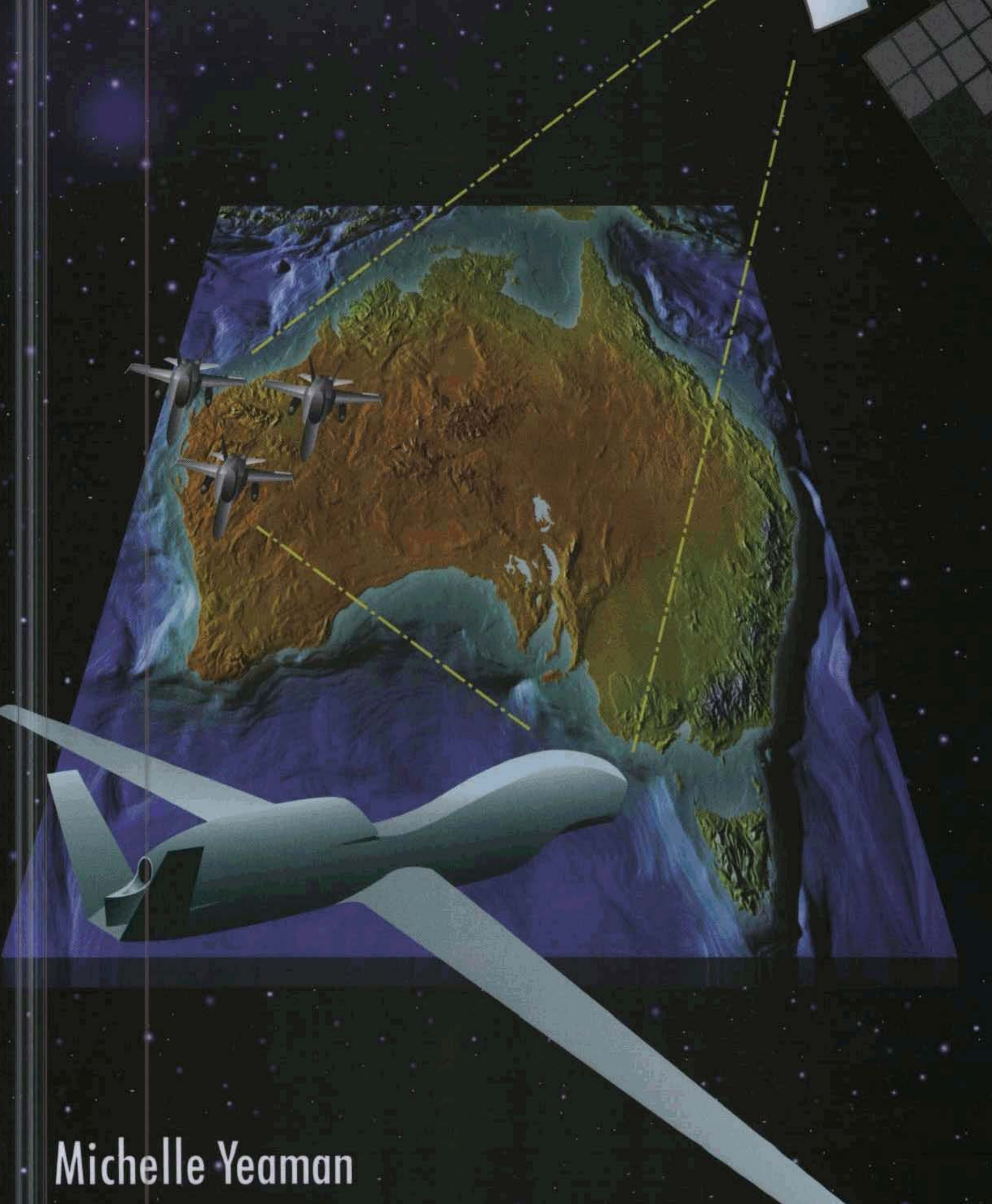
VIRTUAL AIR POWER

A Case for Complementing ADF Air Operations with Uninhabited Aerial Vehicles



Michelle Yeaman

Air Power Studies Centre

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About The Author

Flight Lieutenant Michelle Yeaman graduated from the Australian Defence Force Academy with a Bachelor of Arts degree in 1990. Her postings have included a short period at No 2 Stores Depot and a three year posting in the Movements Policy section at Air Headquarters. In 1995 she was posted to No 6 Squadron as the supply officer where she developed an interest in capability development. In 1997 she commenced the CAF Air Power Fellowship at the Air Power Studies Centre. Upon completion of the fellowship, Flight Lieutenant Yeaman was posted to the F-111G Project Office within the Defence Acquisition Organisation, where she is currently employed. Flight Lieutenant Yeaman holds a Graduate Diploma and Master of Defence Studies from Deakin University.

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Michelle Yeaman
Canberra, 1998

Contents

Acronyms

AA	Anti-Aircraft
AAA	Anti-Aircraft Artillery
AAM	Air-to-Air Missile
ACN	Airborne Communications Node
ADF	Australian Defence Force
AEW&C	Airborne Early Warning and Control Aircraft
ARM	Anti-Radiation Missiles
ASEAN	Association of South-East Asian Nations
BDA	Battle Damage Assessment
BVR	Beyond Visual Range
C^3I	Command, Control, Communications and Intelligence
CAP	Combat Air Patrol
CASA	Civil Aviation Safety Authority
CEP	Circular Error Probability
COMINT	Communications Intelligence
Csbms	Confidence and Security Building Measures
DCP	Defence Cooperation Program
Db	Decibel
DGPS	Differential Global Positioning System
DoD	Department of Defense (US)
DSTO	Defence Science and Technology Organisation
ECM	Electronic Countermeasures
EEZ	Economic Exclusion Zone
EHF	Extremely High Frequency
ELF	Extremely Low Frequency
ELINT	Electronic Intelligence
EMP	Electromagnetic Pulse
EO	Electro-Optical
ESM	Electronic Support Measures
EW	Electronic Warfare
FLIR	Forward-Looking Infra-Red
GDP	Gross Domestic Product
GCS	Ground Control Station
GPS	Global Positioning System
GSE	Ground Support Equipment
HAE	High Altitude, Endurance
HALE	High Altitude, Long Endurance
HARM	High-Speed Anti-Radiation Missiles

HF	High Frequency
HMI	Human Machine Interface
HUD	Head-Up Display
IAI	Israel Aircraft Industries
IFF	Identification, Friend or Foe
IIRS	Imagery Interpretability
IMINT	Imagery Intelligence
INS	Inertial Navigation System
IR	Infra-Red
JORN	Jindalee Operational Radar Network
JSTARS	Joint Surveillance Target Attack Radar System
JTIDS	Joint Tactical Information Distribution System
LCC	Life Cycle Costs
LEO	Low Earth Orbiting (Satellite)
LOS	Line-of-Sight
MAE	Medium Altitude, Endurance
MCS	Mission Control Station
MMW	Millimetre Wave
Mod	Ministry of Defence (UK)
MTBF	Mean Time Between Failures
MTI	Moving Target Indicator
NASA	National Aeronautics and Space Administration (US)
OOTW	Operations Other Than War
PPB	Pacific Patrol Boat
PMSA	Program of Major Service Activities
R&D	Research and Development
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy
RCS	Radar Cross-Section
RMA	Revolution in Military Affairs
RPV	Remotely Piloted Vehicle
RSTA	Reconnaissance, Surveillance and Target Acquisition
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SEAD	Suppression of Enemy Air Defence
SEANWFZ	South-East Asian Nuclear Weapon Free Zone
SHF	Super High Frequency
SIGINT	Signals Intelligence
SLOC	Sea Lanes of Communication
STOL	Short Take-Off and Landing

TALD	Tactical Air-Launched Decoy
TBM	Trust Building Measures
TERCOM	Terrain Contour Matching
T&S	Travel and Subsistence
TUAV	Tactical Uninhabited Aerial Vehicle
TV	Television
UAV	Uninhabited (or Unmanned) Aerial Vehicle
UCAV	Uninhabited Combat Aerial Vehicle
UN	United Nations
USAF	United States Air Force
USMC	United Stated Marine Corps
USN	United States Navy
VHF	Very High Frequency
VTOL	Vertical Take-Off and Landing
WAAS	Wide-Area Augmentation System
WMD	Weapons of Mass Destruction
WSLM	Weapons System Logistic Management
ZOPFAN	Zone of Freedom, Peace and Neutrality

Definitions

COMINT	Communications Intelligence from telephones, radios and datalinks.
ELINT	Electronic Intelligence from radar and other non-communications signals.
Reconnaissance	A mission undertaken to obtain by visual observation or other detection means, information about the activities and resources of an enemy or potential enemy; or to secure data concerning the meteorological, hydrographic or geographic characteristics of a particular area.[1]
Sea Surveillance	The systematic observation of surface and sub-surface sea areas by all available and practicable means primarily for the purpose of locating, identifying, and determining the movements of ships, submarines, and other vehicles, friendly and enemy, proceeding on or under the surface of the world's seas and oceans.[2]
SIGINT	The passive collection and analysis of electromagnetic emissions to locate and identify the source of a signal and develop countermeasures for neutralising the emitters.
Strategic Surveillance	The systematic observation of target areas where the time between observations is not a critical factor.
Surveillance	The systematic observation of aerospace, surface and sub-surface areas, places, persons or things, by visual, aural, electronic, photographic, or other means.[3]
Tactical Surveillance	The systematic observation of aerospace, surface and sub-surface places, persons or things, where the time between observations is critical.[4]
Target Acquisition	The detection, identification and location of a target in sufficient detail to permit the effective employment of weapons.[5]

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[1] *Australian Joint Service Publication JSP(AS)101,* Part 1, Headquarters Australian Defence Force, Edition 3, February 1984, p R-7.
[2] *Australian Defence Force Publication,* Operations Series, ADFP 29.
[3] *Australian Joint Service Publication JSP(AS)101,* Part 1, Headquarters Australian Defence Force, Edition 3, February 1984, p S-25.
[4] Squadron Leader W. Gale, *The Potential of Satellites for Wide Area Surveillance of Australia,* Air Power Studies Centre, Canberra, 1992, p xiv.
[5] *Australian Joint Service Publication JSP (AS) 101,* Part 1, Headquarters Australian Defence Force, Edition 3, February 1984.

Section One

Uninhabited Aerial Vehicles - Emerging Capabilities

Chapter 1

Introduction

By virtue of their unmanned status, Uninhabited Aerial Vehicles (UAVs) have the potential to revolutionise contemporary concepts on air power. Not only does the absence of aircrew enable them to further exploit the characteristic strengths of air power, but it also underpins the UAV's ability to significantly reduce the perceived limitations of air power. Removal of aircrew and their support systems means UAVs are capable of operating to the edge of the aircraft's operational envelope; with endurances, altitudes and G-forces beyond the normal physiological tolerance of aircrew. UAVs demonstrate the potential to fly longer, higher and faster without endangering lives. In short, UAVs have the potential to take and to hold the 'virtual high ground'. Furthermore, they promise better cost-effectiveness and greater utility than manned aircraft for 'dirty, dull and dangerous' mission profiles.

For these reasons, UAVs have gained increased popularity in recent times and are being incorporated into defence forces worldwide. Their potential application to the Australian Defence Force (ADF) has been referred to in a number of key policy documents such as *Australia's Strategic Policy*, the 1997 Strategic Review. In addition, UAVs are currently being examined as options in Project *Warrendi*, which seeks an airborne surveillance capability to support ADF land operations. Indeed, the ADF has had a long association with UAVs through its indigenous development and operation of the Jindavick target drone for the Royal Australian Navy. Despite these activities, however, little analysis has been undertaken on the application of UAVs to the Australian scenario generally, with even less emphasis being given to the challenges to their introduction and exploitation.

The advanced nature of several significant studies on force capabilities and the reference by the 1997 Strategic Review to UAVs as a subject of research priority provides the impetus for a study on their applicability to the ADF and issues particular to their successful integration.[1] Failure to undertake an analysis of their applicability sooner rather than later may result in the omission of these cost-effective platforms from force capability considerations. Alternatively, their hasty integration into the ADF without adequate planning could result in their under-utilisation or inappropriate employment in support of the ADF.

The purpose of this paper, therefore, is to examine the potential for UAVs to contribute to ADF air operations and to provide a foundation for their introduction through generating a better understanding of their inherent strengths and limitations. The paper also provides a

[1] *Australia's Strategic Policy*, Department of Defence, Australian Government Publishing Service, Canberra, December 1997, pp 59-60, 64, 66.

critical analysis on the applicability of UAVs to the ADF and flags those issues which must be addressed in order to fully optimise the potential for UAVs to contribute to ADF air operations.

The Requirement For a Study on UAVs

This study is timely for several reasons. First, the force development guidance provided in the 1997 strategic review - *Australia's Strategic Policy* - requires the ADF to 'take account of the contribution that different [capability] options would make to other tasks'.[2] Arguably, several characteristics of UAVs including their endurance and minimisation of aircrew casualties increase their opportunity for employment across a number of tasks and conflict scenarios. This is evidenced in their increased employment in peacekeeping and peace enforcement missions, where public tolerance to casualties is significantly lower than for conflicts which directly threaten the interests of the participating nation.[3] UAVs demonstrate utility across the spectrum of conflict and should therefore be afforded some consideration in future ADF force capability deliberations. An understanding of their strengths and limitations will enable those involved in ADF capability development to identify where UAVs constitute appropriate weapons system options. The ability to discern where UAVs do not represent cost-effective or operationally viable options as a result of their limitations or technological maturity is equally important for the timely development of ADF capabilities.

ADF recognition of the advantages inherent in the concepts of warfighting espoused by the so-called Revolution in Military Affairs (RMA) provides the second incentive for examining the applicability of UAVs to the ADF.[4] In particular, the ADF has identified the importance of dominating the information spectrum in order to gain more accurate and timely knowledge of an adversary and their intentions both at a strategic and tactical level. The ADF's emphasis on further developing reconnaissance and surveillance capabilities has already resulted in the initiation of several projects, one of which is considering UAVs as weapons systems options. Project *Warrendi* is detailed with generating an airborne surveillance capability in support of land operations and has considered both manned and unmanned aircraft within its concept definition phase. A more detailed analysis of the relative cost-effectiveness and operational capability provided by each weapons system will be conducted as part of the Request for Tender (RFT) and Tender Evaluation phases which will not be completed before early 1999.

The success or otherwise of UAVs in Project *Warrendi* and subsequent projects will be largely dependent on the level of understanding within the broader defence community. Too little knowledge results in either unconditional advocacy or rejection. In truth, UAVs have significant limitations and pose unique challenges, but are undoubtedly cost-effective and

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[2] *Australia's Strategic Policy*, p 36.

[3] US and French forces are employing UAVs in Bosnia for reconnaissance and surveillance tasks. UAVs were also used by the US Army and Marines in the 1991 Gulf War to provide tactical reconnaissance of Iraqi positions.

[4] *Australia's Strategic Policy*, pp 55-57.

offer considerable utility when employed appropriately. This paper seeks to identify how, why and where UAVs can be considered cost-effective and operationally-effective weapons systems in support of ADF tasks.

Finally, given the 'counter-capability' defence posture advocated by the Australian government, there is a real requirement to develop an understanding of the operational capabilities and limitations of UAVs. Acquiring a sound knowledge of UAVs is a precedent to empowering the ADF with the ability to develop counter-capabilities to limit the effectiveness of UAV employment by a potential adversary. The speed and spread of nations in the Asia-Pacific region acquiring UAV systems is such that consideration of developing counter-capabilities to UAVs is warranted. [5] Therefore, even if the ADF does not acquire UAVs in the near future, it needs to develop a sound understanding of UAVs in order to develop a counter-capability.

Parameters of the Study

Owing to the limited time available, several parameters were adopted for the purpose of defining the boundaries of the study. In examining the potential ADF acquisition of UAVs, the year 2015 is set as the outside limit due to difficulties in predicting the maturity of UAVs, and combat UAVs in particular, beyond 2015. Many other unknowns such as the cost and the accessibility of such technology to third-party nations also make predictions after 2015 meaningless.

The period around 2015 is selected also because of its significance to the ADF. With the retirement of the F-111 and F/A-18 set for the 2010-2020 period, the ADF will be faced with finding suitable replacements for the fighter, strategic strike and strategic reconnaissance capabilities provided by the two principal RAAF platforms. Given the time associated with capital equipment acquisitions, the decisions on replacement platforms will have been resolved well before 2015. Conceptually, both strategic strike and strategic reconnaissance capabilities can be provided by UAV platforms; however, the maturity of combat UAVs within the 1998-2015 time-frame is likely to discount re-useable combat UAVs for the RAAF. On the other hand, cruise missiles and reconnaissance UAVs are likely to be given serious consideration as complementary systems to the manned strike/fighter replacement/s.

For the Army and Navy, the introduction of UAVs may occur in the nearer term. Their potential for greater endurance and lower operating costs could see them considered as complementary platforms to rotary wing operations. Continued performance improvements in reconnaissance, surveillance and target acquisition tasks will further advance the prospect of their acceptance by the ADF. With the commensurate reduction in operating and procurement costs, it is foreseeable that UAVs will have a secured a place in both the Army and Navy before 2015.

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[5] The counter-capability may be in the form of operational doctrine designed to minimise the effectiveness of UAVs employed against Australian forces. Alternatively, it may consist of EW systems or anti-aircraft artillery. In either case, the ADF needs to develop a sound understanding of UAV systems and operations.

Methodology

Owing to the specific focus of this study, UAVs are analysed using a platform-centred approach, where the platform is measured in terms of what type of force capabilities it can support. The alternative - a capability-based approach - is not suitable due to the political and military sensitivities surrounding detailed capability requirements. Additionally, the adoption of a capability-based approach which fails to acknowledge the utility of platforms in providing support across a spectrum of capabilities would inhibit discussion of the strengths of UAVs in the emerging strategic environment.

Taking a platform-centred approach is not intended to convince readers that UAVs or any other military platform should be acquired through a hardware-based approach. The purpose is simply to analyse UAVs as a unique piece of military hardware and, in the process, suggest where they should be considered as contenders for meeting ADF force capability requirements. This said, the approach provides a valuable exercise in demonstrating the potential for multi-role tasking and may aid in the allocation of the asset to the most appropriate command and control level.

Organisation

This monograph is divided into four distinct sections, each of which is compiled so that it may be read in isolation of the others. This approach is adopted so that the monograph can meet its objective to educate the broader defence community, whilst enabling those with some prior understanding of UAVs to turn directly to the section/s of specific interest to them.

For those with little or no previous exposure to UAVs, Section One of the monograph is intended to provide the basic fundamentals of UAV systems and their operations. The section gives a brief overview on UAVs, discusses how and why they differ to manned aircraft, and identifies the emerging technology that will have significant impact on their future development and employment.

Owing to the unmanned nature of UAVs, they have several advantages over manned aircraft, not least of which is the preservation of human life. Despite these associated advantages, UAVs also have specific limitations which must be appreciated when comparing them to manned platforms. Both the advantages and limitations of UAVs are discussed in Section One. The maturation of emerging technology will in time address many of these limitations and enable UAVs to perform the full range of roles currently performed by manned aircraft. An understanding of their operational limitations, however, is required for the early development of operating procedures to minimise the impact of these on operations. The classification, development and employment of current and future types of UAVs is examined to introduce readers to the breadth of air power roles that can theoretically be undertaken by UAVs.

A vital component in analysing the applicability of UAVs to armed forces, and the ADF in particular, is the determination of its cost-effectiveness as a weapon system. To date, few methodologies and models are available which compare the cost-effectiveness of UAVs with manned aircraft and other systems. For several nations currently operating UAVs, the cost-effectiveness may be self-evident, such as is the case with Israel. The on-going requirement to conduct surveillance operations of Hamas and Hezbollah activities is sufficiently dangerous to manned aircraft to warrant the use of relatively cheap tactical UAVs. This application bears little relevance to Australia's surveillance requirements which are measured in terms of hundreds of kilometres coverage rather than tens of kilometres. On the other hand, the US is investing billions of dollars into the development of UAVs to supplement its manned reconnaissance and surveillance platforms. The financial constraints on the ADF is such that it cannot afford to acquire a particular platform type for the sake of maintaining a technological edge in every weapon system. As such, the cost-effectiveness of a system to one country does not automatically translate to another. There is a requirement, therefore, for a more generic methodology which can be employed by any country to determine the relative effectiveness of one platform type over another. Accordingly, Section Two proposes a methodology for performing a comparative analysis of UAVs with alternate platforms. The methodology examines three major drivers including; operational effectiveness, cost and utility.

Section Three examines the potential application of UAVs to the ADF. This is achieved through a detailed comparison of the relative ability of manned aircraft, UAVs and satellites to undertake a range of tasks in support of ADF force capabilities. The approach adopted is to examine the specific strengths and limitations of each platform type in performing surveillance, reconnaissance, electronic warfare and offensive roles. This exercise quickly highlights the tasks where certain platform types are not currently technically or financially suitable and could be used as a guide for discounting options at the force development level. Alternatively, where the examination has revealed some potential in undertaking specific roles, further analysis of the platform type is warranted. As a result, Section Three identifies tasks where UAVs could prove realistic acquisition options to the ADF out to the year 2015.

Challenges posed by the integration of UAVs into the ADF in terms of introduction, management and operation are examined in Section Four. Issues such as cultural barriers, management of airspace and concepts of employment are dealt with both in general and in an Australian context. These issues are fundamental to the effective introduction and operation of UAVs. Inadequate consideration of how UAVs will be managed and employed will result in a limited exploitation of their capabilities by a defence force that can little afford to ignore the range and endurance they offer.

Chapter 2

UAVs - An Overview

In order to analyse the effectiveness of UAVs to the ADF, an appreciation of what constitutes a UAV system and how it differs from manned aircraft is first required. To that end, this chapter provides a definition of UAVs and discusses some of the more important components of the UAV system. Components which pose potential limitations to the operational reliability of UAVs, such as datalinks for command and control, are given significant attention. While few components are unique to the UAV system, fundamental differences in the importance and function of the various components form the basis of both the inherent strengths and limitations of UAVs in comparison to manned aircraft. An understanding of those components which differ in function or criticality provides the basis from which judgements about the utility and applicability of UAVs can be formed.

Definition

For the purposes of this paper, an Uninhabited Aerial Vehicle 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.[1]

Using this definition, UAVs range from target drones, decoys, and reconnaissance and surveillance platforms, to cruise missiles. This definition encompasses an extensive variety of single and multiple use, lethal and non-lethal systems. While there is a tendency by many to discount cruise missiles and other single-use offensive systems from the UAV family because of the breadth of the subject matter, their exclusion based on lethality is difficult to justify. Arguably, given the widespread acceptance of decoys within the greater UAV family, and the incorporation of UAV loiter characteristics within several lethal missile systems, this paper adopts the broader definition of UAVs.[2]

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[1] M. Lax & B. Sutherland, *An Extended Role for Unmanned Aerial Vehicles in the Royal Australian Air Force,* Paper Number 46, Air Power Studies Centre, Canberra, July 1996, p 2.

[2] For example, IAI's 'Harpy' anti-radar missile has a two hour loiter capability and is classified by IAI as a UAV.

Many of the UAV variants are well known, having reached a level of maturity through operational successes in the Arab-Israeli wars, the Vietnam War, and more recently, the Gulf War and the Bosnian conflict. Their classification into distinct categories such as cruise missiles, decoys and remotely-piloted vehicles has, however, masked their collective success. Much of this is due to the association of the term 'unmanned aerial vehicle' with aircraft normally designed for aircrew, but where the pilot had been removed. The recent change in nomenclature from 'unmanned aerial vehicles' to 'uninhabited aerial vehicles' provides a more appropriate terminology for the inclusion of expendable and single-use UAVs while reflecting a quantum leap in thinking on UAVs (as well as a desire for political correctness !). The USAF has adopted the term 'uninhabited aerial vehicles' to emphasise the development of aircraft that can provide superior capabilities through exploitation of 'design freedom'.[3] This design freedom contrasts with the constraints imposed on the design of manned aircraft which focuses on providing aircrew with optimal viewing capability.[4] Manned aircraft designs are also constrained by the need to incorporate crew modules and associated life-support systems.

Differences Between UAVs and Manned Aircraft

As the designation suggests, the single characteristic that differentiates UAVs from manned aircraft is the absence of an on-board operator - the pilot. This one variation significantly changes the properties of the platform and impacts on the criticality of several system components in conducting effective flying operations.

The primary change resulting from the removal of aircrew from the aircraft is to the method of effecting command and control of the platform. For all UAVs other than fully automatic variants, command and control is physically transferred from the aircraft cockpit to another location, represented generically by the Ground Control Station.[5] By virtue of its removal from the UAV, a heavy reliance on datalinks for the relay of command and control information between the UAV and the station exists. This reliance on datalinks poses one of the greatest vulnerabilities and cost drivers of UAVs. For those UAVs that are largely automated, the navigation and guidance systems take on added importance in relation to their manned counterparts. Similarly, radars and other sensors have increased importance in replicating the pilot's capability to 'see' other air traffic.

One advantage of UAVs is that there is no requirement for crew modules and life support systems, thereby freeing up space and weight for increased payload capacities. Another advantage enabled through the removal of aircrew is the ability for operators to employ more

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[3] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century - Summary Volume*, 15 December 1995, p 8.

