfully developed, the vehicle will be capable of cruising at 70,000 feet for up to four months.²⁴

Fixed wing UAVs are limited in performing some tasks in the land and maritime environments, such as the deployment and employment of acoustic sensors. These difficulties are further compounded when very low speeds are required, such as the recovery stage for confined land areas and sea platforms. To overcome these limitations, a number of programs are being developed using vertical launch and recovery (VLAR) UAVs. Rotary-wing UAVs being developed under the US Autonomous Scout Rotorcraft Testbed (ASRT) Program include the Sikorsky Cipher weighing 115 kilograms and the Georgia Technical Institute American Sportscopter Ultrasport 331 miniature helicopter weighing 225 kilograms.²⁵ A further development aimed at exploiting the benefits of both fixed-wing and rotary-wing aircraft, similar to the V22 Osprey, is the Bell Helicopter Textron Tilt Rotor UAV which weighs 815 kilograms and can carry a 16.4 kilograms payload.²⁶

Australian UAV developments to date have been limited but successful, including the Jindivik aerial target, the Ikara anti-submarine warfare weapon and the Nulka ship-launched missile decoy system. Although Australia trails in advanced UAV production, an imaginative project currently being developed is the thin air communications aircraft (TACA). Using a platform based on a Twindex 1500 glider, TACA incorporates either two split cycle technology (SCT) engines or two Zoche

²² Based on information supplied by TRA San Diego and TRA's Australian representative.

²³ DarkStar crashed on its second test flight but the cause has yet to be publicly advised.

²⁴ Hewish, Mark, 'Airborne Ground Surveillance: New Technologies Meet Urgent Demands', *International Defence Review*, January 1995, p 39.

²⁵ 'Programs and Markets: US Army tests unmanned scouts' *International Defence Review*, September 1995, p 25.

²⁶ *Unmanned Aerial Vehicles: 1994 Master Plan*, US Department of Defense, 31 May 1994, Annex B-4.

diesel engines, together with US components. Performance parameters being sought are an endurance of up to 12 months while operating between 80,000 ft and 100,000 ft altitude with a payload of 100 kilograms. The desired performance is impressive but many critical technological problems still need to be resolved in developing this vehicle.²⁷

Current Payload and Communications Developments

With most of the emphasis for current UAVs being on the reconnaissance, surveillance and targeting acquisition (RSTA) roles, most of the payload developmental work has been on imagery sensors and the means to communicate this in real or near-real-time. As precision guided munitions require precision reconnaissance, much of the development has focussed on producing lightweight sensors that combine wide-area coverage with the necessary degree of resolution. For example, the TRA Global Hawk will have to carry an 820 kilogram package of EO, IR and SAR sensors with resolutions of 0.3 metre in the spot mode and 1 metre in the search mode, covering over 400,000 square kilometres per hour. Sensors cued with a GPS reference will be able to locate targets to within 20 metres.²⁸

With the amount of data which can be collected by on-board sensors, there is a need when operating out of line-of-sight to transmit all or part of the data via satellites to commanders in real-time. It is now possible to process raw SAR data on board a vehicle rather than on the ground which reduces the necessary data link capacities to between one eighth to one tenth. Using sufficient bandwidths such as a Ku Band satellite link, compressing the data and using an antenna of sufficient size now allow either all or a significant part of spot or search imagery to be transmitted in real-time.²⁹ The challenge for the future is to be able to transmit all of the data from all sensors in real-time or in periodic bursts. With the smaller Predator UAV, a program has already been tested using a direct broadcast transmitter to send 20 channels of digital video routed around the battlefield to allow commanders to 'channel surf' for imagery.³⁰

Future Developments and Employment

This next generation of UAVs for post-2010 employment has already been re-classified as uninhabited combat aerial vehicles (UCAVs) and uninhabited reconnaissance aerial vehicles (URAVs), a distinction based upon role rather than design. The classification for this generation is shown in Figure 2. UCAVs are planned to be stealthy, incorporating seamless airframes (with undercarriage on top to minimise radar reflections - the UAV simply inverts to land), highly agile and use light beam or particle beam weapons, such as microwave impulse beams or advanced lasers. Capable of being very fast, they are planned to operate at the hypersonic

²⁷ A SCT engine is a development employing a hydrogen ignition system with a mixture of water and fuel, where there is a molecular separation of the water. These features contribute to producing an engine with a low radar cross-section and a low infra-red signature. Details are based on information provided by Force Development(Aerospace) staff at Headquarters Australian Defence Force and by TACA's Australian Agents, Aviation Consultants International in May and June 1996 respectively.

²⁸ Dorheim, Michael A., 'New Sensors Show Two Paths of Reconnaissance', *Aviation Week and Space Technology*, 10 July 1995, pp 42-44.

²⁹ *ibid.*, p 44.

³⁰ UAV Force Concept, *Aviation Week and Space Technology*, 10 July 1995, p 43.

velocities of Mach 12-15 at altitudes of 85,000-125,000 feet. Similarly, URAVs will be a vast improvement on present reconnaissance systems, incorporating the advanced features of the UCAV with the addition of more capable and longer range sensors. Both types will require complex data processing systems and rapid data transfer to ground stations or combat aircraft to enable the provision and exploitation of real or near-real-time information. These improved capabilities, however, are likely to come at a high cost.

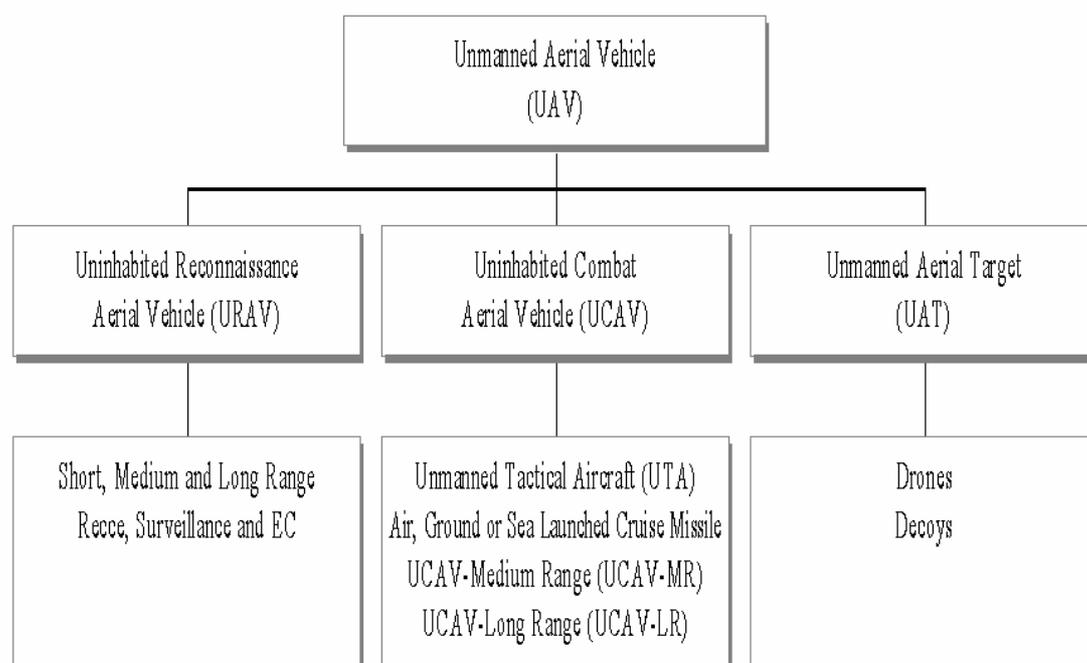


Figure 2 - Post-2010 UAV Family Tree

Future Platform Developments

How long the human remains in the cockpit for fighter/strike missions in hostile environments is yet to be determined. As far back as 1990, Japan experimented with an unmanned version of the F104J Starfighter.³¹ Such is the present level of technological sophistication capable of being built into UCAVs that it is likely that the final production series of the USAF's next generation joint strike fighter (JSF) combat aircraft will include UCAV configurations. Boeing's Defense and Space Group want to develop this concept even further by using major JSF components to construct a UAV with an improved performance but at a cost at least half that of the JSF.³² Such a development would allow performance improvements not possible with a human in the cockpit. Further JSF unmanned developments are likely to produce several variants, including an air-to-air fighter version. Such a proposal would appear to indicate an acceptance by the USAF of the changing needs of their air force while still retaining the flexibility offered by manned systems. Although this is somewhat

³¹ Dantes, Edmund, 'UAV', *Asian Defence Journal*, December 1992, p 34.

³² The improved performance would include a capability for sustained 20g manoeuvres, which would out-maneuvre most current air-to-air and surface-to-air missiles. *Aviation Week and Space Technology*, 4 Mar 1996, p 20.

futuristic and perhaps beyond the present means of the RAAF, the thrust to develop wider applications of UAV technology should not be ignored.

Future Payload and Communications Developments

A number of payload developments are leading to other potential offensive roles for UAVs. The first is the development of 'mini' munitions such as those being developed as part of the US Miniaturised Munitions Technology Demonstration (MMTD) Program. One product being tested under the program is a 250 pound 'smart' bomb capable of penetrating up to 18 metres of concrete, a performance previously requiring a 2,000 pound bomb.³³ Such a weapon immediately increases the offensive capabilities of those UAVs having hard points on their airframes but with low payload capacities.

Another development includes the use of UAVs for the boost phase intercept (BPI) of theatre ballistic missiles (TBM). This requirement had its genesis in the Scud missile menace of the Gulf War. The vehicle envisaged in the BPI Program is a long endurance UAV loitering on station while conducting surveillance of possible TBM launch sites. Targets acquired using infra-red detection of the rocket plumes would be engaged using a smaller and lighter version of the atmospheric interceptor technology (AIT) kill vehicle. This missile, which is currently being developed for use by manned aircraft, would be augmented by an existing missile booster for use from a UAV to give it an extended range of 150 kilometres. One missile would engage the TBM in flight while another would target the TBM launcher. The operational concept estimates that 20 UAVs, each with three to six lightweight missiles, could deal with a Gulf War size conflict area.³⁴

Future Operational Concepts

The technological improvements and miniaturisation of payloads is greatly increasing UAV capabilities to provide many more planning options. In the future, a UAV could be launched in one country, climb to high altitude and fly undetected over another country. Once in position, it could remain in a lazy orbit, unchallenged for periods of three months or longer. During this time it could observe, record, identify, track and fix any number of potential targets. Alternatively, it could intercept communications and electronic transmissions, relaying this information using microburst transmissions³⁵ to an overhead satellite or other UAVs for analysis at a headquarters located anywhere on the globe. If that same UAV carried precision weapons to be launched once hostilities broke out or as a preventative or pre-emptive strike, the problems facing the defender increase enormously.

An offensive UAV could also be employed in an air-to-air role. The advantage of this approach is that without a human pilot, the UAV can be made smaller and able to

³³ Evers, Stacey, 'Technology: USAF mini-munitions to replace 2,000 lb bombs', *Janes Defence Weekly*, 2 December 1995, p 6.

³⁴ Starr, Barbara, 'USA developing missile attack role for UAVs', *Jane's Defence Weekly*, 2 September 1995, p 3.

³⁵ A very short transmission of data made possible by information compression techniques. Such rapid bursts are extremely difficult to detect. However, limitations are imposed by the enormous amount of data that comprises imagery and the current technology.

withstand far greater 'G' forces. USAF officials now predict that such UAVs could out-maneuvre the latest air-to-air missiles,³⁶ thereby adding greatly to survivability. Thus the concepts for the next generation of UAVs should be viewed as enhancing the manned aircraft's flexibility, making full use of the human pilot's situational awareness while reducing casualties, increasing stand-off distance, so aiding attrition management and providing a high probability of mission success.

The technology for the future capabilities discussed so far is already under development. As many of the future, highly capable UAVs will have uses much broader than that of supporting surface forces within a prescribed theatre of operations, they must be considered as strategic assets. Such capabilities will require complex logistic support, a depth of experience for exploiting the optimum capabilities in multiple roles, and the skills for operating, in some cases, in concert with manned air assets in a strategic environment. Therefore, the political, diplomatic, legal, command and control, communications and intelligence (C³I) issues accompanying these capabilities must also be addressed. Thus, future UAV systems may likely be divided into tactical (in support) and strategic (to affect directly the outcome of the entire war or battle). While the use of strategic systems would be decided by the owner country's political leadership and law makers, their ability and value in meeting a wide range of strategic objectives and influencing the major outcomes makes their operation by the air force appropriate in exploiting their fullest use.