[4] For close-space encounters, the tactical advantage for fighter aircraft is still provided through the capability of aircrew to physically 'sight' their opponents rather than through a reliance on radars and other sensors. Until such time as technology can replicate this 'situational awareness' provided through the physical sight of aircrew, UAVs will be inferior to manned aircraft for 'dog-fighting' scenarios.

[5] Command and control of the UAV can be effected from controlling stations aboard manned aircraft, ships, submarines or a number of other locations. The term 'Ground Control Station' is used generically to denote the place from which the UAV is controlled, regardless of location.

dangerous launch and recovery techniques to achieve better responsiveness for tactical missions.

Other than the physical differences associated with the replacement of an on-board operator with a Ground Control Station, UAVs and manned aircraft essentially comprise the same system components. The difference between the two platform types is in the relative importance of each of these components in the aircraft's operation. In the following section those components are examined which, due to the removal of aircrew from the aircraft, have a higher level of criticality in a UAV's operation. Physical differences, including aircraft structure and launch and recovery methods, are also examined as important variations enabled through the removal of aircrew from the aircraft.

UAV System Components

A brief examination is required of components with unique applications to UAV operations. This examination then discusses the importance of these components and, where applicable, briefly examines the advantages and disadvantages of different options available for the various different components of the UAV system. The components which will be examined include:

- the control system,
- the launch and recovery system,
- the navigation and guidance system,
- the ground control station, and
- the datalink, processing and storage system.

Control System

A control system is used to control all aspects of the UAV's flight. Like that for manned aircraft, control of the aircraft can be effected through inputs by an operator, pre-programmed 'autopilot operations' or a combination of the two. UAV control systems can generally be classified as fully autonomous, remotely-monitored, remotely-controlled or remotely-piloted.[6] Basic UAV models tend to employ remotely-piloted systems not unlike that found in hobby-style remote control model aircraft. The remotely-piloted UAVs require control by an operator for take-off and landings, as well as continuous input to direct the UAV over the target area. Unlike basic model aircraft, remotely-piloted UAVs are likely to be fitted with stabilisers and other systems designed to reduce the workload requirement of the operator. Remotely-controlled UAVs require manual input for take-off and landing, and changes in direction, speed and altitude. Most modern navigation and guidance systems are present in remote-controlled UAVs and their operation will generally reflect a combination of operator and autopilot control. Remotely-monitored UAVs include those such as the Block IV Tomahawk cruise missiles which are pre-programmed and, therefore, largely autonomous. A

[6] T. Wilson, quoted in D. Barrie, 'Dull, dirty and dangerous', *Flight International*, 11-17 June 1997, p 61.

control link is maintained with the aircraft so that information on the system's performance and position can be monitored. Remotely-monitored systems also have an up-link which allows ground operators to re-task the UAV mid-flight. Inaccuracies in the UAV's flight path can be rectified through operator input and self-destruction, or return-to-base sequences may be initiated from the ground if the UAV experiences unresolvable technical difficulties. Fully autonomous systems are those which are fully pre-programmed such as the earlier model cruise missiles and expendable decoys. These systems have no reliance on datalinks with a control station, although they may employ GPS or other signals for navigation or targeting purposes.

Each of the four control system variants have their advantages as well as their limitations. The limitation of remotely-piloted and remotely-controlled systems is the heavy reliance on the manned operator with associated requirements for pilot skills and multiple manning. For example, one operator may be required to control the aircraft while another is required to control sensors and interpret sensor data. These systems also require significant concentration by the operator on the task at hand, resulting in similar operational constraints to that of manned aircraft. For endurance missions, consequently, extra shifts of operators and analysts may be needed to reduce fatigue. The human operator has also been identified as a significant cause of UAV mishaps and accidents.[7] UAV accidents attributable to operator error predominantly occur in the take-off and landing stages of flight.

Recognition of these limitations to remotely-piloted and remotely-controlled UAVs has provided the impetus for greater automation of UAVs. Israel Aircraft Industries (IAI) has prioritised the automation of UAV flight in order to significantly reduce manning costs, accidents, and enable cheaper operating costs.[8] However, complete automation of UAVs is unlikely due to increasing safety requirements associated with operations in civil airspace. In rare cases, full automation may be employed, particularly where the UAV is expendable and is employed at the tactical level of the battlefield.

Despite the costs associated with maintaining a man-in-the-loop capability, control systems which enable input from the ground are likely to dominate, given the potential to redirect or to re-task the UAV mid-flight, thereby increasing mission flexibility. Man-in-the-loop control systems also provide another level of redundancy where the UAV can be destroyed, if it is in danger of experiencing a catastrophic failure, or manually flown back to base when minor system failures occur. This capability is particularly important for UAVs carrying sensitive military sensors or, in the case of cruise missiles, a warhead with significant destructive power and classified target acquisition systems.

Given the cost efficiencies that can be found through reducing reliance on qualified-pilot operators and the reduced requirement for 'hands-on' operations, remotely-monitored UAVs will become increasingly common. Remotely-piloted UAVs will be limited to cheaper tactical models where the risk of loss is acceptable due to either a limited probability of loss

[7] J. Chemla, *Future UAV Systems,* An Address to DSTO on 4 February 1997, Israel Aircraft Industries, Malat Division, Salisbury, South Australia.
[8] *Ibid.*

or their cost being low enough to make them attritable. Indications are that labour-intensive remotely-piloted UAVs will only continue to be cost-effective where:

$$\$M + \$R * P(l) < \$A * P(l)$$

Where:
$M = manpower costs
$R = cost of remotely-piloted UAV
P(l) = Probability of loss
$A = cost of automated UAV

All other UAVs will exhibit increasing automation with a man-in-the-loop capability for the purposes of flexibility and safety for both the UAV and personnel.

Launch and Recovery Systems

Similar to that for manned aircraft, a variety of launch and recovery systems exist for UAV operations. However, unlike the limited methods used for manned operations, the full range of launch and recovery systems can be employed by UAVs due to their size and expendable nature. Many of these have been determined as unsuitable for manned operations, but because of the tactical advantage or cost-effectiveness of such systems, they have gained renewed popularity for UAV operations.

Launch systems for UAVs can include booster rocket, hydraulic catapult, pneumatic launch rail, bungee, hand-launched, air-launched and conventional wheeled runway take-off. Such a range of launch systems indicates the priority afforded to providing field commanders with a tactical capability which can operate in the field or from small launch platforms such as ships. The development of these alternate launch systems has come from the recognition that conventional take-offs from runways have significant limitations. These include the cost associated with securing and maintaining the runway to suitable standards, as well as the additional difficulty of operating under cross-wind conditions. Indeed, this runway limitation continues to be one of the predominant weaknesses of fixed wing aircraft and the prevalence of other launch methods attests to the desire for more tactical and flexible operations, particularly for ground forces.

While the desire to limit reliance on airstrips dominates the thinking of surface forces (such as armies and navies), Israel Aircraft Industries (IAI) specialists believe that conventional runway take-offs will dominate future UAV operations, particularly for endurance systems.[9]

[9] *Ibid.*

The runway take-off presents fewer hazards, is cheaper to achieve and is the only practical method for the larger UAVs being developed. In the Australian context, however, reliance on airstrips for all but strategic platforms has its limitations.

Recovery systems are equally varied, ranging from parafoils, parachutes, skids, nets and conventional landings. Similarly, most of these systems are employed to reduce the reliance on prepared airfields. As with the launch systems, however, progress in the future will likely concentrate on runway landings, particularly for UAVs with endurance capabilities. The accident and damage rate for UAVs employing other than conventional runway landings is sufficiently high to be a serious cost limitation to the tactical capability afforded.[10] To reduce the difficulties associated with the launches and landings of tactical UAV systems, greater experimentation of rotary wing and tilt-rotor UAVs has resulted.

Navigation and Guidance Systems

With the greater employment of automation in UAV systems, the requirement for sophisticated navigation and guidance systems incorporating a redundancy function has increased. Whilst this is one of the primary requirements for the further automation of UAVs, the requirement has largely been satisfied by systems developed for manned aircraft operations. The navigation and guidance systems employed in UAVs, therefore, have similar features to those systems incorporated in manned aircraft. However, Differential Global Positioning System (DGPS) will be crucial to the further automation and widespread acceptance of UAVs in the future, and will be discussed further in Chapter 4.

Ground Control Station/Mission Control Station

The UAV platform is only one component of the total UAV system. UAV systems have Ground Control Stations (GCS) and Mission Control Stations (MCS) to undertake the functions of controlling the UAV in flight and for receiving sensor data on the ground respectively. A cost analysis of any UAV system must take into account the other various components of the system. For example, the manufacturer of Global Hawk - Teledyne Ryan Aeronautical - has a requirement to maintain the vehicle fly-away price to US$10 million. The cost of the complete system must be adequately accounted for when considering the cost-effectiveness of UAVs. As the UAV platform is generally accepted as comprising approximately 15 per cent of the total system cost, the total system, comprising three UAVs, Ground Control Station, Mission Control Station and maintenance support, is more likely to be in the order of US$750 million.[11]

While the GCS is unique to UAV systems, the requirement for MCS is not. Any platform which has the capability and requirement for near-real-time data transfer to the ground will need some form of MCS. As the requirement for real-time data increases, manned

[10] *Ibid.*
[11] *Jane's Unmanned Aerial Vehicle Catalogue*, K. Munson (Ed.), Foreword, Seaford, April 1997.

reconnaissance platforms are likely to display similar system characteristics, such as the requirement for datalinks and MCS, to that of the UAV system. The only exception is likely to be the UAV requirement for a GCS, and the manned aircraft requirement for an on-board operator.

Datalinks and Data Storage Systems

A datalink of some description will generally be used for most UAVs, with the possible exception of some single-use platforms such as fully automated decoys and cruise missiles. Datalinks are established between the UAV and ground station for controlling the platform and the payload, monitoring the performance and position of the UAV, and relaying data from sensors. The use of datalinks may be for one or a number of these functions, depending on the level of control required. For largely pre-programmed UAVs, such as cruise missiles, the establishment of datalinks might only be used for the periodic transmission of positional data for manual verification of their targeting accuracy. More commonly, the establishment of a two-way datalink is being employed to enable retasking or redirection of cruise missiles. The transmission of electro-optical imagery during the missile's final flight path is also gaining in popularity as an instant verification of the missile's accuracy in hitting the allocated target.

The current emphasis on acquiring real-time intelligence from both manned and unmanned platforms will generate an increased reliance on datalinks for transmission of imagery or other sensor outputs. This reliance on datalinks as a means for receiving the data 'product' of reconnaissance and surveillance missions in real-time has resulted in an increased focus on the reliability and security of datalinks for UAV operations.

The datalink represents the most tenuous and potentially weakest component in the UAV system. While greater automation with increased redundancies in guidance and control systems will enable UAVs to operate without the continuous use of an up-link, the link represents a significant redundancy feature - that of using the man-in-the-loop. Maintenance of the datalink for this purpose is considered important, particularly where a comprehensive software failure occurs and the UAV fails to revert to its pre-programmed emergency procedures. The maintenance of the man-in-the-loop redundancy through the UAV-operator datalink is a political (and potentially, legal) imperative for UAVs with lethal payloads, particularly where a UAV overflies friendly population centres. Another important function of the UAV-operator datalink is to increase the platform's survivability through pilot input. Understanding the limitations imposed by the datalink is essential to any in-depth analysis of the applicability and employability of UAVs in the military.

UAVs can use a variety of datalinks, ranging from radio and light beams to physical links, depending on the operational requirement. High Frequency (HF) and Very High Frequency (VHF) are used but the more common link is based on Ultra High Frequency (UHF) bands and microwave bands. For increased range, satellites or other airborne platforms are used to relay information between the operator and the UAV using the C, L (UHF) and K_u Super

High Frequency (SHF) communication bands. Further technological development will see satellites and other relay platforms employing laser datalinks and the Extremely High Frequency (EHF) K_a band. In limited scenarios, physical links such as fibre optics may also be utilised with great success. Owing to the importance of the datalink to the majority of UAV systems, further examination of the advantages and disadvantages of different types of datalinks is worthwhile.

High Frequency Datalinks

High Frequency (HF) is rarely used as a datalink for UAV systems, particularly where the datalink is required for the transmission of high quality visual data. HF links are generally considered unstable and of unreliable quality due to the changing properties of the ionosphere which is used to 'bounce' the signal between the UAV and transmission site. The primary advantage of an HF link is the ability to operate beyond line-of-sight. To date, HF has been discounted by UAV operators for reasons of security, reliability and the inability to transmit real-time video-quality imagery using contemporary data compression techniques.[12] Developments in this field would be of significant interest to Australia given the absence of an organic ADF satellite capability and the requirement to conduct surveillance over vast areas of territory.

VHF, UHF and Microwave Datalinks

VHF, UHF and microwave links are the predominant forms used for tactical UAV systems. They provide sufficient bandwidth to carry real-time video and the link is generally secure because the ground station uses a high gain tracking antenna with a narrow up-link beam. Some UAVs use directional aerials to provide further security to the link. The obvious disadvantage with these links are that they are limited to line-of-sight operations, generally restricting the use of the UAV to within a 200-300 kilometre radius depending on its operating altitude.

Satellite Communications

Satellite links using the K_u and C band offer significant advantages over other forms of communications. Satellite-relayed datalinks enable a UAV to transmit large amounts of data in near-real-time whilst providing it with a capability to operate beyond visual range. The primary disadvantage with the employment of satellite datalinks is their susceptibility to interception and jamming, and the inherent costs associated with satellite communications. To ensure adequate reliability of the link and an acceptable level of security, a UAV requires a steerable antenna. In the near future, employment of laser links using satellites will provide more secure beyond-visual-range communications links for UAV operations.[13]

[12] K. Cameron, V. Kowalenko and J. Phipps, *Data Link Technology for a Portable Unmanned Aerial Vehicle*, Defence Science and Technology Organisation, Department of Defence, Salisbury, 1997.
[13] USAF Scientific Advisory Board, *New World Vistas: Summary Volume*, p 20.

Optical Datalinks

Another form of link which has limited but notable applications is the optical link. This type of link may provide reasonably security but once again is limited to line-of-sight operations; directional aerials are required at both ends but may be smaller than those required for VHF/UHF.[14]

Fibre Optic Datalinks

'For two-way communications, fibre is rapidly becoming the medium of choice.'[15] A physical datalink is most notably used in fly-by-wire anti-tank missiles (technically a UAV). The advantages of using fibre optic links for reconnaissance UAVs lies in the capability to down-load large amounts of data with a reasonably secure link. The difficulties with such systems are the amount of cable required for reasonable range, strength and the currently prohibitive cost associated with fibre optics. Despite these limitations, several systems continue to use optical fibre as their preferred datalink with a high degree of success in tactical training and operation scenarios. Aerospatiale's C22-aerial target set a new record in 1996 by operating with some 60 kilometres of fibre optic cabling.[16] This reach enabled the drone to simulate aircraft and missile threats to air force, naval and artillery units, employing beyond-visual-range (BVR) approaches.

Laser Datalinks

The USAF Scientific Advisory Board has forecast that high bandwidth laser links will become the way of the future in terms of enabling secure communications for sensor-to-analyst operations. In *New World Vistas,* the Advisory Board has predicted that '... laser links will approach the capacity of fibre, where 40 Gigabytes/s is becoming routine'.[17] Furthermore, they believe that the employment of satellite and aircraft laser cross-links and down-links will alleviate the impending challenge of finite bandwidth available for global communications. The development of satellite-based laser communications for cross-links and down-links (with equivalent rates to fibre) is not likely to become available for another 10-20 years.

Summary

Understanding the main components and their relative importance to UAV operations is essential to gain an appreciation of the differences between UAVs, manned aircraft and satellites. Owing to the removal of the on-board operator, most UAVs have a heavy reliance on datalinks for command and control purposes. These links can be difficult to secure and,

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[14] K. Cameron, *Unmanned Aerial Vehicle Technology*, Defence Science and Technology Organisation, Department of Defence, DSTO-GD-0044, February 1995, p 9.
[15] USAF Scientific Advisory Board, *New World Vistas: Summary Volume*, p 42.
[16] F. Lert 'Playing with fire', in *Unmanned Vehicles*, August 1997, p 17.
[17] USAF Scientific Advisory Board, *New World Vistas: Summary Volume*, p 20.

in the case of providing beyond-visual-range capabilities, can prove a major cost driver. While employing similar navigation and guidance systems as manned aircraft, these systems are critical to a UAV's operation. Consequently, UAVs with considerable strategic or dollar value will require redundancies of these systems, further increasing their cost.

In their favour, UAVs can be launched and recovered utilising the full range of available methods, thereby increasing their tactical utility over manned aircraft for use by ground forces. The different treatment of the system components discussed represents the basis of both the inherent strengths and limitations of UAVs.

The strengths and limitations particular to UAVs become more apparent when analysed in the context of the general characteristics of air power which is the subject of examination in the following chapter. This analysis will form the basis for discerning how best to exploit the strengths of UAVs through the development of more detailed concepts of operations.

Chapter 3

UAVs and the Characteristics of Air Power

Introduction

As with any military weapons system, exploitation of the comparative advantages of UAVs is dependent upon their appropriate employment. The absence of aircrew in UAVs optimises their employment in roles considered too dirty, dull or dangerous for manned aircraft. The 'dirty, dull and dangerous' concept recognises the physiological constraints on humans in undertaking missions in 'dirty' environments such as proximity to suspected chemical, biological or nuclear facilities, or over bushfires where smoke inhalation could harm or detract from the pilot's capability to fly the aircraft. Physiological constraints also prevent aircrew from undertaking ultra-long 'dull' endurance missions at ultra-high altitudes. More notably, UAVs can be utilised in high-threat scenarios where the aircrew are placed in considerable 'danger'. The drive to reduce attrition of crewed aircraft in high-threat scenarios has resulted in the widespread use of UAVs across a range of conflicts throughout history. The employment of UAVs for the express purpose of reducing aircrew attrition in conflict has been achieved using tactical reconnaissance UAVs, cruise missiles and decoys. Using unmanned aircraft in 'dirty, dull and dangerous' missions, therefore, is not new; the concept, however, is gaining momentum as the drive intensifies for information dominance, precision strike, and casualty minimisation.

A more complete understanding of the rationale for the employment of UAVs in various roles is gained through an examination of their standing against the strengths and limitations of air power.[1] The remainder of this chapter discusses the potential for UAVs to further exploit the *inherent strengths of air power whilst reducing the limitations.*

Strengths of Air Power

Versatility

A common feature in the design of contemporary UAVs is the incorporation of features for improved versatility. Increasing payload capacities and the employment of datalinks for UAV control will provide improved flexibility of employment. Where past employment of UAVs has generally been in one role, UAVs can now perform multiple roles simultaneously

[1] *The Air Power Manual*, 3rd Edition, Air Power Studies Centre, Royal Australian Air Force, Canberra, 1998, pp 25-34.

due to the ability to incorporate and to operate a number of sensors and systems in the one platform. For reconnaissance UAVs, this may equate to an all-weather, day/night capability using Synthetic Aperture Radar (SAR), Infra-Red (IR) and optical sensors. Alternatively, a reconnaissance UAV might also undertake Electronic Warfare (EW) tasks in addition to its reconnaissance role. UAVs have also offered a level of flexibility in targeting, much like other manned reconnaissance platforms. This flexibility is achieved through the re-tasking of the vehicle from the Ground Control Station via the up-link.

To increase their utility as military platforms, the development of UAVs to perform multiple roles has been recognised as important. The need for greater versatility to justify high platform costs has seen the development of UAVs for multiple roles. An example of this is the found in the developing concept of employing UAVs in Theatre Ballistic Missile Defence (TBM) systems where the UAV will detect the ballistic missile launch and destroy it in flight using an air-to-air missile. At the same time, the UAV may acquire the position of the ballistic missile launcher and destroy it using another missile or by diving onto the target.[2] The USAF are also exploring the concept of using UAVs to detect, acquire and neutralise a target and perform immediate Battle Damage Assessment (BDA) with a single platform.[3]

Reach

One of the more notable characteristics of aerospace power is its ability to 'operate unconstrained by physical barriers anywhere over the surface of the earth.'[4] UAVs and other unmanned systems such as satellites demonstrate cost-effectiveness in exploiting this characteristic as there is no requirement to provide life-support systems for a human operator. For satellites, this means there is no requirement to re-provision the operating system for its life-of-type. With UAVs, the removal of life-support systems provides greater capacity for fuel or other payload, translating into the potential for greater reach.

In terms of range and endurance, UAVs such as Teledyne Ryan Aeronautical's Global Hawk will boast a 3000 nautical mile (nm) operating radius with a 24 hour loiter capability. While manned aircraft are capable of long ranges, they are limited by the human requirement for food and rest. Unmanned aircraft can exploit the full range of the aircraft parameters by changing the ground controllers without requiring the aircraft to return to the ground. Automated UAVs are even less dependent on the 'man-in-the-loop' and can be programmed to communicate only when there are difficulties or human targeting input is required.

[2] 'Israel's MOAB Scud interceptor detailed', *Jane's International Defense Review*, 7/1996, p 5; and W.B. Scott, 'Kinetic-kill Boost Phase Intercept Regains Favor', *Aviation Week & Space Technology*, 4 March 1996, pp 22-23.
[3] D.A. Fulghum, 'New Tomahawks Offer Low Price and Agility', *Aviation Week & Space Technology*,
[4] *The Air Power Manual*, p 26.

The reach of UAVs may be limited by their datalink requirement. UAVs which depend on datalinks for continuous control or the real-time transfer of information, will be 'reach' limited by their datalink. For nations like the US, this is not likely to pose a considerable constraint given their global satellite network. For smaller military forces, this constraint will require some consideration. The potential 'reach' limitation of datalinks into highly defended territory, in EW terms, also deserves attention. This potential constraint on UAV operations can be addressed through greater automation, incorporation of artificial intelligence capabilities and decision matrices, as well as through measures to reduce the vulnerability of datalinks to jamming and other threats.

Perspective

Through the use of air as its operating medium, aerospace power is able to deliver a wide range of 'perspectives' of the battlespace. Rotary wing and low altitude aircraft are able to achieve similar perspective to that of land and maritime vehicles, whilst satellites can provide a view of the entire battlespace. Owing to the flexibility of air-breathing aircraft to alternate between various altitudes with relative ease, UAVs represent a versatile capability for delivering a range of perspective to the commander. This versatility can be achieved with fewer limitations than those imposed on manned aircraft or satellites.[5]

Speed

Recognition of the physiological constraints of the human body will ultimately limit the exploitation of speed past a certain point. For UAVs, and more specifically missiles, speed can be further exploited to defeat enemy defence systems and to gain the element of surprise. The development of hypersonic missiles and the concept of developing re-useable hypersonic UAVs demonstrate the ability for UAVs to further exploit this characteristic strength.

Penetration

Like manned aircraft, the characteristics for reach, speed and perspective enables UAVs to penetrate the enemy's territory with relative ease compared to other forms of military power. In contrast to manned aircraft, the expendable nature of UAVs means they are more likely to be employed to achieve penetration of heavily defended or high threat environments. The use of UAVs to penetrate high threat areas is demonstrated through the increased use of cruise missiles and decoys as complementary systems to increase the survivability of manned aircraft. This cumulative characteristic epitomises one of the key strengths of UAVs over manned aircraft in modern warfare.

[5] For example, endurance at ultra-high altitudes are limited for manned aircraft by the capacity of the life-support system for its crew. Low level reconnaissance by manned aircraft is also limited by the threat environment. Low Earth Orbital (LEO) satellites have very short times over target due to their orbital characteristics, whilst Geostationary satellites maintain a presence over a selected area but this is only achieved at altitudes with limited use for sensors optimised for battlespace surveillance.

Pervasiveness

Like satellites, UAVs are able to exploit the attribute of pervasiveness through increased altitude. With this capability, UAVs demonstrate a particular advantage over manned aircraft in that they can achieve greater endurance at increased altitudes. Teledyne Ryan Aeronautical's Global Hawk, for example, is likely to operate at an altitude of 65,000 feet for periods of up to 42 hours. The capability to exploit the characteristic of pervasiveness through greater altitudes and increased endurances will see the further development of UAVs for high-altitude, long endurance missions.

Additionally, in the short term, high altitude UAVs will be capable of operations beyond the reach of most manned aircraft and contemporary Surface-to-Air Missiles and thus will have extra freedom of action over manned platforms. This tactical advantage is only likely to endure until the imperatives for destroying UAVs encourage nations to redesign missiles. A high altitude advantage, therefore, is likely to be temporary.

The limitation to the exploitation of ubiquity by UAVs during peacetime will be the constraints imposed by the irregular development of international and national airspace regulations. If the employment of UAVs is to be optimised, or the future attention must be given to the development of flexible airspace regulations.

Responsiveness

With the ability to launch some UAVs from unprepared airstrips using catapult or other techniques, their responsiveness can be significant. This is particularly applicable to the support of ground operations where UAVs may be more responsive than manned aircraft. Similarly, the cruise missile family utilises speed to exploit surprise and to apply force quickly.

The continued development of long-range, long-endurance UAVs will furnish governments with the capability to swiftly deploy platforms to operational areas with sufficient endurance to commence their mission tasking upon arrival over the area. This capability will see UAVs exceed their manned counterparts in providing swiftness of application by removing the requirement for large logistic 'tails'. The major advantage will be endurance; another will be the reduction of the logistics 'footprint' in the Area of Operations (AO). These advantages will be particularly relevant in missions requiring surveillance for long duration.

Concentration of Force/Tempo

Using offensive UAVs such as cruise missiles, rapid concentration of firepower can be achieved where required. The complementary use of high cost cruise missiles with low cost decoys and waves of manned aircraft in a Supression of Enemy Air Defence (SEAD) mission demonstrate the potential for UAVs to achieve rapid concentration of firepower and to overwhelm enemy defences. Furthermore, the use of UAVs in the high-risk missions such as the employment of expendable decoys to activate the enemy SAM radars is more cost-effective than using high-cost manned aircraft. Complementary operations involving manned and unmanned systems can be planned to exploit the principle of rapid concentration.

Asymmetric Response

With the combined reach and lethality of modern air power, it is often used to achieve an asymmetric response to a perceived threat. Governments can destroy high-value strategic targets with minimal effort using aerospace weapons systems, such as long-range cruise missiles or strike aircraft. UAV systems are increasingly favoured for achieving asymmetric response due to their minimisation of casualties and increased range.

Lethality

Cruise missiles encapsulate the fundamental characteristics of the lethality achieved through air power. Their precision, range and explosive power, coupled with the ubiquity afforded to aerospace systems, provide UAVs with lethality unmatched by many other weapons systems. The cost of this lethality represents one of the current limitations to air power. Future development of UAVs aims to decrease the cost of air-borne lethality through the design of reusable combat UAVs and cruise missiles with multiple warheads.

Casualty Minimisation

From reconnaissance platform to cruise missiles, UAVs enable a government to demonstrate political intent from an arm's length. Furthermore, the removal of the pilot from the cockpit removes the risk of an adversary using captured aircrew to gain psychological advantage. The political effect of such actions on governments sensitive to casualties was demonstrated in Somalia when the sight of the bodies of US Army aircrew being dragged through the streets of Mogadishu contributed to the US decision to pull out of the peacekeeping mission. Therefore, perhaps the most positive attribute of UAVs is the elimination of risking aircrew casualties by removing aircrew from the aircraft. This attribute makes UAVs more politically acceptable in high-threat environments, particularly for nations that are extremely sensitive to casualties.

While the vulnerability to casualties is removed from the aircraft, adequate provisions must be made to protect the operators in their ground station. This is only likely to be of concern for tactical reconnaissance platforms employing Line-of-Sight (LOS) datalinks. In these cases, little political leverage is likely to be gained, given the tactical nature of these missions.

For predominantly automated flights and those using satellite relayed datalinks, the probability of operator casualties is significantly reduced, given the longer operating distances between controllers and UAVs. The concept of removing the operators from the aircraft should be employed to reduce the threat to operators performing 'airborne early warning and control' (AEW&C) type operations. By minimising the number of crew on-board AEW&C aircraft to those required to safely 'pilot' the aircraft, and transferring the majority of technical operators and analysts to the ground, air forces could significantly reduce the 'political value' associated with AEW&C and other aircraft with large crews.

Limitations of Air Power

Base Dependence

Like rotary wing aircraft, the design of tactical and short-range UAVs is focused on reducing the dependence on runways and bases. This is achieved through the employment of launch systems, such as catapults and rocket launchers, that remove the requirement for established airfields. The complementary landing systems for these tactical UAVs employ skids, parachutes, aerofoils or nets to remove or to reduce the length of runway for landing.

For larger or more complex UAV systems, the requirement for prepared runways and support organisations will approach that of manned aircraft and will pose similar limitations and costs in terms of base security, logistics and administrative support. The development of long endurance UAVs will offset the vulnerability associated with base dependency to an extent, particularly where the UAV can be launched from outside the theatre of operations. The vulnerability of bases for Predator operations over Bosnia, for example, was reduced by using bases in Hungary and Croatia.

Fragility

UAVs have advantages and disadvantages over manned aircraft in relation to vulnerability. Some UAV datalinks are vulnerable to jamming and interference and do not possess the 'autonomous' capability to operate independently of ground control (with some exceptions). With the need for crew modules removed, UAVs can be made comparatively smaller with potentially reduced radar cross sections, thus making their detection more difficult.

Limited Payload

In comparison to aircraft of similar size, the removal of on-board operators along with their support systems provides UAVs with a relatively greater payload than that of manned aircraft. While aerospace systems will always be payload-limited compared to surface vessels and vehicles, UAVs can be seen as systems which address the limitation with respect to air power.

Information Dependence

'Air power is critically dependent on information' and, for UAVs in particular, information dependence represents one of their greatest vulnerabilities. [6] Accurate targeting and navigational information is required for largely automated UAVs, whilst remotely piloted UAVs depend on datalinks for the continuous update of information for control purposes.

The transition to more autonomous UAVs will reduce the operational constraints associated with the requirement for datalinks to receive information for control purposes. In contrast however the requirement to transmit real-time data from sensors on both manned and unmanned platforms will increase the reliance on datalinks.

Nations without an indigenous satellite capability will be restricted to LOS communications or by the constraints associated with hired satellite bandwidth (which may include the political inclinations of the satellite owners). Alternatively, other relay platforms such as manned aircraft or UAVs could be employed to deliver beyond-visual-range capabilities.

Cost

The cost of air power is identified as one of its fundamental limitations. Cost is identified as one area where UAVs are capable of reducing the limitations of air power and is considered one of the predominant advantages over manned aircraft. The manufacture of many UAVs utilise 'commercial-off-the-shelf' (COTS) or 'military-off-the-shelf' (MOTS) components, representing reductions in both research and development (R&D), and manufacturing costs. By removing the requirement for crew modules and life-support systems, further reductions in production and maintenance costs are also realised. Lower acquisition costs can also be achieved at the expense of reliability due to fewer or non-existent redundancy features. However, this saving is likely only to apply to UAVs with limited life-spans and tactical applications, given the existing requirements for safety and cost-effectiveness in systems.

Operational cost-effectiveness is being addressed as UAVs achieve greater reliability and offer increased endurance over manned aircraft. Owing to the complexity of the datalinks required and other associated equipment (ground control stations, satellites, etc), these vehicles are not yet competitive with general aviation aircraft such as those made by Beechcraft, Cessna or Piper. UAVs demonstrate cost-effectiveness where the threat to human life is assessed as being high, or alternatively, where manned operations are limited by human endurance. Thus, while cruise missiles are an extremely costly munition, they are cost-effective where the risk to manned aircraft without a stand-off capability is high. The cost-effectiveness of UAVs will predominantly be satisfied in the 'dirty, dull and dangerous' environments.

[6] *The Air Power Manual*, p 31.

Impermanence

One particular weakness of air power is its relative impermanence compared to other forces that can 'hold ground'. UAVs are being developed for increased range and endurance, addressing some of the limitations of impermanence. Futuristic visions of UAVs envisage vehicles that can essentially 'hold airspace' or provide 'air occupation' with both surveillance and strike capabilities. This concept of operations for UAVs has the potential to add a new dimension to air power.

Cultural Acceptability

While not necessarily representing a limitation of air power *per se*, the cultural acceptability of UAVs will prove one of their greatest limitations in the short term. Though this is likely to be overcome through the maturation of UAV systems, appropriate application and more widespread education, their cultural acceptance both by the aircrew community specifically and the public generally, may be viewed as a limitation to their further development.

Summary

UAVs are capable of exploiting some of the strengths of air power, particularly through the removal of aircrew. Their main advantages over manned aircraft are likely to be range, endurance, cost-effectiveness and minimisation of casualties. Also their relatively small size and capability for high altitude operations provide the UAV with an improved level of survivability. However, the absence of a pilot with the capacity for 'situational awareness' makes offensive roles more difficult and the UAV vulnerable to air-to-air combat. Additionally, datalinks may prove to be another significant vulnerability.

Much of the emerging technology will address these limitations and provide UAVs with capabilities that will further exploit their advantages and potential to perform roles currently restricted to manned aircraft. These will be discussed in the following chapter.

Chapter 4

Emerging Technology

With the exception of much of the airframe systems, most other UAV systems are generally constructed from 'commercial-off-the-shelf' (COTS) components. Therefore, while UAVs have never driven the development of a dedicated technology, they often represent a clever incorporation of technologies developed for other purposes. Few of the emerging technologies are identified specifically with UAV developments; however, several key developments in systems and munitions over the next decade will have profound effects on the reliability and utility of UAVs as military platforms. A brief examination of the key technologies and their role in UAV developments provides a foundation for appreciating and understanding the evolution of future roles for UAVs, their strengths and their limitations. Emerging technologies will be examined under three main headings: enabling technologies, sensors and weapons.

UAV Enabling Technologies

UAV enabling technologies are defined as technologies that increase the reliability, autonomy and performance of the UAV. Developments in guidance systems, propulsion and stealth technology will enable UAVs to operate with minimal input from their operators at speeds, altitudes and endurances generally unachievable by manned aircraft. Examples include DGPS, situational sensors, propulsion and fuels.

Differential Global Positioning System

The establishment of the Global Positioning System (GPS) has had enormous impact on UAV development over the past decade. GPS has enabled greater automation of UAV operations, providing accurate navigation data used to update the UAVs flight computers. For cruise missiles, GPS provides positional verification to their primary navigation system, the Terrain Contour Matching (TERCOM). This system provides the means by which ground profiles are compared with pre-programmed terrain matrices (map to ground matching).[1] Similarly, GPS has simplified the operation of reconnaissance UAVs, improving the accuracy of pre-programmed flight paths over Inertial Navigation System (INS) guided missions. Reconnaissance data transmitted from the UAV can be matched with its position, giving commanders more accurate bearings of their reconnaissance targets.

[1] Wing Commander P.A. Hislop, *Employment of Cruise Missiles by the ADF*, Paper No 57, Air Power Studies Centre, Royal Australian Air Force, Canberra, August, 1997, p 13.

Like GPS, the further development of Differential GPS (DGPS) is having a revolutionary impact on UAV development and utilisation. Fully automated take-off and landing will be the most significant outcome of DGPS, addressing the flight phases of greatest risk to the aircraft. Automated take-off and landings will also remove the requirement for qualified pilots as controllers, reducing the operating costs of UAVs. DGPS will also become particularly useful for airspace management, where the exact location of the UAV can be monitored in relation to other platforms. DGPS is already utilised for UAV operations in the US but will provide global access from about 2005 when the Wide-Area Augmentation System (WAAS) based on globally accessible DGPS is completed.[2]

Situational Sensors

One of the crucial technologies to the development of 'combat' UAVs for offensive roles will be the ability to create 'situational awareness' for the controller through the development of external sensors and application of data fusion techniques. The technologies are twofold: physical sensors are required to gather the information, while complex software is required to fuse the images to give a continuous 'view' out of the UAV. This capability could be further developed to provide a spherical view to the controller, removing the 'blind spots' associated with conventional manned aircraft. The concept of the 'windowless' cockpit to protect crews from lasers is likely to see the adoption of situational sensors for manned aircraft also.[3]

Virtual Environment

Maturation of 'virtual' technology will further contribute to providing UAV operators with 'situational awareness'. A three-dimensional 'virtual environment' will replicate the environment of the UAV, with the operators 'controlling' UAVs as if they were in the cockpit. In the future, fighter pilots could very well be recruited from the local 'game parlour', with their ability to fly these high performance vehicles being unconstrained by the psychological parameters which may beset contemporary combat pilots. The control of UAVs by current fighter pilots may be limited by their mindfulness of human physiological restrictions such as the effect of gravity, thereby failing to fully exploit the operational characteristics offered by future UAVs.

While the use of 'virtual' technology to control UAVs is still being developed, the technology is beginning to be used for training purposes. Aircrew will soon be able to train with Helmet Mounted Displays (HMD), replacing the requirement for expensive visual displays and domes in flight simulators whilst providing greater realism.[4] Technical staff

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[2] J. Chemla, *Future UAV Systems*, An Address to the Defence Science and Technology Organisation on 4 February 1997, Israel Aircraft Industries, Malat Division, Salisbury, South Australia, 1997, p 41.

[3] B. Sweetman, 'US Air Force Probes Technological Frontiers', *Jane's International Defense Review Extra,* Vol 1, No 6, June 1996, p 5.

[4] D.A. Fulghum, 'Joint Strike Fighter Explores Virtual Reality', *Aviation Week & Space Technology*, 2 September 1996, p 101.

could also be trained to maintain aircraft through the use of 'virtual' technology, amalgamating computer-based theoretical training with computer-aided on-the-job training, releasing qualified personnel from instruction and supervision tasks.

Propulsion

Significant research and development is being undertaken in the area of propulsion, specifically for systems providing High Altitude Long Endurance (HALE) capabilities. Areas of research include split cycle engines, beamed microwave radiation, solar power and refined turbo-prop and turbo-fan engines. The significance of developing a capability for HALE aircraft lies in its utility as a 'poor country's satellite' in that it would be comparatively cheap to launch, retrieve and reuse. Also, the altitude flown by HALE aircraft offers a measure of protection by making the UAV more difficult to detect and even more difficult to destroy with current generation missiles. In this field, the most recent development is AeroVironment's Pathfinder which has flown at an altitude of 71,500 feet. Conventionally powered HALE UAVs, such as Perseus, have flown to altitudes in the order of 50,000 feet, but most programs have an aim of 80,000 feet plus which should place them at an altitude beyond the range of most SAMs and manned aircraft.

Further development in the propulsion field is a concerted effort to achieve civil aerospace authority accreditation for the engines, thereby giving them a better level of acceptability for operations in civil airspace. Israel Aircraft Industries (IAI), for example, has placed significant emphasis on utilising 'certified' piston engines in their most recent UAVs.[5]

In the US, the Integrated High Performance Turbine Engine Technology (IHPTET) program is developing turbine engine technologies with an aim of increasing performance whilst reducing operating and life cycle costs. The goals of the program are to achieve a turbofan/turbojet engine with a 100 per cent increase of thrust to weight ratio, a 40 per cent decrease in fuel burn, a 35 per cent decrease in production costs and a 35 per cent decrease in maintenance costs. For turboshaft/turboprop engines, the goals are similar with an expected increase of 120 per cent power-to-weight ratio.[6] IHPTET expects to achieve these goals through the development of super cooled turbine blade designs, coupled with variable cycle engine concepts.[7]

Fuels

Fuel types normally considered too dangerous for use in manned aircraft, may be used in UAVs due to the removal of the manned component. Such fuel developments could be promising in terms of better fuel efficiencies but are still in their infancy with regard to UAVs. The IHPTET program, for example, forecast the increased use of JP-8+100 fuel with

[5] J. Chemla, *Future UAV Systems*, p 20.
[6] R.W. Davis & D.R. Selegan, 'Impact of Technology Advance on Air Operations', a paper presented to *Air Power Conference and Exhibition: 27th & 28th February 1997*, Royal Lancaster Hotel, London.
[7] *Ibid.*

current studies reporting increased engine performances with reduced fouling and coking of engine and aircraft fuel systems.[8] Currently, however, manufacturers continue to rely on the use of common fuels for logistics and ground safety reasons.

The prevalence of tactical UAVs using AVGAS is also set to change. Increasingly, UAVs are incorporating heavy fuel engines to enable the use of diesel and other common fuels that are safe to handle and easy to supply to the field.

IFF and Other Avionics Systems

Advances in IFF and other avionics systems have the potential to make the most significant impact on the widespread development and acceptance of UAVs. For example, Israel Aircraft Industries (IAI) has identified their main design goals for the near future as achieving airworthiness and reliability, civilian airspace compatibility, 'see and avoid' capability, and flight termination capability.[9] IAI has also placed an emphasis on achieving fully autonomous flight which requires, for all reusable UAVs, redundancies in critical flight systems, automatic failure detection, automatic navigation, and automatic take-off and landing.[10]

Airframe Design and Construction

Micro UAVs

Initial studies indicate it may be possible to develop Micro UAVs which would be no larger than 15 centimetres in span or length but could fly for an hour and travel 16 kilometres. The miniaturisation of much of the relevant technology over the past decade has made such a concept possible, although the greatest challenges will be the design integration, flight control and navigation.[11]

Stealth

The absence of aircrew within UAVs increases the ease of incorporating stealth into their design in order to overcome some of their vulnerabilities. Consequently, UAV airframes are now being designed for maximum performance, either to exploit the potential for speed, altitude or stealth. In the US, the Fixed Wing Program has incorporated goals for greater survivability, aiming to achieve a 30-45 per cent reduction in IR signature and a 30-40 per cent reduction in RF signature through programs such as the Advanced Compact Inlet, Aeroelastic Wing and Advanced LO Air Data system.[12] These could be applied to future UAV systems.

[8] *Ibid.*
[9] J. Chemla, *Future UAV Systems*, p 11.
[10] *Ibid.*, p 31.
[11] S. Evers, 'ARPA pursues pocket-sized pilotless vehicles', *Jane's Defence Weekly*, 20 March 1996, p 3.
[12] R.W. Davis & D.R. Selegan, 'Impact of Technology Advance on Air Operations'.

Composite Materials

Despite the availability of composite materials for the construction of airframes, IAI forecast that the emphasis will remain with aircraft metals due to their lower cost and ease of repair. This will be the case for low cost battlefield reconnaissance UAVs. Where there is a requirement for payload capacity to be maximised or where low signature is required, composite materials may be more appropriate. The use of composite materials to maximise payload capacity and reduce radar signature is evidenced in its use in cruise missiles.

Sensor Payloads

In order to increase the utility of UAVs, many are being designed to have interchangeable payloads or complimentary payloads which will enable the UAV to undertake a number of roles within the one mission. Sensors and other payloads such as EW suites are being developed to enable ease of interchange or concurrent operations from a single platform. Particular developments in the field of Synthetic Aperture Radar (SAR) are providing a capability to 'see' through cloud and battlefield smoke. This SAR capability enables UAVs to operate at higher altitudes, thereby providing greater protection from detection and surface fire.

Imagery Sensors

Synthetic Aperture Radar

SAR is a sideways-looking radar-imaging technique which uses a smaller aperture antenna to collect sampled returns from several positions along a track to synthesise the effect of a much larger aperture narrow beam radar. A proven breakthrough in technology, SAR greatly increases the utility of battlefield UAVs. However, the development of SAR will prove to have even greater impact on the development of long range surveillance UAVs, given that it will enable them to provide clear ground images where optical sensors are incapable due to the presence of cloud, rain, fog, smoke or dust. SAR provides the capability to conduct wide area searches, strip mapping, spot searches and the detection of low flying aircraft. The Hughes Integrated Synthetic Aperture Radar (HISAR) for example, gives the following types of coverage:

- Wide-area search - covering 5,600 square kilometres every 75 seconds with a resolution of 20 metres;
- Strip Map - covers swath of 37 kilometres with a 6 metre resolution at the aircraft speed; and
- Spot Mode - covers a 10 square kilometre patch with 1.8 metre resolution.[13]

[13] P.L. Young, 'Synthetic Aperture Radar', *Asian Defence Journal,* 12/96, p 88.

The three modes of SAR provide surveillance and reconnaissance capabilities which can be applied to both ground and ocean environments. In the air-to-air surveillance mode, SAR can detect low flying aircraft at a range of 70 kilometre.[14]

For Global Hawk, the sensor suite[15] being developed will collect, process and disseminate, wide area search imagery at 1.0 metre resolution at a rate of 138,000 square kilometres per day at a range of 200 kilometres or 1900 Spot images per day at 0.3 metre resolution.[16]

Foliage and Ground Penetration Radars

Development of ultra-wideband radar (UWB) will enable military forces to detect and to classify military targets concealed by foliage and buried at shallow depths.[17] The USAF Scientific Advisory Board has recommended that the USAF pursue the development of HF/VHF/UHF SAR for the purpose of detecting concealed targets. Such systems will require massive transmission rates and robust target detection algorithms, modelled from extensive trials. While current trials are limited to cargo-sized aircraft, such as the ARPA FOPEN (foliage penetration) trial which uses a UWB SAR mounted in a P-3 aircraft, the technology could be developed for future use with UAVs. [18] These sensors will further contribute to the potential utility of UAVs.

Hyperspectral and Ultraspectral Imaging

Hyperspectral and Ultraspectral imaging essentially results from the use of tens of narrow spectral bands to analyse targets. Current projections for Hyperspectral and Ultraspectral imaging are that they will eventually provide a capability to analyse specific types of chemicals being emitted from smokestacks. This capability will also have commercial application in areas such as agricultural and pollution monitoring. Hyperspectral imaging relies on reflected energy in the 0.4 to 1.5 micron range and will be used to detect man-made targets against natural backgrounds, where paints and canvas reflect energy in a specific range. Gas emissions will be analysed through ultraspectral imaging which deals with mid to long wave infra-red frequencies. Further development in software will see this capability develop.[19]

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[14] *Ibid.*, p 88.
[15] The ASARS2 is a derivative of HISAR. Sourced from Wing Commander Filmer, Project Manager, Project *Warrendi*, December 1997.
[16] P. L. Young, 'Synthetic Aperture Radar', p 88.
[17] *New World Vistas: Air and Space Power for the 21st Century - Sensors Volume*, USAF Scientific Advisory Board, Department of the Air Force, Department of Defense, 1997, p 161.
[18] *Ibid.*, p 161.
[19] D.A. Fulghum, 'Military Reconnaissance Slices the Spectrum Anew', *Aviation Week & Space Technology*, November 1996, p 27.

'Sniffer' Sensors

'Sniffer' sensors will have a unique application to UAVs, given their role is to analyse nuclear, chemical and biological samples over suspected sites. There is little likelihood this role will be performed by manned aircraft although the technology will extend to man-portable sensors for those on the ground who suspect the presence of NBC agents. Stand-off sensors developed predominantly for the detection of nuclear materials are being modified to deal with the increasing risk of chemical weapon production. One system, CALIOPE (Chemical Analyses by Laser Interrogation of Proliferation Effluents) is being developed to identify, track and map chemical clouds.[20] While the capability has not yet been fully developed, sensors have been demonstrated which differentiate between vehicle emissions, dust and biological agents. These capabilities will enable long range detection of the manufacture of nuclear, biological and chemical weapons, vital to the development of counter-proliferation strategies.[21]

Signal Processing

Data Compression

The ability to compress data without loss of resolution is one of the key developmental areas which will effect the utility of UAVs. Discrete cosine, fractal and wavelet transform coding techniques are considered the three state-of-the-art image compression techniques and are undergoing continuous development.[22] To produce a low resolution (320x200x8 pixels) image at a rate of 1 frame/second, a transmission rate of about 0.6 Mbits/s is required. For higher resolution images (1024x1024x8/16/32/64 pixels), far greater transmission rates and, hence, bandwidth are required. The transmission of medium to high resolution images is achievable through line-of-sight (LOS) transmissions in the VHF and higher frequency bands. For non-LOS operations, transmission is only possible in the HF range provided the available (ADF) military bandwidth is extended to 10 kbits.[23] Generally, the different data compression techniques are a trade-off between the ability to generate near real-time Discrete Cosine Transform (DCT), better resolution and better compression ratios (fractal compression).

The finite availability of bandwidth and limitations to the amount of data which can be effectively processed by analysts on the ground have led to the development of systems that can process much of the data prior to transmission to ground stations. Development in the field of artificial intelligence will go some way to reduce the data requiring transmission.

[20] P. Mann, 'Detection Sensors Crucial, But Technically Exacting', in *Aviation Week & Space Technology*, 17 June, 1996, p 66.
[21] *Ibid.*, p 66.
[22] K. Cameron, V. Kowalenko, & J. Phipps, *Data Link Technology For A Portable Unmanned Aerial Vehicle*, Research Report DSTO-RR-0087, AR-009-761, Department of Defence, November 1996, Executive Summary.
[23] *Ibid.*, p 31.

Incorporation of artificial intelligence software will enable greater automation of UAVs, including their unassisted response to external threats. More importantly, on-board processing should reduce the numbers of ground-based analysts.

Artificial Intelligence and Decision Support Systems

Automatic Target Recognition

As the amount of data collected by contemporary sensors increases with the resolution required, the race is on to develop methods for reducing the amount of bandwidth required to transmit the data from the aerial platform to the ground station. This can be achieved through either the compression of data or the on-board analysis of data, using artificial intelligence. The development of an Automatic Target Recognition system, for example, would enable the on-board computer to analyse incoming imagery by comparing it to stored target images using an 'Optical Correlator'.[24] Should a close match be achieved, the computer would then transmit the incoming sensor imagery to an operator at the mission control station who then can verify the target and action the identification.

Threat Avoidance

Decision support systems have been widely incorporated into current weapons systems where defensive aid suites are activated in response to threats. Fourth generation air-to-air missiles also incorporate algorithms to distinguish between chaff, flares, decoys and the real aircraft in order to maintain tracking of their target aircraft. The further development of these decision algorithms in providing UAVs with greater automated survivability will reduce the reliance on datalinks for 'man-in-the-loop' input.