Offensively, a UAV could be used as either a guided weapon or a launch platform to release a number of guided or unguided sub-munitions. In the increasingly hostile air environment that can be expected over enemy territory, such a proposal has some merit but the problems of targeting, recall and legal issues will need to be resolved. These problems have led US analysts to propose the option of a manned 'master' ship employing several remotely piloted 'slave' UAVs for the deeper strikes or strikes into the more heavily defended areas of enemy held territory. Such a concept is already in the embryonic stage of development with a proposal by the USAF to use the TRA BQM145A Medium Range UAV carrying a RSTA sensor package and launched from a F16 or a F/A-18. Further considerations have UAVs transmitting RSTA or BDA information via ground stations using advanced processing, possibly assisted by artificial intelligence, to the cockpits of manned attack aircraft to provide near-real-time intelligence.³⁷ Thus UAVs will be able to be employed either independently or in concert with manned vehicles.

Future Potential for UAVs

The full potential for employment of UAVs by air forces has only just begun to be explored. The possibility is dawning for UAVs to undertake the full spectrum of conventional air roles, including offensive roles such as land and maritime strike, traditional fighter tasks and perhaps even transport. Some US analysts expect the greater proportion of combat aircraft of the future will be unmanned.³⁸ Not only is

³⁶ Fulghum, David A., 'Boeing Plans Unmanned Fighter', *Aviation Week and Space Technology*, 4 March 1996, p 20.

³⁷ Marshall, Maj James P., USAF, *Near-Real-Time Intelligence on the Tactical Battlefield*, Air University Press, January 1994, pp 73-74.

³⁸ *Aviation Week and Space Technology*, 5 February 1996, pp 26-28 and 4 March 1996, pp 20-22.

technology driving such a possibility, but a predicted world-wide shortage of experienced pilots coupled with the increasing cost of training military pilots may also favour UAV use. Nevertheless, total replacement of the manned aircraft by UAVs is unlikely in the near-to-medium term.

What is the future for UAVs around the globe? All four US Services have embraced UAV technology in some form or other. The US Army, Navy and Marine Corps have focussed on the short-range or tactical applications, while the USAF is examining the strategic application of UAVs. Other nations, such as Russia and China, are embarking on the progressive development of a UAV capability, primarily on the grounds of cost and survivability. Yet other military powers, such as Britain and France, are equally interested in the employment of UAVs but trends indicate that in the case of their strategic strike forces of the future, cost effectiveness will be the driving factor. Such forces will probably consist of a mix of manned and unmanned strike assets. Industry predictions are that the next generation of air platforms will most likely be a combination of manned aircraft with more capable stand-off weapons, or manned 'master ships' with several semi-autonomous UAVs controlled by the parent aircraft. Regardless of which system results, there remains a place for both manned and unmanned aircraft for the foreseeable future.

EVALUATING UAV EMPLOYMENT

The description of UAV systems has shown that they can range considerably in their complexity and support. Likewise, the history of UAVs showed that they have not been readily embraced and that a high level of popularity has emerged only over the last 20 years. While they may offer advantages, they may also suffer from disadvantages and these must be carefully weighed in evaluating them against other systems offering similar capabilities. In determining meaningful criteria that can assist evaluating UAVs against other options as part of a cost-benefit analysis, some of their major advantages and disadvantages need first to be identified.

Advantages

The advantages are as follows:

- a. The risk to on-board human operators is eliminated.
- b. They can be cost-effective when properly employed.
- c. They can be used when political or environmental constraints limit the use of other systems.
- d. The low cost and simplicity of some systems allows an organic tactical air capability that cannot be provided economically by manned air assets.
- e. The absence of a crew, cockpit systems and life support systems allows the use of less complex, smaller and less detectable, and more manoeuvrable vehicles.

- f. Their endurance is not affected by crew fatigue.
- g. Their operational effectiveness is not affected by combat stress.
- h. The long endurance of some vehicles allows greater flexibility of use.
- i. They release assets for missions requiring the flexibility of manned aircraft.
- j. Many current UAV platforms are capable of being produced by indigenous industries in most developed countries using COTS augmentation.

Disadvantages

The disadvantages are as follows:

- a. More complex vehicles still require highly trained mission support personnel and controllers.
- b. Absence of crew removes situational awareness necessary to optimise protective measures and hence survivability.
- c. Some UAVs require relay facilities for control signals when these cannot be sent by line-of-sight.
- d. Most current UAVs are less well equipped to cope with weather extremes, especially icing.
- e. Manned aircraft can more easily be used to collect data from sensitive locations under the guise of peacetime training missions.
- f. Deployment requirements for UAVs incapable of making autonomous transit flights may require significant airlift requirements.
- g. More complex vehicles require special mission planning and ground control facilities.
- h. Some types require launch and recovery facilities beyond that of normal airfield infrastructure.
- i. Vehicles using parachute recovery are more likely to be damaged during mission recovery.

Cost-Benefit Analysis

The discussion so far of the characteristics, concepts, roles, advantages and disadvantages of operating UAVs shows that they differ in many ways from those of manned aircraft, making a direct comparison difficult. For example, any cost-effectiveness considerations for the UAVs used in the Gulf War would need to include their overall costs compared to manned aircraft options, attrition rates, reduction in risk to human life, the air supremacy environment attained by Coalition

forces and the impact of the missions performed. In evaluating the UAV versus manned aircraft options, there are many variables to be considered, including those that may be affected by individual national needs. Some of these major variables for consideration are:

- a. capability requirements,
- b. cost effectiveness,
- c. utility,
- d. commonality and interoperability,
- e. risk management, and
- f. political factors.

Capability Requirements

Capability requirements will always be the prime driving force in any UAV acquisition and these are usually focussed on the five key operational requirements of endurance, speed, radius of action, altitude and payload. Payload, coupled with the mission and environmental requirements, is the key feature in determining the type of platform required. Unlike manned aircraft where life cycle costs, training costs and the ability to perform multiple roles have produced a limited variety of multi-role platforms, there is currently a wide variety of UAVs being produced to perform specific roles. Although this variety may continue for the smaller tactical UAVs, some rationalisation must be expected for the larger, more complex UAVs. With their greater payload capacity, these vehicles may become like their manned counterparts and take on a wider variety of roles. As these larger vehicles generally have autonomous control, safety considerations will also be part of their capability requirement, particularly if they are expected to operate in the same airspace as manned civil and military aircraft.