Weapons

While UAVs are capable of employing the range of current weapons (as demonstrated in the 1971 trials of a TRA Model 234 dropping MK 82 bombs, and firing Maverick anti-surface missiles (ASMs) and Shrike anti-radiation missiles (ARMs))[25], the focus on endurance over payload generally limits the payload capacity of UAVs for weapons carriage. The development of smarter weapons has two implications for employment by UAVs. Firstly, with smarter, more accurate weapons, fewer are required to achieve the desired result. Secondly, the development of more intelligent fuses, more powerful explosives and better target penetration has enabled manufacturers to produce smaller weapons capable of the same destructive power as their larger predecessors. Maturation of these weapons can furnish UAVs with lethal payloads without sacrificing their attributes of endurance and size. For example, the development of small munitions could allow Teledyne Ryan

[24] G. Ferguson, 'Smart Eyes: Automatic Target Recognition may feature as part of future ADF reconnaissance systems', in *Australian Defence Magazine,* September 1996, p 40.
[25] M. Armitage, *Unmanned Aircraft*, Brassey's Air Power: Aircraft, Weapons Systems and Technology Series, Volume 3, Brassey's Defence Publishers, London, 1988, p 81.

Aeronautical's Global Hawk to be employed in lethal roles in the near future by utilising its two wing hardpoints, each capable of carrying 450 kilograms.[26]

GPS Aided Munitions

Recent trials with GPS Aided Munitions (GAM), with a demonstrated accuracy of 6 metres Circular Error Probable (CEP),[27] present these weapons as a relatively cheap alternative to cruise missiles. Combined with the use of SAR for targeting, GAM has an all weather potential over laser and optically guided systems.[28] GAM therefore can enhance the effectiveness of UAVs in offensive roles, as well as that of manned offensive aircraft.

Mini Munitions

Significant work is being done to develop mini munitions which can penetrate targets traditionally requiring a 2000 pound bomb. Initial tests are concentrating on a 250 pound 'smart' bomb using a combination of Differential GPS/ Inertial Navigation System and Hard Target Smart Fuze (HTSF) to determine the optimum detonation point with an accuracy of less than three metres.[29] A Miniaturised Munitions Technology Demonstration (MMTD) program has been set up and is aiming to achieve a weapon able to penetrate 1.8 metres of concrete, carrying only 50 pound of explosive. The weapons are predicted to be in production by 2005.

The significance of these weapons to the utility of UAVs is enormous. With the development of such lightweight weapons, the potential for use of UAVs as weapons platforms to penetrate and strike heavily defended targets will be more easily realised.

Laser and Kinetic Energy Weapons

In concert with the simultaneous development of long endurance UAVs the development of laser and kinetic energy weapons is predicted to revolutionise 'aerospace power'. The significance of these weapons will be the accuracy and increased number of 'shots' offered by this technology. Coupled with a long endurance UAV, these weapons will provide 'persistence' to air power, potentially generating an 'air occupation' capability - 'the ability of *aerospace power* to continuously control the environment of the area into which it is projected'.[30]

The most significant challenge associated with the development of laser weapons for operation by UAVs is that of providing sufficient power to operate the weapons. In the nearer term, airborne lasers are likely to require large aircraft on the scale of the B747 as a

[26] 'Tier II - plus: taking the UAV to new heights', *Jane's Defence Weekly*, 12 August 1995, p 37.
[27] A measure of accuracy, where the weapon is likely to fall within the stated CEP of its original aim point.
[28] C. Kopp, 'GPS-US Direct Attack Munition Programs: Part 3', in *Australian Aviation*, October 1996, p 53.
[29] S. Evers, 'USAF mini-munition to replace 2000 lb bombs', in *Jane's Defence Weekly*, 2 December 1995, p 6.
[30] Colonel B. W. Carmichael, Major T. E. DeVine, Major R. E. Kaufman, Major P. E. Pence & Major R. S. Wilcox, *StrikeStar 2025: A Research Paper Presented to Air Force 2025*, August 1996, p 11.

test platform currently being used in order to generate sufficient power to operate laser weapons.[31] Once developed, however, such weapons will have significant impact on the tempo of air warfare.

Summary

Emerging technology in the form of enabling technology, sensors and weapons, will have a profound effect on both the maturity and potential application of UAVs in offensive roles. A discussion on current and projected roles based on this emerging technology is provided in Chapter 5.

[31] 'Airborne laser breaks through the barriers', *Jane's Defence Weekly*, 10 September 1997, p 53.

Chapter 5

Classification and Roles

Introduction

Uninhabited Aerial Vehicles (UAVs) have been classified by various methods including their control systems (whether autonomous or remotely piloted), their range and survivability features (Tier classification), their function (URAV, UCAV, Targets), and their design for single or multiple missions. No single classification system is free from exceptions and most ignore the potential developments of future UAVs. A classification based on functional roles, similar to that for manned aircraft, is perhaps the most appropriate, even though one platform may fall into several functional categories by virtue of its payloads. In time, it may be prudent to adopt manned aircraft designators with a prefix of '(U)' given the difficulty of finding suitable acronyms and the projected roles envisaged for UAVs in the future.

The current USAF method for classifying reconnaissance UAVs is based around a description of their operating characteristics, such as High Altitude Long Endurance (HALE). However, UAVs are increasingly intended for use as platforms with interchangeable payloads; therefore, the current system of classifying them by mission characteristics seems more appropriate given their capability to perform a range of roles.

For the purpose of this monograph, a modified classification has been adopted and is illustrated at Figure 5.1. This classification divides UAVs into Support and Combat Aircraft, further breaking them down into functional groupings. These groupings will be discussed in turn to provide the reader with an appreciation of the current and future capabilities which are likely to become available over the next twenty years.

Uninhabited Support Aerial Vehicles (USAV)

Uninhabited Reconnaissance Aerial Vehicles (URAVs)

The current emphasis of UAV development is in the reconnaissance and surveillance field. Whilst termed 'Reconnaissance', these platforms are being utilised for a number of battlefield tasks including command and control (C2), Electronic Warfare (EW), Meteorology (MET), Reconnaissance and Surveillance (RS), Signals Intelligence (SIGINT), Target Acquisition (TA), Target Spotting (TS) and Target Designator (TD). In 1995 there were some 60 UAVs in full scale production or advanced stages of development, all

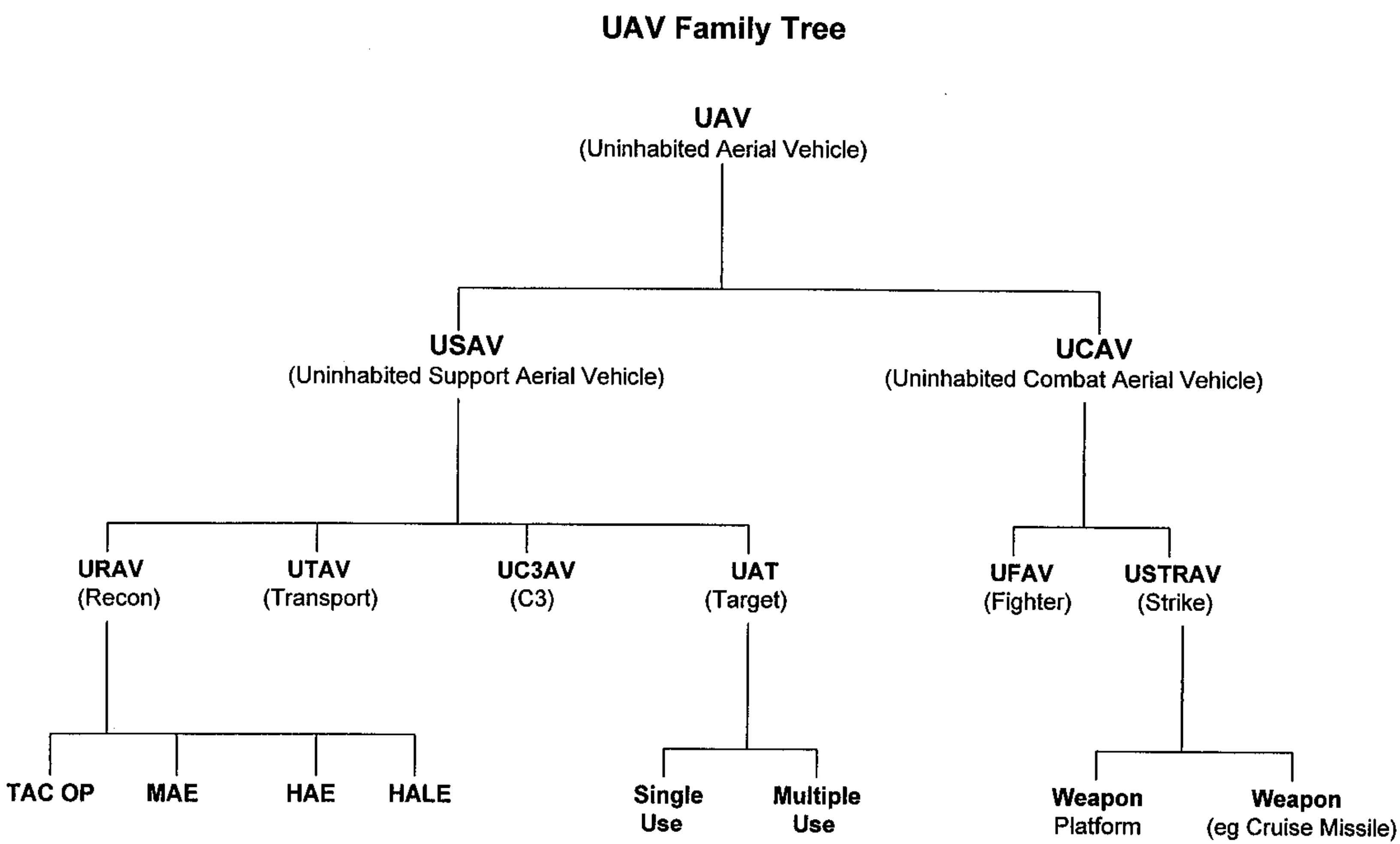

Figure 5.1: Modified Classification of UAVs

predominantly for use in Reconnaissance/Surveillance roles.[1] Their success in these roles have been proven, for example, during the Gulf War, Bosnia and, in paramilitary operations in South Africa. Although classifications may vary slightly from one country to another, Israel Aircraft Industries (IAI) has identified four levels of capability based on range, endurance and altitude: Tactical, Operative, Medium Altitude Endurance (MAE) and High Altitude Endurance (HAE). In the US, Tactical and Operative UAVs are combined and fall under the classification 'Tactical UAV' (TUAV). Under the USAF's Tier classification Low-Observable UAVs are distinguished as a separate category. Figure 5.2 provides an overview of the operating ranges and altitudes of the different classifications based on the IAI classification.

The development of High Altitude Long Endurance (HALE) UAVs is still in its infancy but, if realised, will provide the most exciting development in the field, giving UAVs a satellite-like capability. This category is therefore included as a modification to the IAI classification at Figure 5.2 because of its potential to revolutionise air power through providing an 'air occupation' capability.

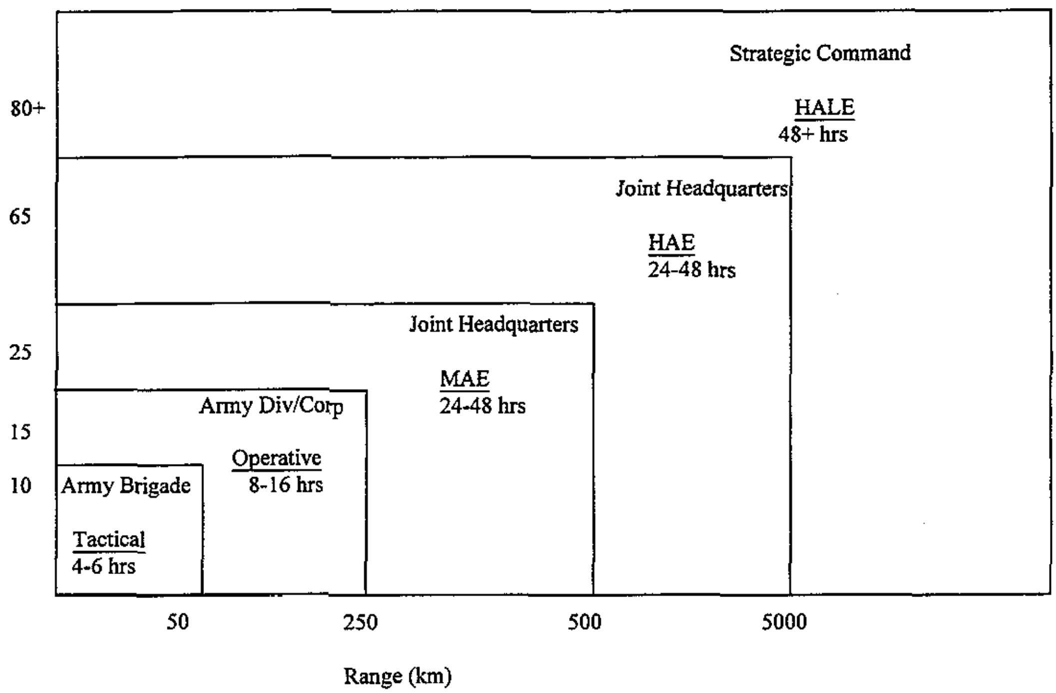

Figure 5.2 Categories of Capabilities[2]

Figure 5.3 illustrates some of the UAVs in the various categories of capabilities.

[1] *Shephard's Unmanned Vehicles Handbook: 1995-1996*, I. Parker (Ed.), The Shephard Press Ltd, England, 1995.

[2] Adapted from J. Chemla, *Future UAV Systems*, An Address to DSTO on 4 February 1997, Israel Aircraft Industries, Malat Division, Salisbury, South Australia, 1997, p 15.

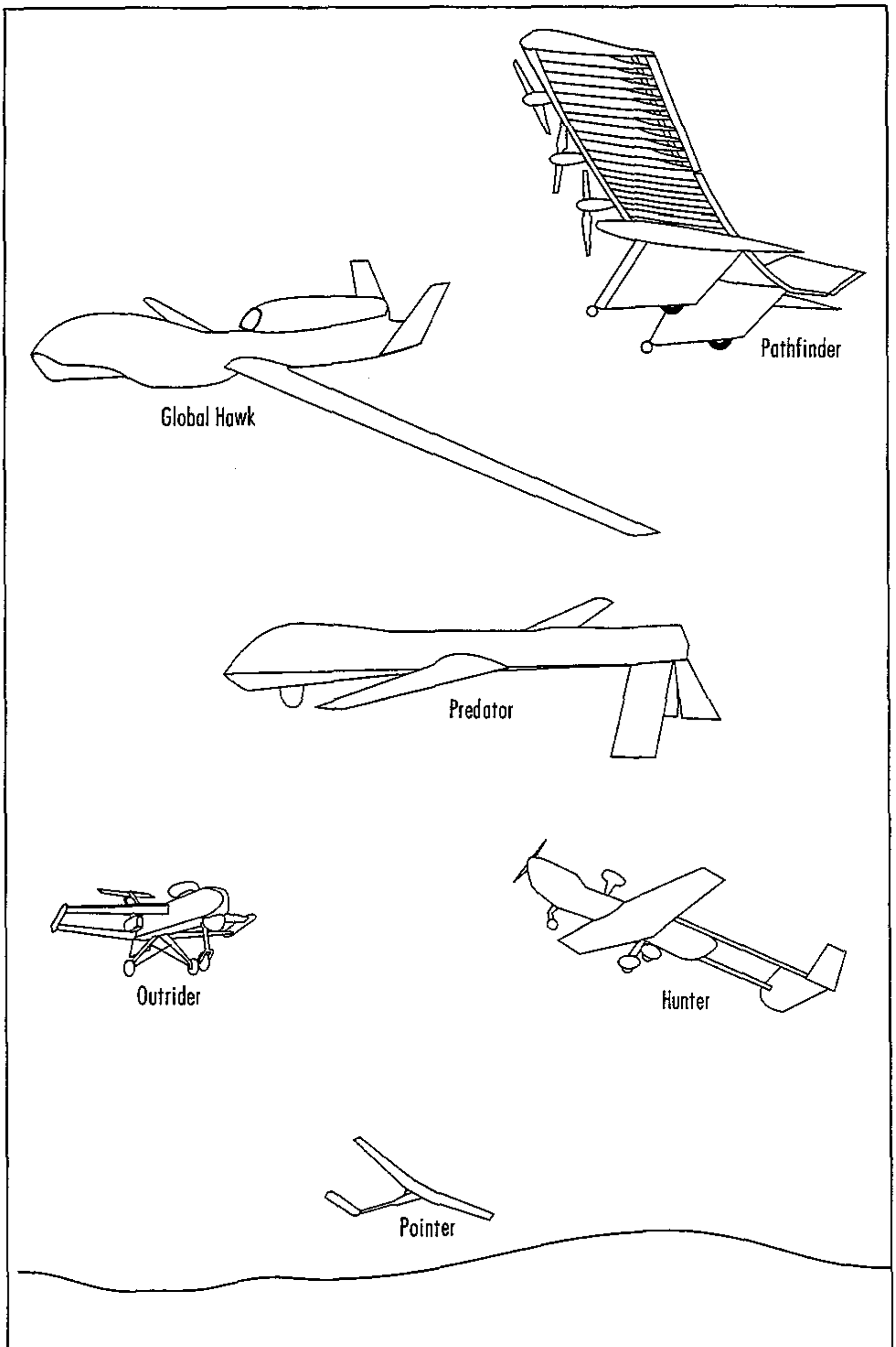

Figure 5.3: A sample of UAVs used for reconnaissance, surveillance and other support roles.

Tactical URAVs

The smallest UAV on the military market used for close-range surveillance and target acquisition by the US Marines in the Gulf War is the Pointer. This miniature sailplane is man-portable, and once dismantled can be carried, with its imagery receiving equipment and ground control equipment, in two backpacks with a combined weight of only 34 kilograms. It has an operating radius of eight kilometres and an endurance of one hour and 15 minutes. Extending from this basic operating model is a range of other tactical UAV platforms. Tactical URAVs are generally intended for command at an Army Brigade level, though their employment is usually in support of the Battalion level or lower, depending on the capability. Falling within the tactical range of UAVs, Vertical Take-off and Landing (VTOL) UAVs deserve particular mention for their unique characteristics. Such UAVs are well-suited to tactical roles given that they provide quick egress to the battle-space, are capable of being launched without the requirement for runways or large cleared patches of ground, and are capable of hovering over a designated spot. Also, they are particularly suited to naval operations on ships where there is limited space for conventional fixed wing take-off and landings, and where other short landing mechanisms, such as the landing net system used for the Pioneer tactical UAV, often damages the aircraft.

Operative URAVs

UAVs representative of the Operative capabilities have dominated the scene in recent years. Among the more notable examples (all having significant operational experience), are the Pioneer, Hunter, Searcher and Seeker which have ranges over 200 kilometres and endurances ranging from five hours to over 24 hours. During the Gulf War, the Pioneer was deployed with US Army, Navy and Marine units and was used for reconnaissance, targeting, naval gunfire support, artillery adjustment, mine sweeping, close air support coordination and battle damage assessment.[3]

Medium Altitude Endurance URAVs (MAE)

Representative of the Medium Altitude Endurance UAV class is the General Atomics Predator UAV which has received widespread publicity through its performances supporting peacekeeping activities in Bosnia. Predator is capable of a 930 kilometres radius of action with a 24 hour loiter over target at that distance from base. Predator cruises at about 25,000 feet and can carry a 200 kilogram payload. During operations in Bosnia, the Predator employed a Tactical Endurance Synthetic Aperture Radar, to address earlier reconnaissance difficulties caused by poor weather, as well as EO and IR sensors.

Another UAV system which falls into the MAE class is the IAI Heron (medium and high altitude UAV). This vehicle currently holds the record for long endurance, recording a flight time of over 51 hours whilst carrying a 200 kilogram payload, and can cruise up to 35,000 feet.

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[3] E. Dantes 'UAV: A New Philosophy in Asia-Pacific', in *Asian Defence Journal*, 12/92, p 29.

High Altitude Endurance URAVs (HAE)

The US DoD has supported the development of a Low Observable - High Altitude Endurance UAV to provide a capability of infiltrating high-risk, heavily defended areas for reconnaissance, target acquisition and battle damage assessment missions. Lockheed Martin's DarkStar will have a 500 nautical mile radius (930 kilometres), cruise at 45,000 feet and loiter over target area for up to 8 hours. Its successful first flight was made completely autonomously, proving the viability of fully autonomous flight patterns from take-off to landing.[4] DarkStar will carry either an electro-optical sensor or synthetic aperture radar. Differential GPS provided the guidance during the take-off roll, demonstrating its potential application in the UAV field. Despite the claim that the flight was autonomous, data-links remained important as they were required to feed the differential GPS corrections to the UAV. The down-link also continues to be important in providing information for decisions on aborting the mission. DarkStar's developmental program was significantly hampered after it crashed on its second flight, completely destroying the vehicle. The crash, on 22 April 1996, occurred as a result of flaws in the aircraft's software, causing it's ailerons to over-correct and stall the vehicle, whilst trying to address the porpoising effect caused by a flight dynamic divergent oscillation.[5] A second DarkStar prototype has been completed and successfully flew its first test flight on 29 June 1998.

Teledyne Ryan Aeronautical's Global Hawk represents one of the most ambitious UAV programs at the time of writing. The US DoD sponsored project has set out to provide Global Hawk with the endurance capability of 42 hours which would enable it to loiter for 24 hours over target area at a radius of 3,000 nautical miles from its launch point. It will be capable of achieving altitudes of over 60,000 feet with its 116 feet wingspan. Global Hawk successfully completed its first flight on 28 February 1998, flying for 56 minutes and reaching an altitude of 32,000 feet.[6]

High Altitude Long Endurance URAVs (HALE)

With advances in propulsion technology and the development of UAVs with the capability to fly at altitudes in excess of 50,000 feet, there has been growing support for developing HALE UAVs. The development of an air-breathing UAV which can loiter in racetrack patterns over a battlefield for a period of days would provide capabilities similar to satellites at a fraction of the cost.[7] Furthermore, they provide the advantage of better revisit rates and ease of retasking. Such aircraft would perform roles including reconnaissance, communications relay and even perhaps control of the air if fitted with appropriate armaments and systems. Alternatively, further capability development would alternatively provide commanders with an 'in situ' relay for military communications or on-going surveillance of the battlefield without the requirement for a geostationary LEO satellite or a

[4] M. A. Dornheim 'Darkstar makes 'solo' first flight', in *Aviation Week & Space Technology*, April 8, 1996, p 20.
[5] 'Inquiry rules out design flaw for UAV crash', *Jane's Defence Weekly*, 26 June 1996, p 5.
[6] B. Bender, 'USA takes historic step in drone technology', *Jane's Defence Weekly*, 11 March 1998, p 4.
[7] A. Knoth 'Aerial weapons for a new era', in *International Defense Review*, 12/1993, p 962.

constellation of LEO satellites. The comparative cost, flexibility and ability to easily change the flight pattern of the UAV whilst maintaining them at altitudes where few contemporary air-defence missiles present a threat, will revolutionise current concepts of air power.

Development of HALE UAVs is currently being undertaken through the NASA program for Environmental Research Aircraft and Sensor Technology (ERAST) which has been in operation since 1991. Whilst the purpose of the program is to develop high altitude capable UAVs for atmospheric research, the military application of such technology is obvious. Performances to date reflect the difficulties associated with achieving high altitudes but significant progress is being made. The Aurora Perseus A UAV has reached a 50,000 feet milestone, but is expected to attain its goal of 77,000 feet. Its 'brother', Perseus B, is expected to operate at 65,000 feet with a 200 kilogram payload for a period of two to three days. AeroVironment's Pathfinder, a solar-powered UAV, reached over 71,500 feet breaking an unofficial world record for solar-powered vehicles in July 1997.[8] The USAF Scientific Advisory Board predicts that UAVs in this league will be capable of endurances measured in months.[9]

Uninhabited Aerial Targets (UATS)

One of the most successful uses of UAVs to date has been their employment as decoys in Suppression of Enemy Air Defence (SEAD) campaigns. In Vietnam, the Yom Kippur War, the Beka'a Valley in 1982 and in the Gulf War in 1991, relatively cheap decoys were flown over heavily defended targets to activate air defence systems by deceiving them into believing they were real aircraft. The level of deception used is dependent on the sophistication of the air defence systems and can vary from reliance on dumb drones for representing an incursion in the territory, to more sophisticated operations where the decoys are fitted with either physical reflectors or emitters that transmit the electronic signature of manned aircraft such as F-16s or F-18s. In the Gulf War, the initial strike on Baghdad relied on rudimentary decoys (BQM-74 drones) which were modified for the task by fixing reflectors to simulate the radar cross section of coalition aircraft. These were complemented with the employment of tactical air-launched decoys (TALD), unguided decoys with a range of only 30-40 miles.[10] The rockets flew over the city, activating the air defence system which was then targeted by F-4Gs, FA-18s, A-7s and A-6 aircraft armed with High-Speed Anti-Radiation Missiles (HARM).