Cost Effectiveness

Determining the cost-effectiveness of a UAV can be difficult due to the multitude of roles. The US Defense Airborne Reconnaissance Office (DARO) has approached this problem by developing a performance indicator of 'pound hours per kilo (1,000) dollars'. This indicator measures the payload put into the atmosphere for a certain endurance, divided by the cost. DARO claims the indicator shows that UAVs are much cheaper than manned aircraft, and, not surprisingly, that a premium is paid for low observability, and that as speed requirements increase, so does cost. On a one to ten scale where ten is best, the indicators have been determined for the four UAVs on the US program:

- a. the short-range, short-endurance Hunter (project since cancelled) rates three;
- b. the stealth medium-range, medium-endurance DarkStar rates four;

- c. the medium-range, high-endurance Predator rates five; and
- d. the long-range, high-endurance Global Hawk rates eight.

DARO further contends that it is more cost effective to use a mix of US\$10 million vehicles to meet various capability requirements rather than a single vehicle that meets all requirements of low observability, large payloads and long range; such a vehicle would cost in the range of US\$40-150 million.³⁹ Care needs to be taken in considering overall cost in terms of the system component costs for individual vehicles. For example, the TRA BQM-145A Medium Range UAV airframe is 15 per cent of the total program cost, with the GCS being 16 per cent, the payload 20 per cent, training and support 34 per cent, and other costs 15 per cent.⁴⁰

Utility

The utility of UAVs varies enormously according to the type. Low cost, low capability UAVs can operate from primitive facilities but tend to be more susceptible to weather conditions, reducing their flexibility. High cost, high capability UAVs usually require increased support such as hangars, paved runways and mission support facilities but can be employed on task for longer periods than manned aircraft. This employment may be affected by weather and environmental conditions.

While most UAVs tend to have limited capabilities compared to most manned combat aircraft, they usually employ a much higher percentage of their total capability in a set mission. This capability should be able to extend the operating life of the UAV to where it is at least comparable in cost effectiveness with manned platforms. Where UAVs cannot be flown to distant deployment areas, valuable airlift capacity may be required to transport airframes, as well as the mission support facilities. This deployability capability needs to be factored not only into cost effectiveness calculations but also into the opportunity costs of the resources diverted, the percentage of capability used and the predicted availability to perform missions under a variety of conditions.

Commonality and Interoperability

A mix of UAVs for meeting different capabilities has been shown to be better than one multi-purpose vehicle. However, a mix of vehicles is more likely to increase the logistics support costs and reduce the utility if commonality factors are not optimised. These support factors can be reduced by using common equipment and software not only from other UAVs but also from manned vehicles where possible. Similarly, interoperability factors need to be examined not only among the different UAVs but also among the UAVs and manned aircraft, especially for fitting into current C³I architecture. For example, GCSs and MSSs receiving sensor data transmitted from UAVs should also be able to receive sensor data from manned aircraft. Commonality of mission planning systems should also be considered.

³⁹ Fulghum, David A., 'International Market Eyes Endurance UAVs', *Aviation Week and Space Technology*, 10 July 1995, pp 41-42.

⁴⁰ Longino, LtCol Dana A., USAF, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios*, Air University Press, Maxwell AFB, December 1994, p 18.

Risk Management

The predominant advantage of UAVs over manned aircraft is that the risk of losing aircrew, as well as highly capable and valuable platforms, is eliminated. In addressing capability, the environment and scenarios in which manned and unmanned aircraft could be expected to operate need to be analysed to determine the probabilities of each type being either lost or damaged. Factors such as active and passive self-protection measures, detectability and defensive actions need to be considered in determining this risk factor. For example, while the crew of a manned aircraft provides the situational awareness to defend the platform, many UAVs are difficult to detect either visually or with sensors due to their size, shape, construction or operating environment. These risk factors need to be considered in conjunction with the cost of the platform, the cost of the crew and the overall platform capability that may be lost. As the value of the platform increases, so the risk of losing that platform needs to be more effectively managed.

Political Factors

In certain circumstances, political factors alone may decide the use of a UAV for a role where it meets capability requirements. The ability of the media to televise conflicts into the homes of a country's population, combined with the sensitivity to casualties, may influence public opinion towards the management of conflict. Images such as the captured Coalition aircrew in the Gulf War, the desecration of the bodies of US helicopter crewmen in Somalia and the world focus on the aircrew downed in Bosnia may galvanise public and political opinion so strongly as to dictate the strategies and systems employed. A further political factor is the potential loss of UAVs over foreign territory. Although the US lost some UAVs while gathering photographic and electronic intelligence over countries such as China during the 1960s and 1970s, this '... led to little more than routine diplomatic protests from the target countries, in circumstances when the use of manned aircraft could have led to serious political embarrassment.'⁴¹

UAV CONSIDERATIONS FOR AUSTRALIA

Based on the development and employment of UAVs to date, there are now sound political, economic and military reasons for the ADF, and the RAAF in particular, to seriously examine the employment of UAVs as platforms for meeting a range of capability requirements. While present Australian strategic guidance has determined that the capabilities of very long range UAVs (capable of greater than 5,000 kilometres radius of action) are unlikely to be required in the near term, this must change as the RF-111C approaches its retirement from service. With the recent and significant technological improvements, UAVs are becoming a more attractive option in satisfying a range of requirements. At the same time, the ADF and the RAAF will need to address the doctrinal considerations not only for employing UAVs but also for countering them as a potential future threat.

⁴¹ Armitage, *Unmanned Aircraft*, p 81.

Current Considerations for UAV Use

The ADF's most promising area for the use of UAVs is for surveillance of land and maritime environments. Australia's most recent Defence White Paper, *Defending Australia 1994* (DA94), gives credence to establishing a full and comprehensive surveillance cordon. The Paper calls for a surveillance and reconnaissance capability⁴² that, in the case of northern Australia and our northern approaches, may use both air and land assets.⁴³ Encouragingly, DA94 specifically identifies UAVs as potential surveillance platforms, employing a variety of sensors to provide flexible and responsive surveillance coverage.⁴⁴

Currently, the RAAF is considering UAVs for surveillance, electronic support and communications roles. The Australian Army and, to a lesser extent, the Royal Australian Navy are examining the acquisition of UAVs to fulfil a number of requirements. In 1993, Army conducted a conceptual study of battlespace reconnaissance, using an IAI Scout UAV for evaluation purposes. While the shorter range battlespace reconnaissance is an important consideration, Army's primary concern is the need for responsive surveillance over the north of Australia and the northern approaches. Major nations, such as the United States expend enormous resources observing hundreds of thousands of square kilometres of the earth's surface instantaneously as part of their defence requirements. Australia has a comparable area to observe as part of its national security, but must achieve this with far less resources. In addition to the Services, Australia's Defence Science and Technology Organisation (DSTO) has also been reviewing the possibilities of UAV use in the ADF, mainly on behalf of the Australian Army. A recent DSTO report on the possibilities for UAV technology concluded:

The potential of UAVs is such that despite the lack of general success so far their development is being pursued by many countries, and their appearance as significant military systems seems to be inevitable. It is in this context that the ADF should view its approach to UAVs and consider where current UAVs, modified current UAVs, and future developments are likely to enhance its ADF capabilities.⁴⁵

With this in mind, and partly to fulfil a number of 'gaps' in Australia's force structure, the ADF has raised three projects which will likely involve UAVs of some description:

- a. **Joint Project 129.** Joint Project 129 (Project Warrendi) was originated in April 1996 as a result of a restructuring that excised the broad area aerial surveillance (BAAS) capability from Project Air 87 - Land Force Surveillance, Reconnaissance and Fire Support Capability, and combined this with the UAV component of Project Ninox (Phase 2B). Also, JP129 incorporates corridor surveillance from Project Land 53 and the electronic support capability sought by Project Land 50. Indications are that JP129 could possibly see a long range, long endurance UAV system fielded in direct support of the land force.

⁴² *Defending Australia 1994*, AGPS, Canberra, 1994, para 4.40.

⁴³ *ibid.*, para 5.17.

⁴⁴ *ibid.*, para 5.19.

⁴⁵ Cameron, Keith, *Unmanned Aerial Vehicle Technology*, DSTO-GD-0044, February 1995, p 34.

- b. **Project Air 5399.** Project Air 5399 - Stand Off Imaging- is examining a revised sensor capability with a strategic emphasis for the RF-111C. A UAV may be among the possible options for consideration as a communications relay in providing a long-range data link from the platform to a ground station.
- c. **Joint Project 7.** Joint Project 7 - ADF Aerial Target System - is a program for replacing the ADF's Jindivik aerial target system. This Project aims to provide all three Services with a retrievable UAT that simulates as close as possible the characteristics of the various possible threats against which ADF weapons systems will be employed. These characteristics relate particularly to manoeuvrability and detection, especially for testing ships' anti-missile defence systems and air-to-air target acquisition.⁴⁶

While these projects will be a step into modern UAV technology for the ADF, further uses should also be examined to exploit developing technologies and capabilities. Australia is already heading down the UAV path in examining their use as a component of the reconnaissance and surveillance network. In the case of Australia's strike and air defence assets, as yet there has been no suggestion of replacing any arm of Australia's strike 'triad'⁴⁷ or fighter aircraft with an unmanned system. With F/A-18 replacement due in about 2015 and the F-111 now being considered for extension to possibly 2020, any consideration must include evaluation of a wide variety of options, including a mix of manned and unmanned aircraft.

Although the post-2010 time frame will concern the next-but-one force structure planners, now is the time for the ADF to start evaluating the possibilities of unmanned aircraft in building the most effective and efficient future force. RAAF planners need to review current combat support and reconnaissance force elements in the light of new UAV developments and in particular, examine emerging UAV technology to at least partially fulfil the requirement for reconnaissance, combat support and battle damage assessment. Regardless, Air Force leaders must now recognise the relative advantages and disadvantages of UAVs when compared with manned systems for both current and future Air Force roles.

Future UAV Strategic Surveillance and Reconnaissance Roles

Because of the RAAF's requirement to provide surveillance and reconnaissance information at the strategic level, it will tend to operate medium to long range and long endurance systems. Any close range and short range information required by Army and Navy is usually best acquired using organic capabilities. Those systems operated by Air Force could provide information to meet the needs of all three Service components at the strategic and operational level headquarters, as well as act as a strategic tool for government, according to the political and military requirements.

Regarding Australia's surveillance requirements, current technological developments make UAVs a suitable option for supplementing the broader surveillance network being established with the introduction of the Jindalee Operational Radar Network (JORN) and the acquisition of Airborne Early Warning and Control platforms.

⁴⁶ 'AWADI-Meteor argues that for JP7, smaller is better', *Australian Defence Report*, 9 May 1996, p5.

⁴⁷ Comprising the RAN's Collins submarines, the Australian Army's SAS Regiment and the RAAF's F-111C fleet.

Although the UAV focus to date has been on short to close range tactical reconnaissance systems, some of the few medium to long range and long endurance systems are at a stage of development where they could now be considered.

One of the proven UAVs in the medium range to long endurance category is the Predator. As indicated in Figure 3, Predator can fly 900 kilometres and loiter on task at a speed of 135 kilometres per hour up to 25,000 feet for 24 hours. In the long range and long endurance category, the more capable Tier II Plus Global Hawk is planned to fly 5,000 kilometres at a speed of 670 kilometres per hour up to 65,000 feet and loiter on task for 24 hours. Over one mission, this aircraft could provide surveillance coverage for the whole of Bosnia, an area equivalent in size to the state of Victoria.⁴⁸ Both aircraft also have the ability to carry SARs in addition to other sensors, thus minimising the impact of weather on surveillance operation.

Platform costs are US\$3 million for each Predator and US\$10 million for each Global Hawk.⁴⁹ Support costs tend to be about two thirds to three quarters of the total package. For a squadron of twelve Global Hawks, the total package of vehicles and ground support is in the vicinity of A\$500 million.⁵⁰ Utility is a further consideration with two C130 loads being required to transport three dismantled Predators and their associated ground support equipment while eight C130 loads are required to transport the ground support equipment and personnel for a detachment of Global Hawks; the aircraft itself is able to transit independently and autonomously to its destination. Both aircraft types require paved operating areas and hangarage, with Predator and Global Hawk having wingspans of 15 metres and 35 metres respectively. While a Global Hawk type vehicle could be best suited for the BAAS requirements, a Predator type vehicle with its shorter range and lower operating altitude could be more suited for the corridor surveillance requirements.

A possible future scenario might see the employment of either long range or long endurance surveillance UAVs over a country where Australian peacekeeping forces are stationed. Such a UAV could be launched from northern Australia or nearer the nation under surveillance, should range be a problem. The vehicle could be controlled from a centralised command centre, such as Headquarters Australia Theatre or a Deployable Joint Force Headquarters. Vital surveillance data could then be provided in real-time to the ADF, Foreign Affairs, political staff, operations planners, commanders and other vital personnel, possibly through satellite or other UAV relays. Using a UAV would be justified by factors such as the high risk of loss, better capability, the reduction of Australia's dependence upon third nation support, and the avoidance of any 'selective filtering' of information or deliberate delays. If risk was a highly weighted factor, a stealth requirement or a self-protection package would be a vital consideration in the type of UAV acquired and employed.