While the decoys represent a cost-effective single-use 'aerial target' or 'decoy', they also are used extensively for training purposes by defence forces. Because of the requirement to simulate the movements of manned aircraft, these multiple-use targets are generally more sophisticated and, therefore more expensive, than their expendable counterparts. The UAVs simulate target enemy aircraft by towing an expendable target behind them representing the enemy aircraft for practice by navies and air defence batteries. Manned options are

[8] *Unmanned Vehicles*, August 1997, p 4.
[9] *New World Vistas: Aircraft and Propulsion Volume*, USAF Scientific Advisory Board, p 20.
[10] M. R. Gordon & General B. E. Trainor, *The General's War: The Inside Story of The Conflict In The Gulf*, Little, Brown and Company, New York, 1995, p 113.

sometimes used; however, the UAV target system enables the target to be towed relatively close to the UAV, providing better simulation of aircraft manoeuvre.

Other Support Functions

Owing to the general design of UAVs incorporating interchangeable payloads, they are being used for a variety of functions including the range of Electronic Warfare roles such as ELINT, COMINT and ECM. Additionally, they are being considered as platforms for communications relay[11] within the battlefield and may have an increased role in AEW&C and JSTARS operations where the airborne sensors relay the incoming data to display monitors on the ground such as the Swedish Air Force's proposed S 100B Argus AEW aircraft.[12] This would significantly reduce the size, cost and vulnerability of the AEW&C platform, as well as removing the risk to analysts and operators on board these platforms becoming casualties.

The US DoD is also considering the use of UAVs to transport small cargo payloads to high-threat areas in support of troops on the front line. This concept of operations is designed to reduce the weaknesses of ground-based lines of supply.

Uninhabited Combat Aerial Vehicles (UCAV)

Cruise Missiles

By definition, cruise missiles form part of the UAV category, but due to their lethal, one-off application, they are often neglected in writings on UAVs. In comparison, however, few contemporary writings quoting the operational successes of UAVs fail to cite the intelligent use of drones and decoys by the Israelis in the Beka'a Valley. The differences between the two systems provide the key, but not the rationale, to the omission of cruise missiles in any general discussion on the potential of UAVs. One reason may be that the combined sophistication and lethality of cruise missiles is representative of technology and mission requirements generally witnessed only in the application of manned aircraft. Acceptance of cruise missiles within the UAV category dispels most myths about the relative unsophistication of UAVs and their inability to compete against manned aircraft for offensive mission profiles. Examination of cruise missiles as a form of UAV reveals the sophistication reached in this field and provides a better appreciation of the technology available for the production of UAVs.

Cruise missiles will continue to undergo development but their sophistication has significant implications on cost. Forces are reluctant to use cruise missiles against any target that does not represent proportionate value in either military impact or political impact. Yet they represent a capability where their delivery platform can maintain a safe distance from

[11] An Airborne Communications Node (ACN) is being designed as an alternative payload (in lieu of SAR) for Global Hawk to provide intra-theatre wideband connectivity.
[12] *Jane's International Defense Review*, 12/1997, p 53.

heavily defended targets. In this sense, the further development of cruise missile technology might see cruise missiles with several smaller, but less sophisticated warheads as additional payload, to hit a multiple number of targets before locking onto the target of highest priority.

Uninhabited Combat Aerial Vehicles (UCAV) - Concepts

Feasibility studies have been initiated on the concept of employing Uninhabited Combat Aerial Vehicles (UCAVs) in roles currently performed by manned fighter aircraft.[13] Studies have revealed that UCAVs may fill a gap between the cost of cruise missiles, which currently cost around $1.4 million per missile, and manned fighters which have a higher payload capability but risk the lives of aircrew where they operate in high-threat environments. The advantages of developing UCAVs are numerous. Notwithstanding the potential for better cost-effectiveness, UCAVs will have greater survivability with the capacity to perform to the limit of the aircraft's capability. For example, UCAVs will be capable of 12-20 G manoeuvres, outflying most current air-to-air-missiles (AAM) and surface-to-air missiles (SAM), although the new family of within-visual-range (WVR) AAMs can manoeuvre at 50-60 G. Once the concept has been developed to maturity, aircraft will be designed from the start to maximise their performance rather than the visual capacity for aircrew engaged in WVR manoeuvres. These new UCAVs will be capable of 20 G manoeuvres whilst being up to 40 per cent smaller than their manned aircraft counterpart. Figure 5.4 demonstrates the Northrop Grumman concept of a UCAV.

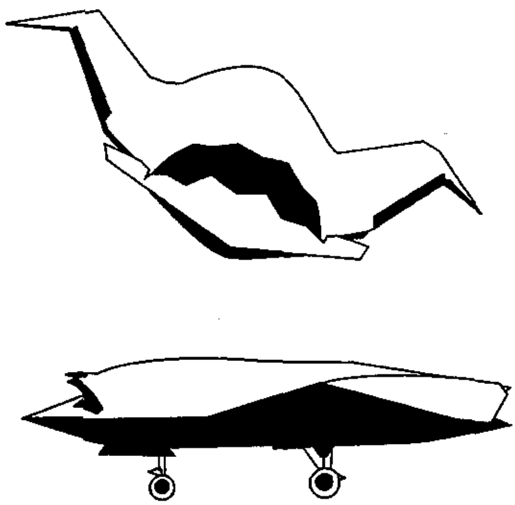

Figure 5.4: A Northrop Grumman concept of a UCAV.

[13] N. Cook, 'Leaving the pilot on the ground', in *Jane's Defence Weekly*, 3 July 1996, p 34.

The UK studies into their future offensive air system (FOAS) have left open the option for an unmanned aircraft.[14] Current thinking for the FOAS involves a long range capable aircraft piloted by using sensors. The incorporation of external sensors to implement the 'windowless cockpit' concept will simultaneously reduce the radar cross section of the aircraft and protect pilots from laser weapons designed to blind them. Once this technology has matured, in terms of the provision of situational awareness through external sensors, there is little reason for maintaining a person in the aircraft. A virtual reality cockpit based on the ground will provide the same awareness in this scenario as that received through a manned vehicles with a shielded canopy.[15] The roles expected to be performed by the FOAS include air interdiction, offensive counter air, tactical reconnaissance, suppression of enemy air defences, offensive air support, battlefield air interdiction and anti-surface warfare.[16] Close air support may present another requirement.

Strike Platforms

In its forecast for the Air Force in 2025, the USAF envisages the development of UAVs as strike platforms. With the maturation of DGPS, guidance systems, propulsion systems and current HALE UAVs, the USAF will further investigate a concept for a strike UAV, dubbed 'StrikeStar'. StrikeStar will essentially represent the combination of Global Hawk's capacity for range, altitude and endurance and DarkStar's low observability. To this they will introduce a weapons system, with preference given to laser or directed energy weapons in order to increase the amount of firepower available for one mission. The airborne laser concept being developed using a B747-400F platform, for instance, predicts that the aircraft will have sufficient fuel for up to 200 engagements by its laser weapon.[17]

StrikeStar will conceivably provide the USAF with a platform capable of loitering for 24 hours over a target area some 3,700 miles from its launch point. The UAV will have reconnaissance sensors to acquire targets and provide timely battle damage assessment after applying its weapons. Particularly the endurance loiter capability is seen to address one of the fundamental weaknesses of air power – impermanence, enabling a form of 'air occupation'.

The USAF considers that the development of a StrikeStar capability could be achieved by about 2015, though it is doubtful that the technology would be sufficiently mature for nations other than the US to incorporate into their order of battle. The capability for persistence, combined with a weapon with sufficient firepower would make the StrikeStar platform suitable for control of the air roles, both SEAD and defensive control of the air. If this concept was pursued, StrikeStar could possibly act as both a localised fighter aircraft as well as a strike aircraft. It is conceivable, therefore, that the F-22 may represent the last

[14] M. J. Witt, 'Britain Ponders UAV Alternative', in *Defense News*, Vol 12, No 1, 6-12 January 1997, p 1.
[15] *Ibid.*, p 26.
[16] N. Cook 'Europe's Future Attack Aircraft', in *Jane's Defence Weekly*, 4 September 1996, p 33.
[17] 'Airborne laser breaks through the barrier', *Jane's Defence Weekly*, 10 September 1997, p 54.

generation of manned fighters. Development on StrikeStar may have conceivably commenced with the production of the third DarkStar prototype with extended wings (from 69 feet to 110 feet).[18]

Theatre Ballistic Missile Defence

Another area of intense research is in the field of Boost-Phase Intercept systems to neutralise theatre ballistic missiles (TBMs) during their initial stages of flight.[19] The marriage of UAVs with kinetic energy or laser weapons is seen to provide a low-risk, cost-effective system for theatre ballistic missile defence. Exploitation of a high operating altitude will include the ability to acquire missile launch early in its boost phase, increasing the likelihood of destroying the missile over enemy territory. Also included in the BPI capability is the location, engagement and destruction of the transporter erector launcher to prevent the launching of further TBMs. The high altitude will also reduce issues of 'deconfliction' with other friendly aircraft and enable the UAV to engage the missiles at greater ranges than other aircraft operating at lower altitudes (due to the reduced drag).[20] An estimate is that approximately 20 UAVs would be required to neutralise the ballistic missile threat associated with a Gulf War sized conflict, with their cost being approximately US $1.5 billion over a ten year life-cycle.[21]

Suppression of Enemy Air Defences

The concept of operations for UCAVs is predominantly to use them for initial attacks on air defences and other fixed targets in first and second wave assaults.[22] Boeing, for example, was investigating the possibility of producing an unmanned variant of the Joint Strike Fighter (JSF) which would represent a 50 per cent reduction of the cost of the $30 million dollar manned JSF.[23] Should the concept prove viable, they envisaged the production of two types of aircraft to be used for ground attack and air-to-air roles.

Lockheed Martin believe modification of retired F-16As in storage could provide demonstrators for the UCAV concept within two years.[24] Removal of the cockpit and life support systems will potentially increase the endurance from five to eight hours. The aircraft are envisaged for use in defence against theatre ballistic and cruise missiles with estimates indicating that three UCAVs could perform the role of a squadron of manned aircraft.

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[18] Discussions with Wing Commander S. W. Filmer, JP129 Project Manager, SRSSPO, after visit to US UAV manufacturers (inc. Lockheed Martin) and operators in March-April 1997.

[19] 'Israel's MOAB Scud-Interceptor Detailed', in *Jane's International Defense Review*, 7/1996, p 5.

[20] W.B. Scott, 'Kinetic-Kill Boost Phase Intercept Regains Favor', in *Aviation Week & Space Technology*, 4 March 1996, p 23.

[21] B. Starr, 'USA developing missile attack role for UAVs', in *Jane's Defence Weekly*, 2 September 1995, p 3.

[22] Cook, 'Leaving the pilot on the ground', p 35.

[23] D.A. Fulghum, 'Boeing Plans Unmanned Fighter', *Aviation Week & Space Technology*, 4 March 1996, p 20.

[24] D.A. Fulghum, 'High-G Flying Wings Seen For Unmanned Combat', in *Aviation Week & Space Technology*, 11 November 1996, p 58.

Summary

The classification of UAVs is problematic given the increasing capability of a single platform to perform a multitude of roles. Their classification is best served through categorisation by functions, where it is acknowledged that one UAV could be both a strike platform and a reconnaissance vehicle simultaneously. This paper uses the method illustrated in Figure 5.1.

Section Two

A Methodology For Comparative Analysis

Introduction

In defence and commercial organisations, the acquisition of systems and equipment is determined through a comparison of two overarching factors: performance (or effectiveness) and cost (or efficiency). The selection process for acquisition, however, is rarely as simple as selecting the cheapest system which meets the benchmark performance criteria. Systems will generally differ through the provision of less tangible, non-performance related attributes such as robustness, capacity for upgrade and level of national industry involvement. Moreover, the complexity of defence systems seldom allows competing weapons systems to exhibit equal performance characteristics. Therefore, a trade-off of one attribute on one system against a different attribute on another system forms an inevitable part of the comparative process. For systems with fundamental differences in their inherent strengths and limitations, such as those between UAVs and manned aircraft, identification and consideration of these differences becomes fundamental to any comparative analysis between the two system types.

In determining where UAVs might represent a competitive platform option for stated force capabilities, characteristics unique to the platform must be included in the overall analysis of performance and cost criteria. Failure to adequately address the unique characteristics, representing both the inherent strengths and weaknesses of the system, could result in discounting systems which represent better value overall or, conversely, the acquisition of systems with hidden costs and limitations that could result in dramatic operational consequences.

Aim and Scope of Section

The aim of Section Two is to develop a methodology for performing a comparative analysis on three potentially competitive aerospace platform alternatives: manned aircraft, UAVs and satellites. While some roles are currently unsuitable for the comparison of all three types, such as strike operations from satellites, further developments in technology may permit operations in roles previously discounted as unachievable. Additionally, the inclusion of satellites in this methodology was considered important, given their increasing competitiveness in providing reconnaissance, surveillance and communications capabilities.

The approach taken in developing a methodology involves identifying the different 'properties' of each system. These differences are then analysed and incorporated into more familiar models used for the comparative analysis of systems. This section is primarily concerned with the identification and description of system properties which require inclusion into the comparative analysis process in one form or another. The relationship of one system property to another is developed only insofar as to acknowledge that such a relationship exists. Similarly, the apportionment of the relative importance of system properties, and thus their relative 'weightings' within specific comparative models, is left to those in the force development and system acquisition process where access to official government guidance and knowledge of strategic priorities will help determine the relative value of particular system attributes.

Life-cycle-cost (LCC) analysts, similarly, are better placed to incorporate the nuances of UAVs and satellites into their costing models for manned aircraft systems. The author's role in this comprehensive and complex process is to highlight what new factors may be worthy of consideration, particularly those representing key cost drivers. Thus, for the purposes of this paper, no development is done on detailed mathematical models designed to evaluate life cycle costs. Also, levels of repair analysis and repair and maintainability considerations are not developed.

The 'product' of this section is the identification of properties, or attributes, which should be included in a 'decision-matrix' style model used for the comparative analysis of two or more of the identified system types. Owing to the influence of strategic considerations, mission type and individual bias on the relative importance of one property over another, the assignment of property 'weightings' normally associated with a decision-matrix model is not undertaken. By refraining from assigning 'weightings' to each system property, a generic model is produced which then can be tailored as required for specific mission types. This approach also removes the potential for disagreement, given the somewhat subjective nature of weighting aircraft properties.

Methodology Development

The development of the methodology was achieved by addressing the following questions:

- What criteria are used to measure mission effectiveness for generic force capabilities ?
- What are the significant differences between UAVs, satellites and manned aircraft?
- How are the differences evaluated in terms of cost/benefits?
- Where and how should the measurement of 'intangibles' (such as media influence) fit into any such equation? [1]

While these questions are used to identify key issues and their resolution, current methods for performing specific forms of comparative analysis of systems, such as life-cycle-costing, were examined to ensure critical criteria were included. Additionally, the six key attributes for air vehicles identified by the USAF's *New World Vistas* study were used to qualify the approach selected.[2] Their six attributes are defined as follows:[3]

[1] The 'CNN factor' is used to describe the influence of media, (in particular, television images as broadcast by the CNN television network), on political and military decision-making.
[2] *New World Vistas: Air and Space Power for the 21st Century - Aircraft and Propulsion Volume,* USAF Scientific Advisory Board, Department of the Air Force, Department of Defense, 1997, p 1.
[3] *Ibid.*, p 1.

- **Affordability** means the reduced cost of the weapon or weapon system from conception and development through the life of the system (life-cycle-cost).

- **Survivability** provides the ability to operate successfully in high threat environments.

- **Speed** enables the system to respond rapidly to a military need and enhances survivability.

- **Range** provides the ability to reach trouble spots anywhere on the battlefield or on the globe with minimal support from tankers or bases.

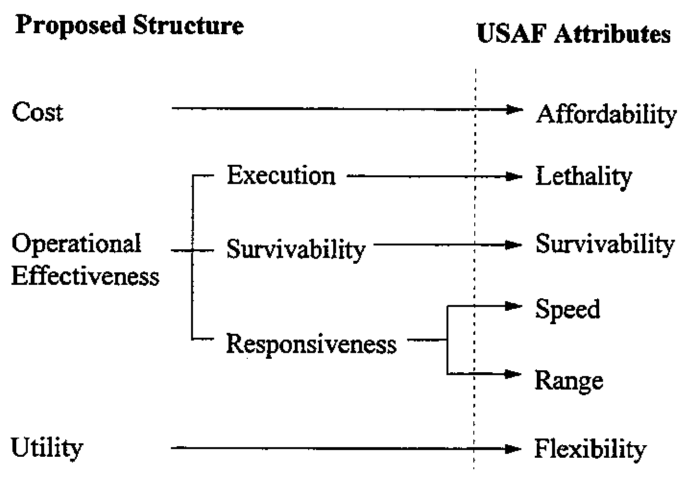
- **Lethality** enables the system to deliver weapons of destruction efficiently to kill on the first try.

- **Flexibility** is the ability to accomplish a variety of missions or carry a variety of payloads to meet differing requirements.

In adopting these attributes *per se*, the difficulty is that they are limited in their application. The attributes tend to apply to the measurement of purely offensive systems rather than providing a measure for the spectrum of capabilities delivered by air power. Consequently, these attributes have been modified to reflect a more generic measurement of a system's comparative worth. In determining the overarching measurements of a system, the following questions were asked:

- Is the system operationally effective?
- How much does the capability cost?
- How useful is the system?

Consequently, 'Operational Effectiveness', 'Cost' and 'Utility' were defined as the three distinct measures of a system's competitiveness, and form the headings of subsequent chapters. These key units of measurement incorporate the qualities of the USAF's six key attributes as shown:



Proposed Structure for Analysis and Linkage with USAF Approach

The term 'cost' was selected in preference to 'affordability' due to the subjective nature of the latter term. A determination of 'affordability' is usually achieved after marrying the 'cost' and 'operational effectiveness' of a system, providing a 'cost-effectiveness' measure. This is then considered in the context of strategic guidance, operational imperatives and resourcing constraints.

Lethality, survivability, speed and range are considered as sub-components in the measurement of operational effectiveness, where speed and range contribute to a system's responsiveness. Similarly, lethality is but one measurement (specifically limited to an offensive task) of a system's ability to 'execute' the mission. Accordingly, responsiveness, survivability and execution are defined within this study as the main components of the 'operational effectiveness' measurement. These are discussed in more detail in the following chapter.

Finally, the term 'utility' is used in preference to 'flexibility' given its general acceptance as an economic term; defining the measurement of a system's usefulness and capacity to satisfy the range of requirements. The terms have been chosen so as to reflect 'measurements' of a system's relative competitiveness, rather than as statements of system 'attributes' or 'qualities' which tend to be more subjective terms. This is done simply in an attempt to make the analysis process more scientific, particularly at the component and sub-component levels of analysis. The relationship of these measurements and a summary of the findings is provided in the final chapter of this section, titled 'A Methodology for Comparison'.

Chapter 6

Operational Effectiveness

The effectiveness of a system in meeting operational requirements is the primary gauge of a system's comparative value. Often measured in terms of range, speed, endurance and lethality, 'operational effectiveness' sets the benchmark level of performance by which systems are compared. This chapter examines the measurement of 'operational effectiveness' with specific reference to how its calculation should incorporate the different properties of manned aircraft, UAVs and satellites.

The chapter begins with a definition of operational effectiveness and proposes its measurement through the analysis of a system's probability of achieving 'mission success'. Three key units are proposed to constitute mission success: survivability, responsiveness and execution of the task. The property differences among UAVs, manned aircraft and satellites are acknowledged in terms of these three units of measurement. These properties are then identified and discussed as potential sub-components of responsiveness, survivability and execution. This should provide a foundation to those who seek to develop decision matrix models for the comparison of two or more system types for specific force capabilities.

Measuring Operational Effectiveness

In the comparative analysis process the primary step is defining what constitutes operational effectiveness. The operational effectiveness of a system is inherently linked to the types of missions required of the system. Measurement of operational effectiveness, therefore, can be calculated through the analysis of systems in performing one or a range of mission profiles. The 'probability of mission success', P(MS), is used hereafter as the base unit of measurement for operational effectiveness. The relationship of 'mission success' to operational effectiveness is cumulative and can consist of a number of mission profiles which are required of the system under analysis, as demonstrated in Figure 6.1.

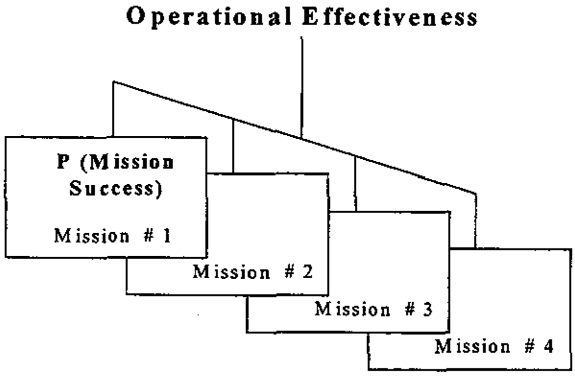


Figure 6.1 Determination of Operational Effectiveness through calculation of Probability of Mission Success

The next step in the process is to identify those attributes, or properties, that contribute to mission success. These attributes are then 'weighted' according to their relative importance for particular mission profiles. Finally, the performance characteristics of competitive systems can be incorporated into a decision matrix for comparison.

Examination of a range of mission types reveals the extent to which the key units of measurement differ from one mission type to another. For surveillance or reconnaissance operations, for example, key properties are likely to include those which relate to the functions of distance, resolution and time. Further for this example the stipulated mission performance parameters for a surveillance platform might be the requirement to conduct surveillance over an area 500 x 500 kilometres at 1 metre resolution with a revisit time of three hours over any one point. For combat missions, the probability of kill (P(k)) forms the predominant unit of measurement for mission effectiveness. Time and range parameters will form part of the performance criteria but weapon precision and destructive power are likely to be weighted as the central measurements of mission effectiveness.

In keeping the methodology generic, the attributes specific to certain mission types, such as lethality, are removed from the top layer of the model. These specific attributes will be referred to as sub-components, and are applied at the lower level of the comparative analysis model where appropriate. The primary units of measurement for mission success have been determined as 'survivability', 'responsiveness' and 'probability of task execution'. These terms are defined as follows:

- **Survivability** is the system's ability to remain functional long enough to execute the required task.
- **Responsiveness** is the system's ability to locate and acquire the target in a timely manner.

- **Execution** is the system's ability to 'execute' the assigned task (ie. to undertake surveillance, destroy, neutralise, etc). Execution of the mission is referred to hereafter as Probability of execution (P(e)), which defines the ability to achieve the desired outcome (expressed in terms of neutralising or destroying a target, or in terms of resolution or area coverage for reconnaissance/surveillance tasks).

Hence, the probability of mission success can be defined as follows:

$$P\ (MS) = P\ (sv) * Rs * P\ (e)$$

Figure 6.2 illustrates the hierarchical relationship between mission success and the three key components.

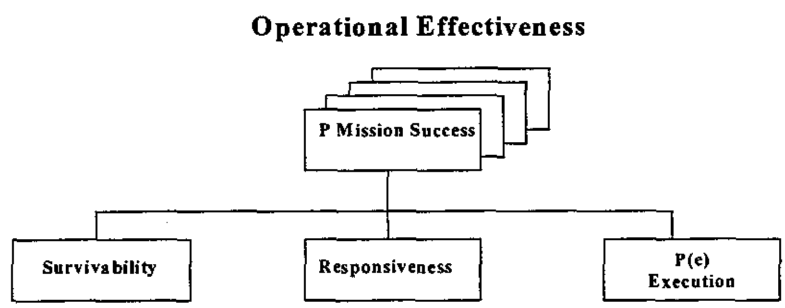


Figure 6.2 Key Measurements of Operational Effectiveness

In determining the relative performance of each platform type with regard to the three key components, further examination of manned aircraft, UAVs and satellites is necessary. System properties, or characteristics, particular to each platform type, and their effect on the measurement of responsiveness, survivability and execution of the task, must first be identified. An understanding of the fundamental differences in system characteristics allows for their incorporation into the comparative analysis process. The key differences between UAVs, manned aircraft and satellites and their effect on operational effectiveness are acknowledged in Table 6.1.

Satellites	UAVs	Manned Aircraft	Impacts on
Fixed orbit	Flexible tasking	Flexible tasking	Responsiveness
Limited dwell	Med-long dwell	Med dwell	Responsiveness/P(e)
Product datalinked	Product datalinked (optional)	Product datalinked (optional)	Survivability/P(e)/ Responsiveness
Independent/datalink	Datalink for control	Independent ops	Survivability
Highly survivable	Varied survivability	Varied survivability	Survivability

Table 6.1 System Properties - Effect on Operational Effectiveness

The effect of the tabled differences in operational properties on the key operational criteria of survivability, responsiveness and execution of the task, P(e), is highlighted in the right-hand column. As a basic demonstration the table illustrates how the mechanics and inherent characteristics of the different platforms can affect their suitability in performing specific mission types. Further examination of the key measurements of mission success will provide a more comprehensive understanding of how the systems will differ within a comparative analysis based on their operational properties.