Competing Options

The alternatives for a BAAS capability are satellites, JORN or manned aircraft. While a detailed comparison is beyond the scope of this paper, some indicative costs or

⁴⁸ Sweetman, Bill, 'UAVs for Joint Forces', *Interavia*, September 1994, p 63.

⁴⁹ Fulghum, David A., Air Force Prepares New UAV Acquisitions, Operations, *Aviation Week and Space Technology*, 27 November 1995, pp 52-53.

⁵⁰ Confirmed as an estimate only with TRA's Australian representative.

limitations of the options can be given. Satellites vary in cost according to their capabilities and whether they are geo-stationary satellites (GSS) or low orbital earth satellites (LOES). While LOESs are cheaper to place in orbit, more than one is required to provide regular surveillance of a given area. As an example, the Western European Union is currently considering a number of satellite programs. The cost for the Helios 1A Satellite Program, consisting of two optical observation polar orbiting satellites providing day-only imagery is US\$2 billion.⁵¹ A more complex program of a two to three constellation providing one metre resolution optical/IR and SAR for deployment in Year 2005 is estimated to cost US\$6 billion. A more ambitious program for Year 2010 consisting of a constellation of surveillance platforms supported by two relay satellites per platform is estimated to cost US\$12 billion.⁵² Such systems are expensive options for Australia, as well as creating a dependence on external sources for launching.

Currently, JORN is known predominantly for its air and sea surveillance capability. In the future, however, the JORN technologies may be adapted to perform a land surveillance role. Considerable development will need to be done in such an adaptation to produce imagery equivalent in quality to that of the SAR that might be used by a UAV. Even if this capability is developed, JORN's performance will continue to be affected by the vagaries of ionospheric disturbances.

Of the RAAF's manned aircraft, the RF-111C, the F/A-18 (sensors would need to be purchased) and the AP3C Orion could provide varying degrees of the BAAS capability but at a full operating cost of A\$50 836 per hour, A\$32 781 and A\$26 981 per hour respectively.⁵³ All have a lower endurance than the UAVs discussed, however, and in this role would use only part of their total capability. Although the operating costs of both Predator and Global Hawk are not available, a safe assumption is that they would be lower due to their simpler airframe and propulsion systems, as well as not needing to utilise highly trained aircrew. A further consideration for Global Hawk is that with its long range, it could operate from a base outside the Area of Operations (AO). Such basing would allow the employment of mostly contractor personnel instead of uniformed personnel, with subsequent savings in salaries. Additional savings would come from not having to activate or augment a forward operating base in the AO for a UAV deployment, as well as not having to provide vital asset protection for the deployment. Thus UAVs compare more than favourably with satellites and manned aircraft for surveillance tasks, and contribute towards self-reliance.

Future Tactical Reconnaissance Roles

Tactical reconnaissance requires a slightly less complex comparison. Current ADF manned aircraft available for tactical reconnaissance are the RF-111C, and to a very limited extent, the Army Aviation Kiowa helicopters when fitted with a recently tested forward looking infra-red (FLIR) sensor pod. Although the F/A-18 has a capability to carry a FLIR pod, it is not used currently in a tactical reconnaissance role. The

⁵¹ International Defence Digest: 'Europe inaugurates space reconnaissance', *International Defence Review*, September 1995, p 5.

⁵² Beal, Clifford, 'Europe Flies Solo', *International Defence Review*, January 1995, p 29.

⁵³ Based on the 1995-1996 Flying Hour Cost Recovery Rates provided by RP-AF Branch.

RF-111C is a highly capable platform which can use its speed and terrain following radar to minimise detection, as well as using its speed to arrive on task quickly. The platform, however, is a highly valuable element of Australia's ORBAT, is costly to operate (as previously shown), uses only a fraction of its potential capability in the tactical reconnaissance role, is detectable in certain circumstances, and cannot presently provide real-time imagery to commanders on the ground.

A wide variety of off-the-shelf UAVs using COTS sensor systems are currently available to provide imagery for tactical reconnaissance. At the very low end of the range and cost scale is the combat proven 3.9 kilogram Pointer, providing real-time video imagery with a duration up to one hour out to a range of five kilometres at a cost of US\$20,000 per vehicle plus US\$20,000 for the ground control and data station. Larger, short range UAVs in the Pioneer/Searcher/Seeker category can carry payloads up to 60 kilograms, usually consisting of real-time EO and IR sensors and data links, with a capability to carry SAR, at ranges up to 200 kilometres and endurances of five to nine hours. Also, a new Tactical UAV with similar capabilities is being developed for the US Army and Navy under the Advanced Concept Technology Demonstration program. Although all of these vehicles cost in the range of US\$300,000-400,000 each, support costs can be gauged by the cost of a package of 12 IAI Searcher UAVs acquired by India being at a quoted cost of US\$15 million.⁵⁴ In terms of utility, most can be transported in hardened canisters, together with their support equipment, and require launch and recovery facilities.

In comparing the different systems, a range of the evaluation factors need to be considered. While the RF-111C's capability, when fitted with the new sensors under Project Air 5399 may be higher, the platform itself may also be in excess of that required for some tasks. In a benign environment, the RF-111C's speed will be an advantage but its size and sensor signature will increase the risk of loss as the environmental hostility increases. The risk factor is further increased in a hostile environment with the number of passes required to update information. A short range UAV in a hostile environment will have an advantage in its smaller size and sensor signature but a disadvantage in its lower speed. With their simpler airframes, propulsion systems and operation, operating costs for the short range UAVs would be significantly less than those for the RF-111C.

Other Future Role Considerations

DA94 fails to go beyond surveillance and reconnaissance as potential UAV roles in the Australian environment. While Australia should not acquire and operate UAVs based simply on the experience of others, such experience forms a valuable basis for examining other roles. As range and endurance are key factors in determining UAV roles, potential roles for UAVs in the ADF can be examined in the context of these parameters. Figure 5 shows the broader range of roles that could be conducted with UAVs already in service with other forces. Data relay considerations also need to be considered if real-time or near-real-time information is required.