Survivability

Survivability requirements vary according to the task and platform type. For example, in order to conduct battle damage assessment (BDA) missions with RF-111Cs, the aircraft must survive the forward and the return legs in order to achieve mission success. With the current RF-111 BDA capability limited to wet film processing, the aircraft must return to base before the reconnaissance data can be extracted and processed. On the other hand, cruise missiles only require survivability for their forward leg, given that they perish in the destruction of the target.

The other factor, often accounted for in the consideration of survivability, is cost. Both UAVs and manned aircraft using satellite communications to relay BDA imagery could notionally achieve their mission requirements even if they are destroyed on their return leg. In such cases, the cost in terms of the loss of capability (and human life) becomes an issue. The requirement for survivability, therefore, is inherently linked to cost factors. In the previous example, survivability of the datalink is also critical to mission success provided no other form of system redundancy is available. Overall survivability of the complete system must dominate any considerations.

Finally, survivability is scenario dependent. The survivability of a system is relative to the effectiveness of enemy air defences. A small UAV flying at 30,000 feet is beyond the reach of small arms fire and should be highly survivable. The same UAV would be extremely vulnerable and have a comparatively low level of survivability if operated over an area heavily defended by advanced surface-to-air missile (SAM) systems.

Determining Survivability

Typically, measurement of survivability is one of the most difficult to gauge. Survivability may be enhanced through the exploitation of a single aircraft property such as speed, manoeuvre or stealth. Defensive aid suites (DAS), including electronic counter measures (ECM), may also be employed. More frequently, though, increased aircraft survivability is achieved through the employment of a combination of features.

In determining the probability of survival (P(sv)), an assessment of the threat to the platform and its weapon or sensor systems is also required. The survivability of a system, therefore, is determined by two elements: avoiding detection, and avoiding or defeating the enemy's defence systems as illustrated:

$$\mathbf{P\ (sv) = P\ (det_{av}) * P\ (def_{av})}$$

where:
$P\ (det_{av})$ - is the probability of detection avoidance, and
$P\ (def_{av})$ - is the probability of avoiding or defeating the enemy's defence systems

where:

$$\mathbf{P\ (det_{av}) = f\ (RCS, ft, Db, DAS, Y(d), m^2)}$$

where:
RCS - is the radar cross section,
ft - is the altitude in feet,
Db - is the noise signature in decibels,
DAS - is the defensive aid suite/s employed, and
Y(d) - is the enemy detection system
m^2 - is the physical size of the aircraft in m^2,

and

$$\mathbf{P\ (def_{av}) = f\ (kts, ft, M, SA, DAS, Y(r))}$$

where:
kts - is the speed in knots,
ft - is the altitude in feet,
M - is manoeuvrability
SA - is situational awareness
DAS - is the defensive aid suite/s employed, and
Y(r) - is the enemy response system

The success of a system's survivability characteristics designed to avoid detection is directly relative to the characteristics of the enemy detection system. If the enemy's detection system has a probability of detecting equal to Y(d), then the probability of detection avoidance P(det_{av}), is inversely proportional to the effectiveness of the enemy's detection system Y(d):

$$P(det_{av}) \propto \frac{1}{Y_{(d)}}$$

Survivability and Detection

The relationship between survivability and detection is inversely proportional. Once detected, speed, manoeuvre and defence-aid-suites are all required in varying degrees to outrun, out-manoeuvre and counter enemy defence mechanisms respectively. Avoiding detection in the first instance significantly increases system survivability. Avoiding detection, therefore, should be afforded significant priority in the survivability equation.

Detection avoidance can be achieved through the development of complex mission profiles designed to reduce the chances of detection, or by technological means. Aircraft design and technology, in the form of stealth, can exponentially decrease the risk of aircraft detection, and is worthy of further examination.

Stealth

Platform stealth is relative to the detection system employed by the adversary. The achievement of stealthy characteristics relies on the employment of measures to reduce the ability of an enemy to detect the aircraft. These measures are designed to reduce visual and aural detection, or detection by radar, or a combination of these. Measures to reduce visual and aural detection include decreasing aircraft size, using paints for camouflage, reducing noise signature through dispersal techniques, and operating at high altitudes. These characteristics are similarly employed to reduce detection by radar where paints and materials are utilised to reduce the reflection of electromagnetic waves and aircraft design aims to minimise radar cross section (RCS).

For aircraft operating in high threat environments where the enemy employs sophisticated radar, RCS becomes an important consideration. The ability to design UAVs for maximum stealth through reduced RCS is simplified due to the removal of the crew module. For example, the US is considering the development of UAVs which fly inverted after take-off to shield air intakes. These concepts may be further exploited in the future and should be addressed in the consideration of survivability criteria.

Radar Cross Section and Detection

Simplistically, detection by radar is directly proportional to RCS:

$$\textbf{Detection}_{(\text{Radar})} \propto \textbf{RCS}$$

In order to demonstrate the measurement of RCS and its relation to radar detection, Figure 6.3 provides examples of aircraft across the spectrum of RCS measurement. Conventional fighter aircraft generally exhibit RCS in the order of square metres whilst cruise missiles have very low RCS. 'Stealth' aircraft can achieve RCS values which place them in the same order as small birds and insects.[1] The relationship between detectability and RCS is therefore an important consideration for survivability.

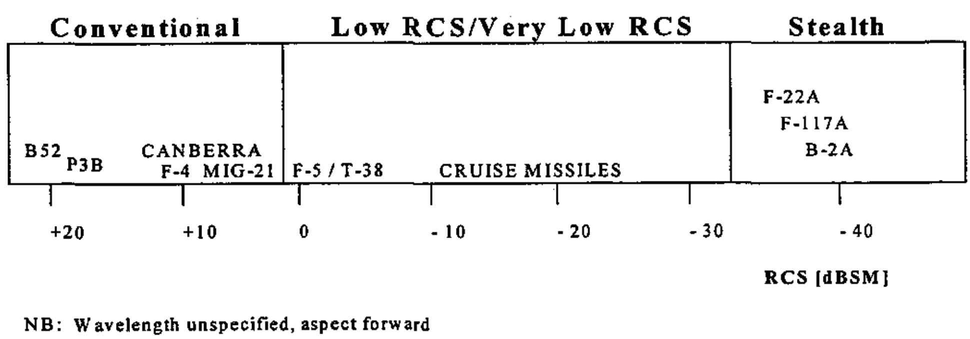


Figure 6.3 Comparative RCS for Various Aircraft Types

[1] C. Kopp *A New Paradigm for the F-111*, Special Study No 1 (Restricted), Air Power Studies Centre, Canberra, 1996, p 39.

Survivability and Defeating Enemy Defence Systems

The previous discussion on survivability criteria focussed on reducing the detection of aircraft. Once detected, different criteria become important in determining survivability. For example, self-protection through DAS such as chaff, flares and jamming capabilities, manoeuvrability, speed and situational awareness become important for defeating surface-to-air and air-to-air missile threats. In defeating missile threats, manned aircraft hold the advantage over current generation UAVs due to the ability for aircrew to provide situational awareness. Additionally, current generation UAVs cannot match the speed and manoeuvrability of manned aircraft. In the future, however, UCAVs are expected to employ sensors to provide greater awareness to the operator on the ground, perhaps providing greater awareness than is achievable by manned aircraft, through 360-degree coverage of the surrounding environment. The manoeuvrability of future UCAVs can also theoretically exceed that of manned aircraft with the development of UCAVs capable of performing 20 G turns.

Calculating Survivability

Platform survivability can be tested through mathematical models with survivability characteristics comprising one or more of the criteria listed in Figure 6.4. The exploitation of these systems is incorporated in the tactics employed by the operators and may include other support measures such as fighter support. The payload capability may also be included in the assessment where the payload extends range or reduces risk to life through a stand-off capability.

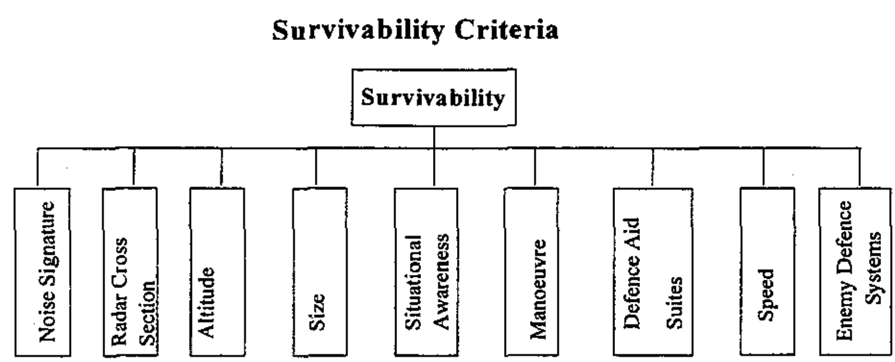


Figure 6.4 Survivability Criteria

In order to assign a probability of survivability value to the overall equation of mission effectiveness, complex calculations of a system's survivability must be undertaken. The preceding discussion on survivability criteria provides some guidance on what the key survivability criteria are likely to be, and how manned aircraft, UAVs and satellites may perform according to the criteria.

In calculating survivability, consideration should also be given to the concept of 'attritability' or expendability of a system. There will be many instances where it will be more cost-effective to lose a number of expendable systems (such as stand-off weapons and cruise missiles) in destroying a target, rather than risk the loss of a costly survivable asset such as a manned aircraft.

This concept is not new, but rarely features in survivability calculations. In this methodology, where a system does not meet the required probability of survival, a calculation of a system's 'attritability' should be undertaken. The following demonstration illustrates the concept.

For cruise missiles, the survivability of the system over a high threat environment may be determined as 33.3 per cent. A single cruise missile is unlikely to satisfy the mission requirements. However, as one of a quantity of three or four missiles, the cruise missile option is likely to satisfy the mission requirement at an acceptable cost. While this concept is dealt with in further detail in Chapter 7, it must be acknowledged in the calculation of survivability. Figure 6.5 indicates that where the probability of survivability is so low as to fall below the required mission effectiveness parameters, a calculation of expendability is required. The four considerations within the calculation include survivability, political/public acceptance, platform cost and value of life.

Survivability versus Expendability

A unique concept in the employment of UAVs is the potential to use them as expendable assets. The absence of on-board operators provides them with this unique attribute. While manned aircraft have historically been used as expendable assets to destroy high value targets, such as US naval units sunk or damaged by the Japanese Kamikaze attacks of World War II, it has not become an accepted deliberate practice. Such practice is even less likely in the current environment for the majority of nations due to national values and the cost of aircraft and aircrew training. Additionally, for many nations, the moral and ethical implications of this concept of operations are likely to discount it altogether.

In effect, expendability represents *the cost and risk to the UAV and probability of mission completion* versus *the cost of platform, risk to human life and the probability of mission completion for a manned option.* Calculation of expendability could be based on four factors; survivability, public acceptance, cost of the platform and the value of human life. The relationship is illustrated in Figure 6.5.

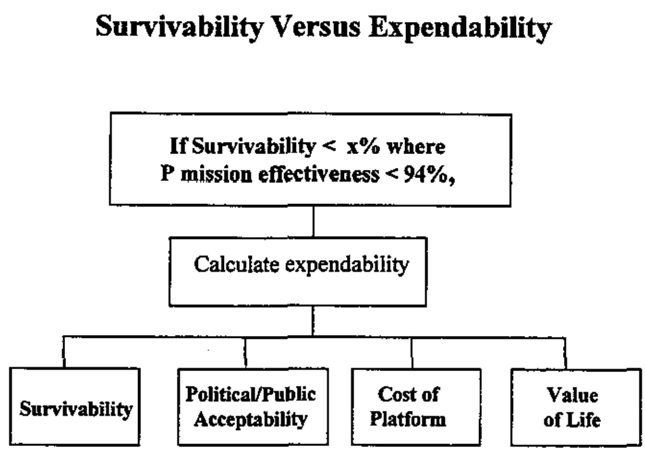


Figure 6.5 Relationship between Survivability and Attrition

In considering the weightings or values assigned against the three factors identified, the following concepts may prove useful:[2]

Political/Public Acceptance

The political or public acceptance of the concept of expendability is an important, albeit difficult, factor to measure in relation to UAVs. High attrition rates by UAVs, even if they provide a cost-effective option to military planners, may be publicly unacceptable if they fail to achieve the mission aim or achieve it at high cost compared to the more survivable manned platforms that achieve the missions aim with no losses. Education of commanders, politicians and the public would be required to overcome the existing culture of increasing survivability.

Platform Cost

The critical factor in determining whether a platform is expendable is ultimately its cost. Cost issues are dealt with in greater detail in Chapter 7. However, it is worth noting that for UAVs, calculation of expendability is based on the platform cost only; the other system costs such as the mission and ground control stations, and operating personnel need not be factored into the calculation.

[2] Survivability is discussed in sufficient detail in preceding paragraphs.

Value of Life

Where the loss of human life is deemed unacceptable, expendable unmanned platforms may be given greater weighting. Minimisation of casualties is becoming an increasing priority for commanders and politicians as the public becomes less tolerant of casualties. In cases where aircrew may be subject to public humiliation as occurred in the Vietnam and the Gulf Wars (human casualties may be deemed unacceptable because of the public effect or 'CNN factor'), expendable unmanned platforms may be considered.

Summary on Survivability

Generally speaking, UAVs and manned aircraft demonstrate very similar characteristics for survivability, given the employment of similar system components and the corresponding availability and applicability of technology to the two platform types. Manned aircraft have an advantage over UAVs in that the pilot can provide situational awareness which cannot currently be reproduced for UAV ground operators. Owing to the design freedom available through the absence of aircrew and their related support systems, UAVs demonstrate greater potential for incorporating stealth features. Also, UAVs can be regarded as expendable assets and more easily tailored to provide a balance between survivability and cost. This is demonstrated in the range of stand-off missiles which provide cost-effective options for the spectrum of threat scenarios.

Responsiveness

The calculation of a platform's capability to acquire (or to engage) the target involves consideration of a number of criteria. A platform's range, speed, guidance system and quality of human machine interface (HMI) will all affect its responsiveness, and its ability to locate and to acquire the target. Some of the platforms' unique characteristics are considered within this criteria, such as a satellite's orbit and how it affects revisit times and coverage. Sensor characteristics are also assessed under this criteria. These include field of view, day/night capabilities, infra-red capabilities and other factors which will affect the platform's capability in locating and acquiring the target. Generally speaking, the ability to 'acquire' is represented through the function of time, in terms of the capability to acquire the target within a stated period of time (speed, day/night capability, etc) and maintain this acquisition or engagement over a period of time. The factors which may be considered in the calculation of the probability of the platform to locate and acquire the target are discussed briefly.

Rs = *f* (speed, range, endurance, revisit rate, area coverage, system availability)

Speed/Responsiveness

The requirement for speed is generally associated with either survivability or responsiveness. For fighters, speed represents a large proportion of the aircraft's capability to engage an enemy aircraft and to increase its chances of survivability; for strike aircraft, it enables swift strike as well as offering the aircraft greater survivability. A satellite's responsiveness is determined by its orbital characteristics which are generally fixed. Their responsiveness is therefore dependent on where they are situated at the time of requirement and can only be increased through increasing satellite numbers in the constellation.

Range

For manned and unmanned aircraft, range is an important limiting factor in the ability to locate and acquire targets. Range affects responsiveness in the case where limited-range aircraft are required to refuel on the ground in the course of completing a long range mission. This may be minimised through the use of an air-to-air refuelling capability, but this has other limiting factors.

Endurance

Synonymous with range is the endurance capability offered by a platform. Whether relating to surface ships, submarines or aircraft, endurance is of particular importance where forces wish to maintain an enduring presence in a region, be it for deterrence or 'holding ground'. For air forces, endurance is a key to providing time-on-task for surveillance and reconnaissance missions. Essentially, endurance involves the trade-off between range and time-on-task. Satellites vary in their capability for endurance over a particular site, according to their orbital characteristics. Geostationary satellites provide continuous coverage over a specific region but this capability is only achievable from very high altitude orbits, thereby limiting their use to communications roles. LEO satellites operate at lesser altitudes which are optimised for EO/IR resolutions at the expense of having limited time on target each orbit. For satellites, limited endurance in surveillance tasks can be offset by high revisit rates.

Revisit Rate

In terms of most surveillance systems, revisit time is an important consideration. Satellite revisit times can vary from hours to days, depending on their altitude of orbit, inclination and whether they have geostationary, sun synchronous or polar orbits. Manned and unmanned aircraft revisit times will depend on availability of aircraft, number of crews and the surveillance concept employed, but unlike satellites, they are more flexible in their employment. Defining revisit rates as part of the operational parameters will generally allow the calculation of the number of platforms required to cover a designated area, as well as the basis for determining capability costing.

Area Coverage (Surveillance)

For surveillance capabilities, the area of coverage is one of the primary criteria. Area coverage is generally considered in swath readings of square kilometres or square nautical miles. Characteristics which can affect coverage include platform altitude and speed, and the resolution, aperture and power requirements of the sensor system.

Weapons Systems Availability

While the determination of weapons system availability is not easy at the acquisition phase, the factors involved in the determination are crucial because of this contribution to the responsiveness of the weapons system acquired. Whilst much of weapons availability will be dependent on the operational and maintenance system employed by the operator, some factors can be quantified at the conception and acquisition stage. Considerations should include data on life-of-type hours of engines and airframes and other critical operating parts, Mean-Time-Between-Failure (MTBF) data, maintenance hours per flying hour, and maintenance schedules on system components. These will all give an indication of a quantity of assets required to meet preparedness and sustainability criteria.

Probability of Execution [P(e)]

The execution element of the calculation is defined as the capability to achieve the mission goal. This may be the execution of precision strike, capturing photographic or real-time evidence of target destruction (BDA) or other reconnaissance targets. Factors to be considered may include resolution of sensors, accuracy of weapon systems and timeliness of data. The probability of mission execution can be defined as follows:

P (e) = *f* (resolution, data timeliness, payload capacity, weapon effectiveness)

Resolution

Surveillance and reconnaissance platforms, and their sensors will be judged on the resolution of imagery produced. The higher the altitude, the poorer the resolution for most sensors. For this reason, most surveillance satellites tend to be in the LEO category. At these altitudes, resolution is less than a metre for electro-optical sensors and about 1 metre resolution for SAR. Given the flexibility associated with most air-breathing systems, manned aircraft and UAVs can be tasked to operate at altitudes which provide optimal resolution. Where electro-optical data is preferred, both systems can fly beneath cloud and other conditions which interfere with the collection of data by electro-optical sensors.

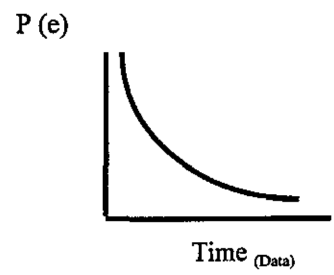
Payload Capacity

Payload capacity represents the capacity of the platform to conduct its mission with greatest effectiveness. A platform with a large capacity, enabling a combination of sensor types, reduces the requirement to task other vehicles for further interrogation of the target. For example, a surveillance/reconnaissance platform with the capacity for simultaneous operation of Electro-Optical, Synthetic Aperture Radar, Real Aperture Radar and Infra-Red will be capable of all-weather day/night operations for tracking stationary and moving targets. This is achieved through an optimum mix of sensors with different characteristics and exploitation features. Similarly, payload capacity represents the amount of firepower which can be carried by the vehicle. In offensive operations, laser designation represents a means of designating targets for other airborne or surface platforms, while a platform with laser designation and an organic arsenal represents a greater capability.

The payload capacity of each of the three platform types vary considerably. With aircraft types on a scale of the Boeing 747 and Airbus, manned aircraft can provide significant payload capacities relative to the current generation UAVs. For aircraft of similar scales, UAVs can offer increased payloads to their manned counterparts by virtue of the extra space and weight available through the removal of the aircrew and their support systems. Satellites are generally limited in their payload capacity due to their power requirements and the costs associated with launching and operating space-based systems.

Datalink Requirement/Timeliness of Data

For reconnaissance and surveillance aircraft, the determination for real-time visual information will have a significant determination to the cost-effectiveness of manned aircraft over UAVs and satellites. By virtue of having an on-board operator who can interrogate and analyse the target area information gathered, and pass information using voice links, manned aircraft represent a more cost-effective method for relaying real-time verbal information (due to smaller bandwidth requirements). Both UAVs and manned aircraft can conduct surveillance/reconnaissance operations where the data is captured and stored on film but not processed until the aircraft is on the ground. However, where there is a requirement for real-time sensor data, satellites, UAVs and manned aircraft require satellite bandwidth to relay information for beyond line-of-sight reconnaissance /surveillance. Generally, mission execution for missions requiring data collection will be inversely proportional to the time taken to collect, receive and exploit data. This can be illustrated as follows:



Weapon Effectiveness

The weapon effectiveness is the effectiveness of a designated weapon to achieve the desired result on a designated target. Lethal or non-lethal weapons may be used depending on the nature of the target and the effect required. Weapons effectiveness may be illustrated by the following relationship:

Wpn Eff = f (required effect, wpn power and type, accuracy, size and nature of target)

To consider 'weapon effectiveness' in more familiar terms, 'lethality' is used as a measurement for missions requiring the destruction of physical targets. Lethality can be defined as the relative ability to incapacitate or destroy the assigned target. Lethality is a function of weapon accuracy, destructive power and the size and nature of the target.

Lethality = f (weapon accuracy, destructive power, size and nature of target)

The lethality of a mission could, therefore, be defined as a measure of weapon lethality and payload capacity. Given their greater payload capacity over current generation UAVs, manned aircraft in strike and fighter roles are likely to demonstrate better lethality where the target requires multiple strikes. Where targeting accuracy is assisted or controlled by an external operator, whether by a manned aircraft or ground control station, the associated radars, sensors and datalinks will also have an influence on lethality.

Summary

The difference in platform properties between UAVs, manned aircraft and satellites requires those undertaking a comparative analysis of two or more of the systems to incorporate those differences within their methodology. Many of the properties examined in this chapter appear self-evident to those familiar with analysing the competitiveness of manned aircraft systems such as range and speed. The purpose of this chapter is to explore the range of properties which should be considered in determining the operational effectiveness between the three platform types. For example, in analysing a satellite's ability to undertake a stated surveillance task, the revisit time and time-on-task become essential to the calculation. In contrast, the expendable nature of UAVs requires that calculations of survivability should acknowledge the option of 'expendability'. While the incorporation of these properties will make the comparative analysis process significantly more complex, it is essential for smaller defence forces which are limited by the acquisition of a minimum number of different platforms. The key to performing a fair and unbiased comparative analysis on the operational effectiveness of competing system types is the incorporation of measurements which account for their unique properties.

To summarise the key points raised in this chapter, the probability of mission success was determined as the ultimate gauge of a platform's viability in meeting a stated force capability requirement. The factors to be considered were identified as survivability, ability to acquire, and ability to execute or achieve the desired result. Figure 6.6 illustrates the relation of these components and key sub-components to operational effectiveness.

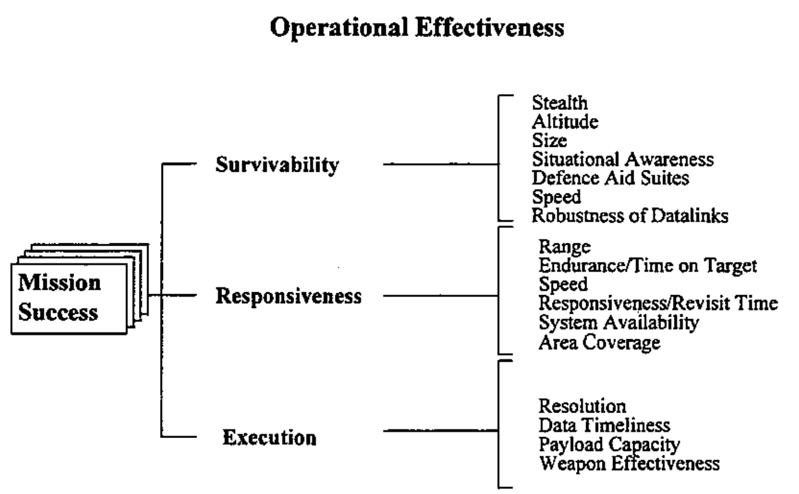


Figure 6.6 Key Criteria in the Calculation of Operational Effectiveness

These factors may not necessarily determine the suitability of various platforms in achieving the mission, but rather may dictate the number of platforms required to achieve the required probability of mission success. The number of platforms required to achieve mission success will impact directly on the cost and viability of the various mission options and, therefore, their viability as options.

The process of determining numbers of platforms is complex and requires very different calculations for the three different platforms types. For example, determining the number of satellites required for continual surveillance of a given area with a limited revisit time will involve calculation of orbital inclination, altitude and deviation. A number of different type of sensors may be required for a high probability of target acquisition, such as SAR for all weather and day/night operations, and EO and RAR for moving target requirements. In contrast, the calculation of the number of manned aircraft platforms required to meet the same surveillance requirements would include factors such as maintenance down-time, number of crews and aircraft required for 24 hour operations.

Overall, the performance or operational parameters provide the basic benchmark required, with results of these complex and varying calculations either confirming or negating a platform's ability to undertake the mission successfully, as well as providing vital data for further analysis of cost-effectiveness.

Chapter 7

Cost of Capability

The cost of a capability is gaining increasing importance in force deliberations worldwide and, for many, cost is becoming the driving criterion behind the development and acquisition of systems. This change in focus, from paying the price for the superior system, to one which focuses on cost as the ultimate criterion in meeting minimum benchmark performance parameters is evident even in force determinations by wealthy nations such as the United States. In the development of the Global Hawk and the DarkStar UAVs, for example, 'cost is the single requirement for the program'.[1] Contractors are able to 'trade off all other system attributes, including performance' to meet the cost requirement.[2]

While this concept does not imply that forces will purchase the cheapest platform on the market, it indicates the importance of costs when considering improvements to force capabilities. In an era of increasing financial constraints on defence spending, defence forces are more likely to assess the viability of achieving increased capabilities in 'value for money' and 'more bang for buck' terms. In seeking increased capabilities, the law of diminishing returns will apply at some point. That is, nations will generally be able to identify a level of capability provided at a certain price, where the succeeding level of capability represents only marginal improvement for a substantially higher cost, as illustrated in Figure 7.1.

[1] 'Global Hawk Unmanned Aerial Vehicle Unveiled', *News Release: Office of Assistant Secretary of Defense (Public Affairs)*, Washington, 20 February 1997 (Ref 082-097) @ http://dtic.dla.mil:80/defenselink/news/Feb97/b022097_bt082-97.html
[2] *Ibid.*

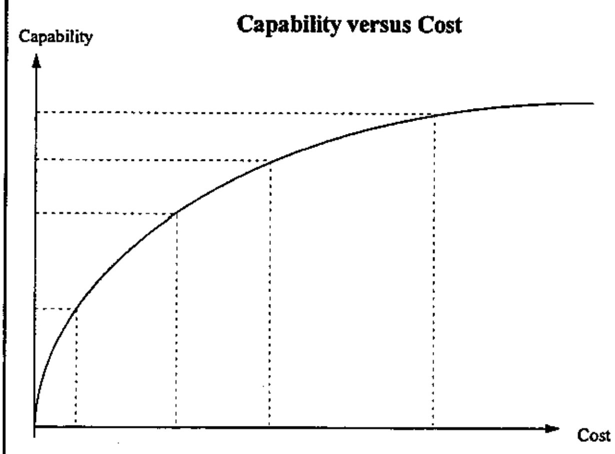


Figure 7.1 Determination of Capability based on Cost

Determination of the cost of delivering a force capability includes consideration of a number of distinct components such as acquisition cost, operating cost and the life-cycle-cost (the sum total of acquisition and annual operating costs over the life of type). These costs can be broken down further into sub-components which include operating workforce, spares support, training and system costs. There are, however, several other factors which should also be accounted for under the costing function. The cost associated with the technical risk of introducing immature technology versus the costs of failing to adopt new technology (or opportunity costs in terms of the development of concepts of operations and organisational changes), should also be given consideration in any comparison. Likewise, the cost associated with attrition rates should be factored into the equation. Each of these costs will be discussed with reference to both the similarities and unique characteristics of the three system types.

The characteristics of each system type which affect cost consideration are illustrated in Table 7.1.

Satellites	UAVs	Manned Aircraft	Attributes Affected
Organic communications	Datalink via satellite (for BVR real-time)	Datalink via satellite (for BVR real time)	Operating costs/ Life cycle costs
No on-board operator	No on-board operator	Aircrew	Attrition
Highly survivable	Varied survivability	Varied survivability	Attrition
Limited operating life	Med-long life	Long life	Life cycle costs
High-V.High launch & platform cost	Low-med platform cost	Med-high platform cost	Acquisition/ Life cycle costs
Low operating cost	Low-med operating cost	Med-high operating cost	Platform availability/ Life cycle costs

Table 7.1 System Characteristics

Life-Cycle-Costs

The comprehensive costing of a system from its conception to disposal constitutes its life-cycle-cost (LCC). In the military context, life-cycle-costing can be defined as the sum total of the cost incurred in acquiring, operating, supporting and disposing of a materiel system.[3]

Consideration of life-cycle-costs over a defined period forms a fundamental part of performing a comparative analysis of potential platforms and systems. The USAF recognises the increasing importance of life-cycle-costs and has adopted the concept as a primary driver for its development into the next century:

> Although it was always considered in the development of systems, total life cycle costs are now the dominant consideration in the fielding and modernization of systems. Performance is still a major factor but the thrust of technology today is to lower life cycle cost while maintaining performance. With defense budgets being reduced, the application of technology to reduce life cycle costs will be the force multiplier in the next millennium.[4]

Consideration of life-cycle-costs in a comparative analysis evaluation is paramount to nations with defence budgets in Australia's order of magnitude.

In calculating the life-cycle-cost of various platform types, there are a number of factors which should be noted. For example, the life-of-type of LEO satellites is in the order of five to seven years. Therefore, in calculating the life-cycle-costs of a LEO system over twenty years, the capital cost (including launch costs) will need to be multiplied by three or four. To this must be added annual operating costs (estimated at $15 million) multiplied by twenty, to generate the cost of a twenty year capability.

Life-cycle-costs can be divided into four distinct categories, as illustrated in Figure 7.2. These main categories will be discussed individually, given the distinct nature of each.

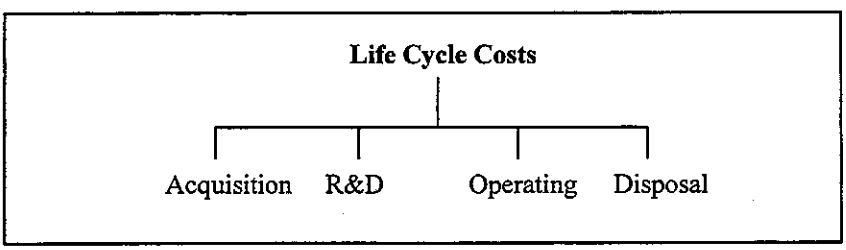


Figure 7.2 Life Cycle Cost Factors

[3] Mr Alan Arnold, (Draft definition), Director Acquisition Management Systems (Systems Engineering), Industry and Procurement Infrastructure Division, Department of Defence, Canberra, July 1997.

[4] R. W. Davis & D. R. Selegan, 'Impact of Technology Advance on Air Operations', a Paper Presented to *Air Power Conference and Exhibition: 27th & 28th February 1997*, Royal Lancaster Hotel, London, UK.

Acquisition Cost

The capital or acquisition cost of a system is generally defined as the up-front cost to get the capability on line. Generally acquisition costs will consist of the following:

- operating system,
- spares,
- software support,
- facilities,
- publications,
- initial training,
- establishment of maintenance infrastructure, and
- establishment of training infrastructure.

With the inclusion of UAVs and satellites, several other costs must be considered:

- purchase of bandwidth for datalinks, and
- launch costs for satellites

Care should also be taken when defining the components of the so-called operating system. For satellites, the operating system includes the cost of the platform, sensors and their installation into orbit. Mission control stations are also an integral part of a satellite operating system. UAV systems comprise mission control stations, ground control stations and three to four UAV platforms per system, as well as the sensor payload. Manned aircraft represent the simplest equation, comprising the costs of the aircraft and payload (where the payload is included as the operating system).

The acquisition cost of a system once represented the primary consideration in procurement strategies, given the visibility and concentration of expenditure within a relatively short time-span.. In recent times, however, much greater consideration is being given to the operating cost of capability and its impact on the life-cycle-costs of a system.

Operating Costs

The operating cost of a system represents the on-going running cost of the system over its life. Operating costs have been calculated to comprise 70 per cent of the life-cycle-cost of a system. Of this, maintenance, support and operating personnel tend to represent the greatest proportion. The determination of operating costs is subsequently being given greater emphasis in today's financially restrictive climate. Simplistically, operating costs are those items associated with the direct functioning of the system such as fuels and other consumables, operational and deeper level maintenance (whether contracted or in-house); also included are the indirect costs in supporting the system such as system support organisations, base support and training. A more comprehensive list of items normally accounted for in the determination of operating costs include:

- Management Costs;
- Engineering Support;
- Maintenance Support, Supply Support, Support Equipment & Maintenance Technical Data;
- Technical Data;
- Packaging, Handling, Shipping and Transportation;
- Manpower and Personnel;
- Training and Training Support;
- Facilities;
- Datalinks; and
- Software support.

The current RAAF methodology for calculating annual operating costs is provided at the end of this chapter.

Determining a true figure for operating costs is difficult. Current RAAF methodology concentrates on calculating direct costs, specifically made up of programmed expenditure from a number of identified program accounts. Indirect costs, such as base and weapon system support are not adequately calculated, particularly for attributing the costs of personnel employed in supporting the weapon system (outside of the actual operating squadrons). These indirect costs may be significantly reduced with satellite systems, particularly for those which employ a high percentage of non-uniformed staff to operate and maintain the system. That is, indirect costs associated with uniformed personnel such as removals, training and pension contributions, may be significantly reduced for some system types.

In developing a generic methodology for calculating operating costs, a proposal is that these be calculated in line with Defence Program costs. Currently the RAAF attributes costs to Support and Maintenance, and Operating costs. The difficulty with this current method is that squadron operating support and maintenance personnel are included as Logistics costs, where in fact they are funded by the operators - Air Command. The ILS methodology provides excellent guidance at the acquisition phase, but merely confuses calculations of ownership costs by accounting for items which fall under a different program cost in the operating environment. Therefore, a suggestion is that costs are drawn from currently identified programs, as illustrated in Figure 7.3.

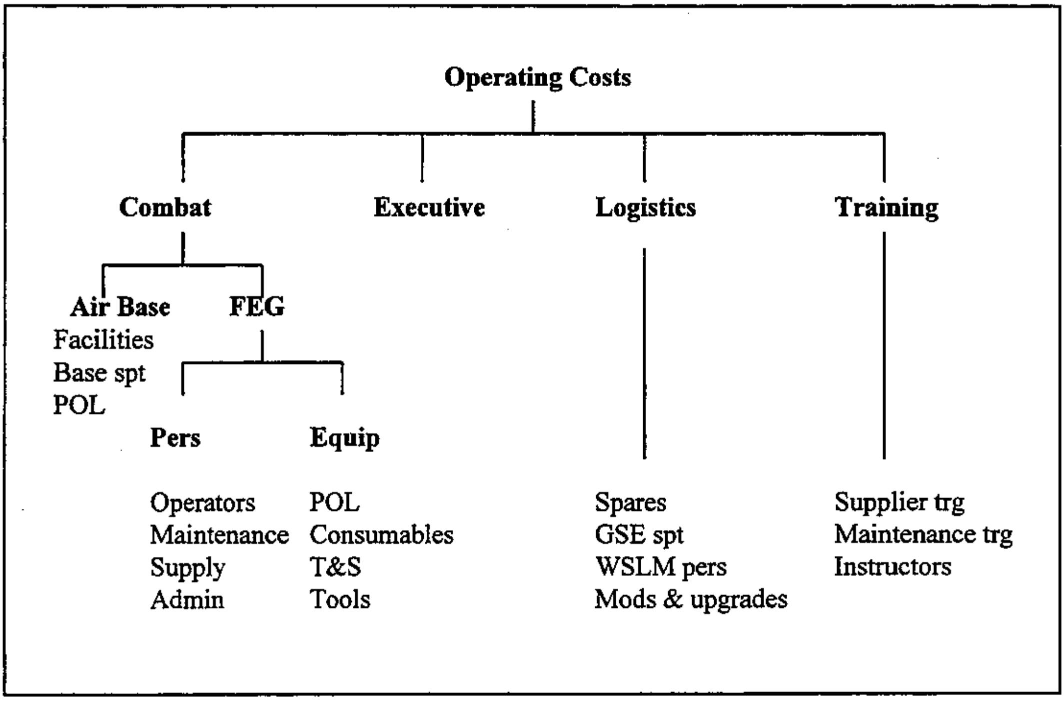


Figure 7.3 Key Elements of Operating Costs

Such an approach may also enable analysts to consider the proportion of support provided by air bases, and attribute a cost accordingly. This may see weapon systems which require fewer numbers of operating and maintenance personnel, having a direct affect on the quantity of base support required. The flow-on effect may be significant. For example, an estimate is that up to 50 per cent of the base services may be generated to support the base itself - not the capability. That is, a catering section may be providing 1,000 meals of which only 400 are provided for the operating squadron personnel. The other 600 represent other uniformed base support such as staff, cooks, clerks, medical staff and suppliers.

Research and Development Support

A feature of military systems is that on-going research and development (R&D) costs are required to increase system life or utility. Many defence departments have organic R&D organisations or contract out R&D to industry. Nevertheless, R&D for through-life support of a system is a common requirement for platforms with lives in excess of ten years. Consideration of R&D expenses for manned and unmanned systems is fundamental to the calculation of the relative costs of such systems in a comparative analysis.

Disposal

Disposal costs of a system are frequently neglected in cost calculations, despite the considerable effort involved in disposing of platforms, spares and support equipment at the end of a system's life. However, the cost incurred in the disposal of a system can often be offset through the sale of various parts of the system. With satellites, the disposal of the platform itself occurs without cost as it is destroyed upon re-entry into the earth's atmosphere. Ground stations and other systems, however, may need to be disposed of if they have been superseded by newer technology. Four general considerations should be examined in determining the disposal costs of a system:

- Disposal procedure costs,
- OH&S issues,
- Environmental impact, and
- Resale potential.

Platform Usage

Another cost, rarely considered due to the prevalence of manned aircraft, is that of platform usage. In a fleet of modern fighters, a percentage of the aircraft numbers will be dedicated for conversion and initial training requirements. Of the operational fleet, a significant proportion of hours must be utilised for currency training. For example, in FY1994/95, the F/A-18 expended 80 per cent of its flying hours on training, the F-111 expended 70 per cent, and the P3C expended 35 per cent. The cost of currency training is, however, already calculated into the life-cycle-cost equation and is generally reflected in the high annual operating costs (fuel, maintenance, etc). Platforms with a requirement for a significant level of currency training also experience shorter life-spans due to the rapid expenditure of their finite airframe hours. The costs are, therefore, already included in most determinations of life-cycle-costs provided forecasts of currency and operational flying requirements are reasonably accurate.

In considering the 'platform usage', general acceptance is that those hours expended on currency training will be utilised as operational hours during contingency. There may, however, be some value in subtracting the percentage of hours required for initial conversion training. This training factor should be included in similar calculations of on-line combat capability based on maintenance pipelines. For example, it is generally accepted that five aircraft are required to ensure three are continuously on-line (within 12 hour period) due to requirements such as rotation into deeper level maintenance.[5] Similarly, potentially for every ten operational aircrew, one aircraft needs to be dedicated for aircrew training.

Examination of the C-130 provides a more realistic picture of the actual training burden on manned aircraft, given that much of the so-called currency training is absorbed in real-time transportation support tasks. In other words, the ratio between training and operational hours should not change dramatically. Table 7.2 details the break-up of flying hours for FY 1994/95.

[5] Discussions with AEW&C ILS staff, Department of Defence, Canberra, June 1997.

Task	Flying Hours Achieved: - 17,614.9 hours	Percentage
National Tasks	644.1	3.7 %
Defence Support	1825.5	10.3 %
PMSA	4116.7	23.4 %
Navy Support	368.2	2.1 %
Army Support	1942.9	11.0 %
Scheduled Services	2837.8	16.1 %
Training	4577.2	26.0 %
RAAF Support	1302.5	7.4 %

Table 7.2 C-130 Flying Hours - FY 1994/95[6]

Generally speaking, the table demonstrates that approximately 26 per cent of the aircraft flying hours are utilised for training. In all scenarios other than those representing the most extreme threat to Australia, an assumption is that approximately one quarter of the fleet would remain dedicated to training aircrew. The remainder of the fleet could be made available for sustained peacekeeping or low-level contingency operations, if required.

The application of platform usage as a capability measurement is not applicable across the range of capabilities. It may, however, be useful in determining the quantity of aircraft (in conjunction with maintenance rotation considerations), required in a fleet to provide the prescribed capability level for sustained operations.

In the Australian context, satellites may be considered to provide only 50 per cent of their life to 'operational utility' given that they are outside Australia's area of strategic interest for a large part of their orbit, as well as being outside line-of-sight communication for extracting real-time data. Therefore, whilst a satellite does not allocate hours to training like air-breathing systems, only a percentage of its operation may be useful for the defined task it is undertaking. Other options exist to rectify this wastage, such as selling off part of the satellite's orbit time to countries interested in activities on the other side of the globe.

UAVs also offer the ability to reduce the expenditure of training and currency hours as a part of the total life of the platform. Through greater employment of simulation training (whether it employs virtual environment or current simulation techniques), UAV operators can undertake both initial and currency training without the employment of the UAV. In the US, this concept is considered to reduce the life-cycle-costs for the operation and maintenance of aircraft, whilst preserving finite airframe hours for operations in exercises, national interests and conflicts.[7]

[6] Department of Defence, *Defence Annual Report: 1994-1995*, Australian Government Publishing Service, Canberra, 1995, p 115.

[7] 'Pentagon to Test Lethal Air Strikes by Robot Planes', *Defense News: International Edition*, Vol 13, No 10, March 9 - 15, 1998, p 36.

Employment Concepts

The concepts for employment for any weapons system will contribute to the overall life-cycle-costs. USAF studies have examined the concept of reducing overall life-cycle-costs for UCAVs through limiting the actual aircraft flying time during peace by training operators on high fidelity simulation systems. This employment allows the aircraft remains stored in a hangar, thereby preserving airframe hours and increasing the aircraft life-of-type. For surveillance/reconnaissance platforms, the better utilisation of assets in the primary role will result in better value for money, given that the cost of sensor suites represents a significant proportion of the overall system cost.

Technical Risk

Another cost associated with platform deliberations is that of technical risk. For example, should planners acquire an immature system, certain costs may arise as a result of its immaturity. These costs can be both financial, operational or even political in nature. Two main factors should be considered under this heading: the cost of adopting immature technology and the cost of overlooking new technology.

Immature Technology Costs

The costs associated with acquiring a system representing immature technology are essentially two-fold. Immature systems may require significant on-going research and development (with its associated financial burden) to bring the system on-line to an operational level by rectifying shortfalls in performance. The other cost associated with acquiring new technology is the potential time lag before the system becomes operational such as occurred with the acquisition of the F-111 in 1968.[8] This has implications for producing a potential gap in delivering force capabilities for the defence of a nation, as well as delaying the development of aircrew for the role. The resultant gap in capability may be bridged only through reintroducing the superseded type back into service and improving its capabilities or by getting a temporary replacement. The latter concept was used by the RAAF when the F4E Phantom was obtained on loan from the USAF due to the delivery delay of the F-111. Normally, these actions would be achieved at excessive cost with the organisation being confronted with financing two systems concurrently.

As the cost of embracing new technology can be excessive, considerable thought should be given to the problems associated with high risk/high technology options. Australia has recently experienced the costs associated with the decision to pursue new technology. The arrival of the 'revolutionary' C-130J has slipped by up to twelve months as a result of 'a series of unanticipated problems.'[9] Another long-term cost could result from the absence of

[8] Owing to structural problems with its wing box mechanism, the F-111 was not delivered to Australia until 1973.

[9] 'Delivery of RAAF's first C-130Js is considerably delayed', in *Australian Defence Report*, Vol 8, No 13, 24 July 1997, p 1-2.

any US purchase of the system, resulting in further R&D costs and re-tooling costs financed by the RAAF and the RAF, the two main customers to date. Test and evaluation on lifed items can represent a significant cost where there is a limited requirement for those parts. The cost to the ADF in carrying this form of system support is demonstrated by the high costs borne by the RAAF as a result of it becoming the sole remaining F-111 operator in the world.

Overlooking New Technology

The decision not to embrace new technology can also represent a cost to military forces. By rejecting a new form of technology to contribute to a force capability, the opportunity to become familiar with such technology is generally delayed by a period equal to the life of the alternative system acquired. For example, should JP129 procure a manned aircraft, the ADF's opportunity to become familiar with UAV operations in the reconnaissance and surveillance roles may be effectively delayed for some 15-20 years.

The loss of opportunity to become familiar with UAV operations also represents a cost to the ADF in terms of providing it the expertise to develop counter-capabilities to UAV operations. Exposure to the operating methods of new technology is often required in order to develop concepts of operations to counter or minimise the influence of that technology on the outcome of the battle. The development of effective counter-technologies is also enhanced with sound knowledge of the technology and operating procedures of the leading-edge system. This could prove a significant 'opportunity cost' given the widespread introduction of UAVs within the Asia-Pacific region.

Attrition

The final cost which should be considered when comparing manned, unmanned and space-based systems is the cost of attrition. For satellites and UAVs, the value of the platform and loss of capability are key considerations. Arguably, the loss of a satellite would represent an enormous cost in terms of both platform value and capability; however, the likelihood of attrition must be calculated within the context of probability. Attrition is a function of:

- survivability features, and
- environmental threat.

While satellites employ limited survivability features, if any, the environmental threat to their effective functioning and survival is currently assessed as extremely limited. For manned and unmanned aircraft, however, the cost of attrition is becoming an issue of increasing concern to governments and military strategists alike. Consideration of this cost, therefore, is an important factor in overall determination of comparative costs and suitability. By placing a value on the aircraft and on-board operators, UAVs can be seen as providing a more cost-effective option in the role of Battle Damage Assessment, as illustrated, given the following assumptions:

- **RF-111** - Value of aircraft plus aircrew ~ $60 M; and
- **DarkStar** - Value of platform/sensors ~ $10 M.

Figure 7.4 shows the relative costs incurred given various attrition rates. Given an attrition rate of two per cent, the relative costs would be $1.2M for an RF-111 in comparison to $0.2M for a DarkStar. Whilst the model is simplistic and assumes equal chances of survivability, it is conceivable that the DarkStar and the RF-111 have similar survivability characteristics given DarkStar's stealth features, and the RF-111's speed, manoeuvrability and pilot situational awareness. Conceivably then, an air force could afford (in financial terms alone) the loss of six DarkStars to every one F-111.

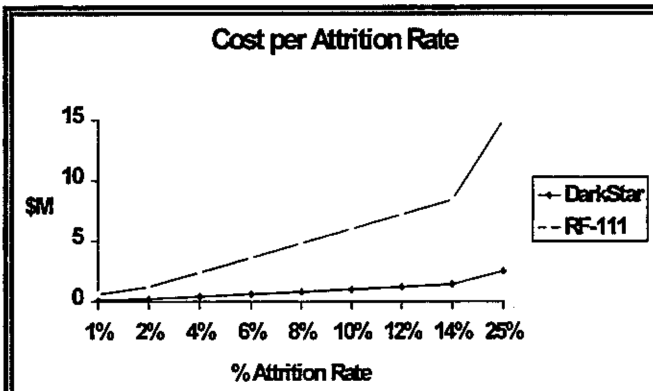


Figure 7.4 Comparative Cost based on Attrition

Cheaper UAVs could be used but when the probability of achieving mission success is also factored into the equation, they may look less attractive. This would be achieved in the initial stages of analysing performance parameters, or the capability of meeting the force capability required.

Another consideration is the trade-off between the costs of bandwidth and on-board processing. The current AEW&C emphasis for on-board processing means approximately seven sensor operators are required on-board the platform in addition to the two-to-three aircrew. The emphasis for on-board processing, therefore, represents a significant attrition cost both in terms of equipment and personnel. This in turn has led operators to demand survivability features for the aircraft, including speed, and defence aid suites. Furthermore, the high value of the platform in terms of cost and its role as a force multiplier, demands significant energies from the fighter squadrons for platform protection. The relationship between attrition and other costs should therefore be taken into account.

Summary

This chapter has provided a brief overview of the key components in calculating system costs. An analysis of satellites and UAVs requires the inclusion of a number of new considerations such as the costs associated with satellite launch and the requirement for ground control stations and datalinks for UAVs. Several potential savings may also be realised through the employment of these alternate systems, such as the savings in operating costs achieved through simulation training for UAV operators, and the ability to sell a portion of a satellite's orbit to achieve greater optimisation of its operating life. These costs and savings should be duly acknowledged in any future determination of the relative costs of competing platform types. The key criteria discussed in this chapter are summarised at Figure 7.5.

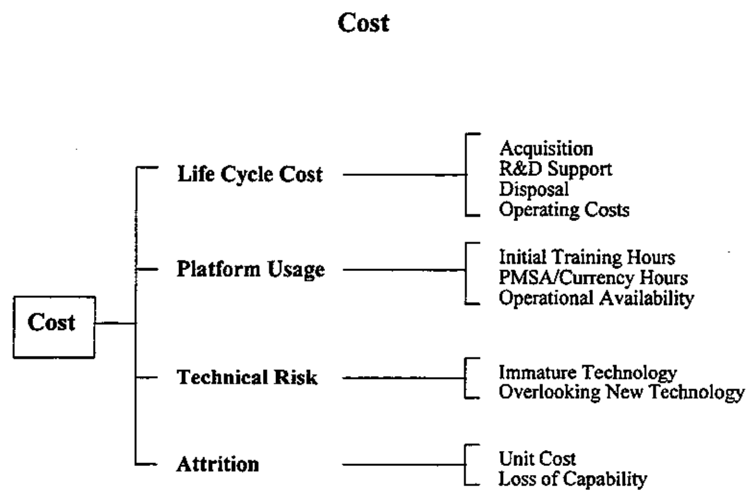


Figure 7.5 Key Criteria in the Evaluation of Cost

Chapter 8

Utility

> The current force development process is project-centred. It focuses on hardware options, rather than giving adequate consideration to the mix of capability in its broadest sense. Issues associated with military doctrine, preparedness, personnel, training, industry and supportability are inadequately addressed.[1]

In the Secretariat Papers of the Defence Efficiency Review (DER) of March 1997, analysts identified the deficiency in force development process as being too focussed on platforms, without sufficient consideration to the full complement of hardware in generating specific force capabilities. Some sections within the force development area had already identified this shortfall. For example, the wide area surveillance capability is being reviewed in a more holistic fashion to include space-based systems, as well as those single Service platforms employed for surveillance tasks.