The examination so far has indicated that the performance of the reconnaissance and surveillance roles in Australia's unique defence environment might be better done in

⁵⁴ *Jane's Defence Weekly*, 30 September 1995.

some cases by UAVs. RAAF decision makers should now look beyond the present technology horizons to identify other roles that may best be performed by UAVs in the future. There is great potential for UAVs to complement both the RAAF's present and planned force structure and so enhance the RAAF's overall effectiveness. With the increasing cost of manned platforms and the need to replace many in the first quarter of the next century, strategies are required that prevent the unnecessary loss in combat of these highly valuable platforms, as well as ensuring that they are used where their unique capabilities are necessary. Examination, in accordance with the previously described evaluation criteria, should be made on the acquisition of UAVs that best satisfy some of the offensive roles

Performance Parameters	Close Range	Short Range	Medium Range	Long Endurance
Task	R&S (including air base security), TA, TS, EW, Met, MCM,	R&S, TA, TD, EW, Met, C ² , Comms	R&S, BDA, C ² , EW	R&S, TA, EW, NBC Detection, Met, C ² , Sigint, Target Drone
Usual Launch Mode	Surface	Air/Surface	Air/Surface	Air/Surface
Range	Up to 100 km	Out to 200 km beyond FEBA	Up to 1,500 km	-
Endurance	Several Hours	6-12 hours	6-12 hours	24 hours or more
Control	Remote or pre-programmed	Remote or pre-programmed	Pre-programmed	Remote or pre-programmed
Notes: R&S - Reconnaissance & Surveillance inc. Mapping & Survey TA - Target Acquisition/Designation, TA Target Spotting Met - Meteorology NBC Nuclear, Biological and Chemical Warfare EW - Electronic Warfare & Jamming BDA - Battle Damage Assessment MCM - Mine Countermeasures				

Table 3 - Possible Roles for ADF UAVs

Close Air Support

Besides reconnaissance and surveillance, the next priority for meeting Australia's capability requirements through use of UAVs is for force enhancement. Close air support (CAIRS) is perhaps one of the RAAF's most controversial roles due to the high risk factor when operating high value platforms in a hostile environment, with the risk increasing with the number of attack passes required. Target designation increases accuracy but exposes the designating aircraft to risk unless a ground base designator is used, also at some risk. Using a UAV platform for target designation removes risk and allows the release of precision guided munitions outside the range of

hostile forces. Already, the US is testing the Night Eagle target designation system on a Pioneer tactical UAV.⁵⁵

The CAIRS employment could be extended to what is termed by the USAF as the closed loop precision strike cycle of surveillance, target acquisition, attack and battle damage assessment. In this cycle, the UAV is used to acquire the target, pass the image through a ground station to the attack aircraft, pass the image after the target is attacked for assessment and begin the cycle again if necessary, all in a very short time. This avoids the need for repeat attacks on targets destroyed in earlier attacks, as well as allowing action within an enemy's decision cycle.⁵⁶ Such uses could possibly extend beyond CAIRS to other offensive roles.

Other Offensive Roles

Perhaps the most imaginative roles still to be developed for UAVs are the offensive roles of strategic strike, battlefield air interdiction (BAI), and either offensive counter air or defensive counter air. Control of the air is a vital factor in determining the attractiveness of the UAV option and the type of UAV that might be used. Where control of the air is not assured, a number of options need to be considered. The first and most expensive option is to use an unmanned conventional type UAV such as a JSF type vehicle, perhaps in conjunction with manned aircraft. The second and less expensive option is to use UAVs employing stealth features to escape detection. Such options would be expensive and may possibly involve some manned aircraft as part of the risk management.

UAVs employing stealth and high altitude capabilities for protection, combined with the employment of smart 'mini' munitions, of the type being developed by the MMTD program, could be employed on strategic strike, BAI or airfield attack missions. Similarly, the BPI concept and the AIT kill vehicle being developed for use against theatre ballistic missiles could lead to UAV systems with missiles capable of engaging manned aircraft or other UAVs, including cruise missiles, at stand-off ranges. While such a concept may require considerable development to use offensively against fighter aircraft, it could particularly be used to some effect against unescorted transport aircraft or rotary-wing aircraft, especially if the UAV was using long endurance to loiter at altitude over known aircraft transit corridors. Such threats could not only lower an enemy's morale but also force a change in defensive tactics, as well as a corresponding diversion of resources.

Electronic Combat and Communications Relay

Electronic combat is another role that can expose manned platforms to high risk. UAVs could also be used to gather strategic, operational and tactical ELINT, act as decoys to stimulate radars for attack by anti-radiation missiles or by the UAV itself, or act as expendable decoys in depleting enemy missiles inventories. Attack packages of manned aircraft could be supported by UAVs providing ECM, dropping chaff or

⁵⁵ The Night Eagle system was successfully operated from a UH-1N Iroquois during Desert Storm. *Unmanned Aerial Vehicles Program Plan*, Defense Airborne Reconnaissance Office, April 1994, pp 8-9.

⁵⁶ *Defense News*, 14-20 August 1995.

firing flares, allowing the attack aircraft to fully utilise their capability for weapons employment.

As part of self-reliance, UAVs could be used as communications relays to avoid dependence on foreign owned satellites. This could be relevant if Australia should ever acquire a cruise missile capability. While cruise missiles can be re-programmed with new mission and targeting data after launching, this can only be done while the missile is within transmission range of the GCS. As the range of the missile can exceed the range of ground control, a UAV could be used as a relay vehicle for the transmission of late mission corrections. This concept was successfully tested in 1994 where a Predator UAV was used not only to relay target information to a Tomahawk cruise missile in flight which then went on to destroy its target, but also to send back imagery of the target damage.⁵⁷

Cultural Acceptance and Integration

Crucial to the future employment of UAVs is their interaction and integration with manned aircraft and satellite capabilities, as well as their acceptance by military personnel. Airmen have often shown reluctance to adopt unmanned aircraft technology due to many factors including:

- a. fear of losing 'pilot prestige',⁵⁸
- b. general scepticism,
- c. relatively poor performance compared with manned aircraft, and
- d. the abundant numbers of manned vehicles

Technology is improving the performance of UAVs at the same time as the number of manned aircraft in air forces continues to decrease. Also, the scepticism is reducing as UAVs continue to gain combat experience, greater capability and greater reliability. Future UAVs will be capable in many cases of meeting a much wider range of roles more cost-effectively, with high probability of mission success at little or no risk to human life. Therefore, cultural acceptance by airmen is required to allow the fullest exploitation of the potential offered by UAVs.

Each of the roles discussed is a valid Air Force role and each is vital to a balanced air force's overall mission. While the offensive roles may seem ambitious to consider in 1996, technological advances should make such roles for UAVs possible early into the next century. In the still-longer term, transport roles may be added to this list. While conducting some of these functions by UAVs may seem a distant dream, most of these capabilities are either being partially conducted by foreign air forces using

⁵⁷ *Defense News*, 11-17 September 1995.

⁵⁸ This concept has been examined by several noted authors, specifically; Dennis M. Drew, 'The American Air Power Doctrine Dilemma', in Vallance, A.G.B. (ed), *Air Power: Collected Essays on Doctrine*, Bracknell, 1990; Stephens, Alan, *Power Plus Attitude: Ideas, Strategy and Doctrine in the RAAF, 1921-1991*, AGPS, Canberra, 1992, pp 181-85; Builder, Carl H., *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the US Air Force*, Transaction Publishers, New Brunswick, 1994.

UAVs or are presently under development as UAV roles, with the majority expected to be fielded by 2020.

DOCTRINAL CONSIDERATIONS

The consideration of UAVs so far has only addressed force structure issues. Doctrinal considerations must also be taken into account. The RAAF *Air Power Manual* states that doctrine is ‘... the central body of beliefs which guides the application of combat power ...’ and further states: ‘Derived from a combination of fundamental guiding principles, innovative thinking and experience, doctrine is authoritative but requires judgement in its use.’⁵⁹ A number of roles have been identified where UAVs can provide an attractive option in meeting Australia’s defence requirements. In modifying current doctrine to accommodate the use of UAVs, the ADF and especially the RAAF will need to adapt current overseas experience to employ UAVs in Australia’s unique defence circumstances. The longer the delay is made in gaining experience at any level in the use of UAVs, however, the more Australia will become dependent on experience that may not be either the best or the most relevant for the ADF’s needs.

Currently, *The Air Power Manual* identifies uses for UAVs only in the reconnaissance role; also, it identifies utility as the major advantage in the tactical reconnaissance role rather than the ability to provide real-time imagery, a feature identified in the Bekaa Valley experience. Doctrine needs to be revised to accommodate a broader range of UAV roles, not necessarily those roles currently being performed overseas but rather those roles that best meet the ADF’s. Particularly, doctrine must recognise that different options may satisfy a capability requirement under different scenarios and that the use of UAVs will need to be integrated with other assets such as manned aircraft, satellites, ground-based sensors and ships.

While the benefits of UAVs are usually identified as the reduction in risk to life, their cost effectiveness and their political advantages, these factors alone are not sufficient for the ADF’s circumstances. All of the evaluation criteria previously described must be considered in emphasising Australia’s unique requirements, especially in regard to the needs of a small air force. These needs especially require optimising the employment of capabilities and reducing the risk of losing the decreasing number of high value platforms available to Australia.

As described in this paper, there are a large number of UAVs that are suited only to specific roles and operating environments, rather than the multiple roles that can be performed by manned aircraft. Recognition should be made that a mix of UAVs may be best to satisfy multiple roles but that interoperability and commonality should be optimised, not only for mission effectiveness but also for efficiency in the life cycle support. This may be particularly relevant where all three Services may be operating different types of vehicles with different capabilities, but still using expensive ground control and mission support stations. This is particularly important where vehicles are collecting and disseminating information for a large number of users.

⁵⁹ RAAF, DI(AF) AAP 1000, *The Air Power Manual*, Second Edition, 1994, p 27.

When a land or maritime unit has a tactical need that has little or no external impact on other units from that Service and is best satisfied by UAV assets, then arguably that Service should own and operate those assets on an organic basis. Assets having either a strategic impact or an impact across a number units, however, should be owned and operated by Air Force. Generally, such impacts will have requirements usually satisfied only by the more capable and thus more costly UAVs, and any 'penny packeting' of such valuable assets would likely prevent the fullest exploitation of that capability.

Any benefits from operating UAVs that are recognised by Australia are also likely to be recognised by any enemy confronting Australia. The benefits of UAVs to the ADF and RAAF also represent a serious threat if they are used against Australia. Even an unsophisticated enemy can have access to relatively cheap but still quite capable UAVs. For example, the use of missiles may be an expensive option in attempting to counter UAV threats, as well as depleting limited inventories, especially if the UAV is a cheap decoy. Therefore, doctrine must recognise that UAVs are a threat that the ADF must be capable of countering in any future conflict or operations. Care will need to be taken in identifying and countering these threats in accordance with the needs of a small defence force and air force.

CONCLUSION

UAVs have established for themselves a place in the ORBATs of modern military forces and their use and availability are likely to greatly increase. UAV technology has already been employed to provide commanders with near-real-time reconnaissance and surveillance information, electronic combat support and battle damage assessment, all at little or no risk to friendly forces. Technology is now advancing at such a pace as to allow UAVs to function in other air power roles such as electronic combat, strike and air defence in either a totally autonomous mode or as remotely directed from either airborne or surface stations. In considering the use of UAVs care must be taken to examine all the components of the system rather than just the platform. While UAVs offer many advantages, they also have some disadvantages, as well as the technological limitations that prevent them at present from replacing manned aircraft in many roles.

The RAAF is facing a number of challenges over the next 20 years and one such challenge will be whether or not to adopt UAVs as part of its force structure. Trends indicate that UAVs will become a part of most advanced air forces within the next ten years and the RAAF must start seriously considering their acquisition for a variety of roles presently undertaken by manned aircraft. Several roles ideally suited to UAVs have been identified including reconnaissance, surveillance, target acquisition, target designation, electronic combat, communications relay and battle damage assessment. Sophisticated UAVs can offer high probability of mission success with little chance of friendly casualties, can be cost effective and can undertake a variety of roles and missions. Care needs to be taken, however, in identifying where UAVs can best satisfy a requirement by evaluating in accordance with the capability offered, cost effectiveness, utility, risk management, commonality and interoperability, and the political factors.

Doctrine needs to address the capabilities offered by UAVs not only in the context of a potential asset but also in the context of a potential threat. Increasingly, the question is becoming not whether the RAAF should adopt UAVs but when and for which roles, if experience is to be gained for developing specific doctrine for Australia's unique circumstances. While UAVs have much to offer, technology will continue to restrict their roles to complementing rather than replacing manned vehicles for some time. UAVs are not a panacea to defence problems and there will need to be a careful balance in force structure between manned and unmanned aircraft in all advanced air forces of the near future. The challenge for the RAAF and the ADF in the next ten years will be to strike that balance in the most efficient and effective way possible.