After the recommendations of the DER are implemented through the Defence Review Program (DRP), greater emphasis on utilising platforms in a more holistic manner may result. The implications of this for platforms, like strategically capable UAVs, could see the employment of UAVs for maritime surveillance, Battle Damage Assessment (BDA), and for coast guard activities such as monitoring illegal fishing, drug trafficking and illegal immigration. The employability of such platforms in various scenarios across the spectrum of conflict is also worthy of consideration given the political ramifications of attrition in low level contingency and peacekeeping operations.

The utility of systems, whilst not directly associated with determination of the suitability or competitiveness of a system on operational or cost parameters, is an attribute which should be given some weighting. For nations with small defence forces, utility across a number of functions and scenarios can reduce the requirement for a greater number of systems and may improve their employment. This chapter introduces the potential benefits of considering utility in an overall analysis of the competitiveness of systems in providing force capability for the ADF. Specifically the following requirements will be examined:

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[1] 'Paper Seven: Capability Development', in *Future Directions for the Management of Australia's Defence: Addendum to the Report of the Defence Efficiency Review-Secretariat Papers*, Director Publishing and Visual Communications, Defence Centre, Canberra, 1997, p 142.

- Multi-Role/Multi-Mission
- Spectrum of Conflict/Employability
- Force Multiplier Effect
- Growth Potential

Multi-Role/Multi-Mission

Increasingly, defences forces seek platforms which offer a level of versatility, particularly where they would not be employed in their primary role 100 per cent of the time, or where they could meet another force capability requirement for little extra cost. The inherent flexibility associated with aircraft which are capable of multi-role operations, such as the F/A-18, is instrumental in providing an adaptable capability for a small air force. In the ADF, the F/A-18 is capable of independently performing a strike role whilst also being capable of performing a control of the air role.

Multi-mission capabilities are also afforded significant priority in small to medium defence forces, where one aircraft type can provide different force capabilities. The F-111 can provide maritime strike, CAIRS, tactical and strategic reconnaissance and ground strike capabilities. Not only does this reduce the requirement for several different operating systems, but also it provides a more effective utilisation of aircraft during different phases of the conflict. For example, an F-111 strategic strike may be required notionally only during a particular phase of a campaign; therefore, it can be used in CAIRS or maritime strike roles for the remaining time.

In determining versatility, consideration must be given also to the comparative cost of utilising two systems to conduct two primary roles as opposed to one system to conduct two roles. Generally, the savings will come in the form of personnel, logistics and training costs. However, if two unlike capabilities such as strategic strike and control of the air are considered, a single multi-role aircraft may in fact be more costly in terms of unit price as well as requiring an air-to-air refuelling capability for strategic strike purposes. Multi-role systems may therefore represent an equal or greater cost than that posed by the acquisition of two purpose-built offensive systems. Therefore, care should be taken in analysing the cost-effectiveness of so-called multi-role platforms.

With aircraft having multi-role capabilities, there is also a danger of hesitancy in their employment on missions considered as high risk, as their loss will impact on two force capabilities. In this scenario, cheaper platforms such as DarkStar at $10 million per copy provide an alternative for a high threat environment where lives are not placed at risk. The more expensive and capable multi-role aircraft is thus spared for more important tasks. The difficulties associated with the requirement for concurrent roles should not be overlooked when considering the multi-capability argument.

Versatility Across the Spectrum of Conflict

The emerging strategic environment demands that some account be given by forces to the utility of their force structure across the spectrum of conflict. For instance, analysts have forecast an increase in low intensity conflicts.[2] They emphasise that these may be economic rather than military in nature, or may occur between ethnic, cultural or economic groups.[3] There is also a belief that there will be a corresponding decrease in the incidence of conventional medium to high level conflicts between nation states. Analysts, such as Martin van Creveld, believe that these low intensity conflicts will continue to involve military forces in their role as protectors of the state.[4] The RAAF has also acknowledged the importance of these types of operations and has incorporated this concept into its doctrine. This doctrine incorporates a spectrum of conflict model (Figure 8.1) reflecting the variety of tasks the ADF expects to perform.[5]

Spectrum of Conflict

PEACE → OPERATIONS OTHER THAN WAR → WAR

Emergency relief
Aid to Authorities
Law enforcement
Hijacking
Terrorism
Sanctions
Coercive Diplomacy
Evacuation
Peacekeeping
Humanitarian Aid
Wider peacekeeping
Protection of alliance interests
Limited intervention
Peace enforcement
Local conflicts
Treaty Commitments
Regional wars
General wars
National survival

The Air Power Manual 3rd Edition

Figure 8.1 Spectrum of Conflict

[2] Analysts include M. van Creveld and J. Mohan Malik.
[3] J. Mohan Malik, 'Sources and Nature of Future Conflicts', in Malik, J. Mohan (Ed), *The Future Battlefield*, Deakin University Press, Geelong, 1997, pp 48-49.
[4] M. van Creveld, *The Transformation of War*, The Free Press, New York, 1991, p 224.
[5] *The Air Power Manual*, 3rd Edition, RAAF Air Power Studies Centre, Fairbairn, Canberra, 1998, p 15.

Additionally, *Australia's Strategic Policy* identifies three basic tasks which could require the ADF to undertake combat operations: defeating attacks on Australia, defending regional interests and supporting global interests. Combined with helping Australia's civil community, the ADF could be involved in operations across the full spectrum of conflict.

Given the prediction that armed forces may play a greater role across the spectrum of conflict, consideration of the relevance of current and projected force structures in adapting to the variety of tasks and scenarios which are likely to involve ADF participation by defence analysts is paramount. The utility of capabilities across the spectrum of conflict (or at least those likely to involve ADF participation) should be considered at every level of the capability definition and acquisition phase.

The consideration of utility often appears to be overlooked as a result of the earlier restrictive defence policy as defined in *Defending Australia 94*. The joint project for developing an airborne surveillance for land operations capability - Joint Project 129 (JP129) *Warrendi* – would have been constrained by the prediction that the most probable form of threat to mainland Australia could be from small-scale units targeting vital assets such as the RAAF Tindal air base. Under *Australia's Strategic Policy,* a multitude of missions can arise as part of the two additional tasks to 'Defeating Attacks on Australia'. As part of the 'Defending Australia's Regional Interests', the CDF has directed that Air Force must be able to deploy and maintain an Expeditionary Main Operating Base and two Forward Operating Bases, with Tindal providing additional DRI support. As an example, Australia may wish to use the airborne surveillance capability in monitoring peace operations on Bougainville. Should the airstrips there prove to be inaccessible or not politically viable, operations may have to be launched from Australia. Annexes A and B demonstrate the difference in operational effectiveness of manned aircraft and UAVs.[6]

Using simple calculations, the following information is extracted and displayed in Table 8.1.

Platform	Speed	Endurance	Swath	Revisit time over point	Comments
Global Hawk	300 kts	34 hrs	1670 sq nm/h	5.2 hrs	Can cover the area 5 times before returning
King Air 350	240 kts	7 hrs	1670 sq nm/h	N/A	Does not have endurance to fly Weipa-Bgvlle-Weipa

Table 8.1 Scenario 1: Surveillance mission of Bougainville

[6] Satellites have not been included in these examples owing to the complexity of calculations and subsequent variation of results incurred by different orbital altitudes and orbital inclination. The orbital characteristics will affect the calculation of swath width, time over target and revisit times over a single point (as a result of the 'apparent regression of nodes' characteristic).

In Scenario 2, Australia wishes to conduct surveillance for a counter-terrorist operation on an oil platform on the North-West shelf of Western Australia. The isolation of the oil platform means that the platform must transit significant distances before reaching the oil platform. Table 8.2 provides information summarising the calculations made in Annexes C and D.

Platform	Speed	Endurance	Surveillance over area	Comments
Global Hawk	300 kts	34 hrs	31.0 hrs	Provides significant time on task
King Air 350	240 kts	7 hrs	3.8 hrs	Provides limited time on task. Would require several systems.

Table 8.2 Scenario 2: Loiter surveillance over Oil Rig

Many other issues such as cost, availability of bandwidth, crew requirements and supportability will significantly influence the competitiveness and suitability of these particular options. While the calculations are simplistic, the scenarios demonstrate the potential utility of the different platforms across the spectrum of conflict. Where initial costings in JP129 have favoured the manned aircraft, the scenarios are limited to the surveillance of regions closely sited to useable airfields. Arguably, some account needs to be given to variances in capabilities and employability outside the past restrictions imposed by focussing too heavily on force structuring based solely on the defence of Australia.

The change in focus on combat tasks outside Australia also impacts significantly on the calculation of survivability of the platform. In some scenarios, enemy forces have limited SAM systems. In providing a surveillance capability over Cambodia during peacekeeping operations, for example, ADF assets may face significantly different anti-air defences.

Employability

The employability of a system will generally be dependent on two inter-related factors other than mission effectiveness: political and financial. For example, the decision on whether to employ cruise missiles will be weighed up against its political impact and financial cost in achieving a desired result.

'CNN Factor' - Minimisation of Casualties

Sensitivity to casualties is a maturing phenomenon in democratic nations as exemplified in the public reactions to the desecration of the bodies of US airmen in Somalia,[7] and in the efforts taken to rescue Captain O'Grady in Bosnia.[8] As a result, defence forces have afforded priority to develop measures to increase the survivability of platforms. As Anderson and Dibb point out, the priority to increase the survivability of platforms stems from a number of inter-related reasons:

> Defence forces must plan for equipment and doctrine to achieve very low levels of operational attrition of equipment and personnel. This is required because of:
>
> - the increasing cost and complexity of defence equipment;
> - the consequent reduction in unit numbers;
> - the increasing capability and responsibility of individual units; and
> - changing public attitudes to loss of life.[9]

Consequently, as a reaction to the 'changing public attitudes to loss of life', UAVs have gained in popularity. UAVs offer commanders the capability to conduct missions in high threat environments without risking the life of aircrew.

UAVs and satellite have gained greater prominence in recent times in their ability to perform certain high-risk missions without risking human life which can be exploited through media images, such as demonstrated in Mogadishu and Baghdad. Accordingly, the potential psychological damage, which can be inflicted through the media, has prompted military commanders and politicians to balance sensitive issues. This balance is between financial cost and the intangible psychological effect of destruction or friendly casualties on the support of the public for the action.

Cost of Attrition

The other issue with employability is the cost of attrition. The physical cost of the platform will largely factor into calculations of its employability, particularly in high risk scenarios. For example, the F-111C is unlikely to be employed in high risk, low strategic value roles such as CAIRS or BAI. This is due both to its actual cost and perceived strategic value, given it is one of a limited number of strategic strike aircraft. Therefore, whilst it offers the multi-mission capability, its employment in non-strategic roles is dubious given its value. The decision not to deploy Australian RF-111s to the 1991 Gulf War despite the acknowledgment

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[7] C. Powell, *A Soldier's Way*, Hutchinson, London, 1995, p 588.

[8] D.A. Fulghum, 'Unmanned Strike Next for Military', *Aviation Week & Space Technology*, 2 June 1997, p 47.

[9] K. Anderson & P. Dibb, *Strategic Guidelines for Enabling Research and Development to Support Australian Defence*, Canberra Papers on Strategy and Defence No 115, Strategic and Defence Studies Centre, Australian National University, Canberra, 1996, p 26.

that it would fill a capability gap in the coalition forces is most likely due to the implications of their possible loss to Australia's strategic reconnaissance capability. That is, the loss of a single RF-111 represents a 25 per cent decrease in capability.

Another critical factor in this equation is the cost associated with losing an operationally trained aircrew. The cost to replace such experience runs into the millions of dollars given the cost in actual training and cost in airframe hours to attain operational currency. Of equal importance is the value of human life lost, particularly given the psychological effect of the 'CNN factor'.

Impact on Alliances

Another political issue to be addressed, when considering weapons systems, is their likely impact on alliances. For example, the acquisition or development of nuclear or cruise missiles by one nation may have far-reaching ramifications across a region. The proposal to purchase a 'spy satellite' by Thailand, for example, led journalists to question whether this would promote a regional satellite race. The requirements to consider these issues when analysing technology or platform options is of some importance if a nation wishes to develop a capability without generating an arms race, thereby destabilising a region. In line with this type of reaction is the more immediate reaction of an enemy during conflict. The risk of employing certain forms of technology may be to prompt unintentional escalation of the conflict. The impact on employing certain systems on an enemy's intent should therefore be given due consideration.

Escalatory Effects

Generally, doctrine gives scant attention to effect of the employment of certain types of weapons on the enemy's intention. The use of theatre ballistic 'Scud' missiles by the Iraqis was employed to escalate the conflict by creating a forceful reaction by the Israelis and so destabilise the Coalition. Had the Iraqis used chemical or nuclear warheads, the effect may have been to escalate the conflict to a level where tactical nuclear weapons were employed against them. Extreme care should be exercised in determining which form of action is employed by a nation to demonstrate intent.

Most military and political leaders subscribe to the view that a conflict is best won through diplomatic and other non-military forms of manoeuvre. Use of military force should always represent the least desirable and less skilful method of winning political or other concessions. Should a nation rely on submarine or ground-launched cruise missiles for their strike capability, little action short of their actual employment will have an effect on the enemy. In scenarios where a nation wishes to employ a capability as a form of manoeuvre, cruise missiles are inappropriate and may escalate tensions to an undesirable level. By virtue of their ability to fly over targets, aircraft represent a more visible form of capability which can be used for political posturing. Several different weapons could be mounted to represent a graduated response to conflict. In this sense, this form of capability can be used as a visible show of force without employment of any offensive capability. By virtue of the offensive nature of cruise missiles and their expense, they are unlikely to be used to provide a 'warning shot' in a similar manner to that achievable by an aircraft. Similarly, submarines are inherently employed in covert operations and would have limited utility for an overt form of military manoeuvre.

Force Multiplier Effect

The value of a system in providing a force multiplier effect is also a factor worthy of consideration. The ability of a system to enhance the capabilities of other systems within a Service perhaps is given the greatest emphasis given the common focus in operating environment. The force multiplier effect may be provided at three levels: Intra-Service, Joint Operations, and Combined and Coalition Operations.

Intra-Service

While the predominant capability pursued is for early warning and coordination for F/A-18 operations, the AEW&C capability can act as a force multiplier for other weapons systems. For example, AEW&C can be employed to provide support for coordinating strike packages of F-111s and enhance JORN surveillance capabilities.

Joint Operations

Joint operations are gaining increasing priority as armed forces accept the concept that battles will rarely involve activities solely by one environmental force. To that end, systems offering a force multiplier effect to another Service increase the likelihood and scale of participation of all Services in conflict scenarios. Operations from another environment can also have disproportionate effects on the outcome of the battle. Examples of such contributions made by aerospace systems is the CAIRS roles played by fighter/strike aircraft in devastating an enemy ground force, and the potential for aircraft like AEW&C or JSTARS to assist land forces through communications and surveillance roles.

Combined and Coalition Operations

Owing to the growing interdependence of nations in the Asia-Pacific, few conflicts in the current climate are likely to be limited to two opposing nations. As coalition warfare becomes more likely, the type of contribution made by the smaller participants should be focussed on providing platforms and units which represent a specialist contribution, as well as a force multiplier to the coalition force as a whole. This can be achieved by technologically advanced nations through the utilisation of expertise in training or technology.

Commonality and Interoperability

In examining the potential for contribution within combined operations, issues of commonality and interoperability are critical. The potential commonality and interoperability of systems within the ADF is already reasonably well considered within capability acquisition phases. Examination of these factors for interoperability within coalition forces will require greater priority as the likelihood for such operations increases with the emerging strategic environment.

Growth Potential

The final issue in the consideration of the comparative utility of systems is their growth potential. The potential either to increase the life of systems through upgrades, or to increase the role of systems through fitted system modifications is a benefit being given greater consideration by military planners. The desire for growth potential is well demonstrated through the example of those who purchase computers with the potential for upgrade. This represents the ability to extend the life through buying additional memory boards, and may also extend the computer's function through employing software and hardware to enable faxing, video-conferencing and other functions.

Summary

In the emerging strategic environment, the utility of systems in being employable across a range of conflict scenarios is gaining increasing importance. Defence forces require force structures which can be effectively employed across the spectrum of conflict. This requires weapons systems that are inherently flexible in their employment and can be utilised in non-national security tasks, such as peacekeeping, with minimal cost and without fear of loss. The endurance capabilities of UAVs provides the platform with the flexibility to fly significant distances from secure bases, thereby minimising the threat to ground-based support personnel. This can represent a significant reduction in the cost of operation, particularly if the operation is supported from the Australian mainland. The removal of aircrew from the platform also makes the system more employable politically, where its loss represents a cost in purely monetary terms. The political and social cost associated with human casualties is removed from the equation.

In order to structure a defence force for operational relevance into the next millennium, the measurements of utility as summarised in Figure 8.2, should be incorporated into the analysis process for weapons systems selection. *Australia's Strategic Policy* now provides a range of tasks across the spectrum of conflict identified in Figure 8.1. This additional range, therefore, will require a structure where the utility of UAVs makes them an attractive option.

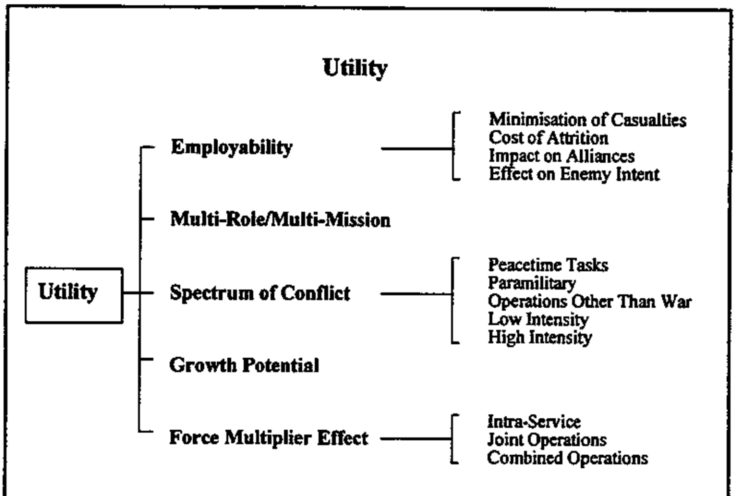

Figure 8.2 Key Elements of Utility

Chapter 9

A Methodology for Comparison

Undertaking a comparative analysis of three essentially different but operationally competitive systems represents a challenge of the highest order to defence planners. Not only does the development of the methodology within this study suggest that planners account for tangible differences in costing and operational parameters, but also it argues that account of less tangible factors are of equal importance. The methodology calls on planners to think at a more strategic level, accounting for political implications and the potential for systems to viably fill other force capability requirements. This will require defence planners to consider ADF capabilities in a more holistic manner than has been evident in the past, where individual Services have tended to pursue weapons systems without adequate regard to integration within an overarching architecture.[1]

Additionally, in order to properly assess the capacity for such systems to realistically perform a variety of roles at different levels of conflict, assessors require intimate knowledge of training and maintenance costs. For example, the contribution to peacetime surveillance by AEW&C, which formed part of its justification, should be quantified at the outset. Measurements in terms of flying hours or operational ratios provide a discernible demonstration of a system's utility. In contrast, a general statement that the AEW&C capability can provide a 'significant' supplement to the surveillance of the sea-air gap is difficult to substantiate. In-depth analysis of the hours required to train and maintain the currency of airborne controllers for air defence operations with the F/A-18 fleet suggests that few hours will be available for surveillance tasks.[2] Furthermore, the decision to base the majority of the AEW&C fleet at RAAF Base Williamtown on the East coast of Australia, limits the opportunity to conduct controller training and undertake real-time surveillance simultaneously.

The aim of this section is to identify the unique characteristics of space-based, manned and unmanned platforms which contribute to their operational effectiveness, cost-effectiveness and utility. The characteristics considered as limitations to operational effectiveness or identified as cost drivers have been discussed. In identifying these characteristics, however, the study has made a limited contribution to the development of a comparative analysis methodology. A number of other tools, such as software packages designed to calculate system survivability, costings and systems availability are also required to conduct a detailed

[1] This is being addressed by many planners as evidenced in examples such as the proposed surveillance architecture by No 41 Wing and studies including the Force Development Division's paper on Wide Area Surveillance.

[2] Interview with Sergeant W. McKinnon, author of *In the Dark: A Greater Role for Airmen in Air Defence*, Air Power Studies Centre, Canberra, 1998.

analysis of the relative operational effectiveness and cost-effectiveness of one system over another. This section has provided a foundation from which more detailed analysis utilising more complex tools can proceed.

This chapter aims to develop the relationships between the various criteria discussed in previous chapters in order to demonstrate how the overall competitiveness of these systems might be measured. Figure 9.1 represents a proposed architecture for determining the competitiveness of a system based on the key criteria identified in this section.

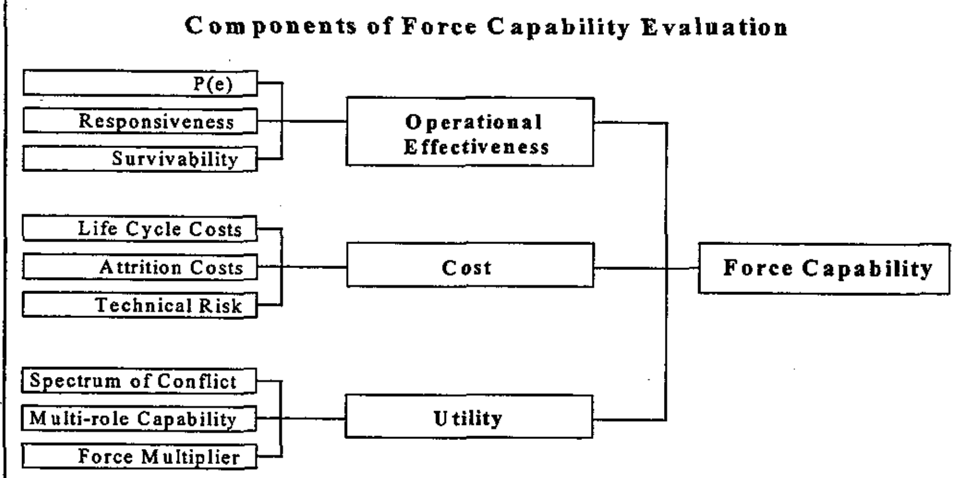

Figure 9.1 Model Structure for Evaluation of System Competitiveness

Evaluating the relative cost-effectiveness of systems, through life-cycle-costing and other economic variables, represents one of the simpler methods for performing a comparative analysis of similar systems. Much greater difficulty is encountered when analysts must compare systems against non-economic criteria such as performance parameters. Determining a comparative rating against more subjective criteria such as political viability, the value of reducing casualties and limiting collateral damage, represents an even greater challenge for analysts.

In their book *Life Cycle Cost and Economic Analysis*, Fabrycky and Blanchard propose a simple model to demonstrate how performance criteria might be analysed against cost in determining the relative competitiveness of three systems. Figure 9.2 demonstrates this concept using the key operational criteria developed in Chapter 7.[3] The life-cycle-cost of the

[3] Sourced from W.J. Fabrycky and B.S. Blanchard, *Life Cycle Cost and Economic Analysis*, Prentice Hall, New Jersey, 1991, p 113.

three competing systems are determined and plotted on the Y-axis, while their performance against the three key operational criteria are plotted separately on X-axis. In this example the values for Survivability, Responsiveness and P(E) represent a score drawn from calculations of the subsidiary elements.

In the example shown in Figure 9.2, one system meets all the minimum performance parameters at a significantly lower cost than its alternatives and is clearly the most competitive option. In reality, the evaluation of systems is often far more complex, where each alternative meets or exceeds the benchmark level against one criteria but falls short against another. Hence, evaluating the competitiveness of systems where each system exhibits both liabilities and benefits across differing performance parameters introduces another level of complexity into the analysis process.

The utility of this form of model as a comparative analysis tool is also limited if a large number of variables are introduced. This model does, however, enable analysts to physically demonstrate the positive factors of all systems, including those which do not meet all of the set benchmarks. Where few alternatives exist, it is often advisable to include those that fall short of the performance parameters, particularly if they offer the capability at a low cost. Further analysis or technical development of the 'inferior' option may succeed in addressing some of its shortfalls. Alternatively, further analysis may result in a reassessment of the benchmarks as being too ambitious, too expensive or not technically feasible.

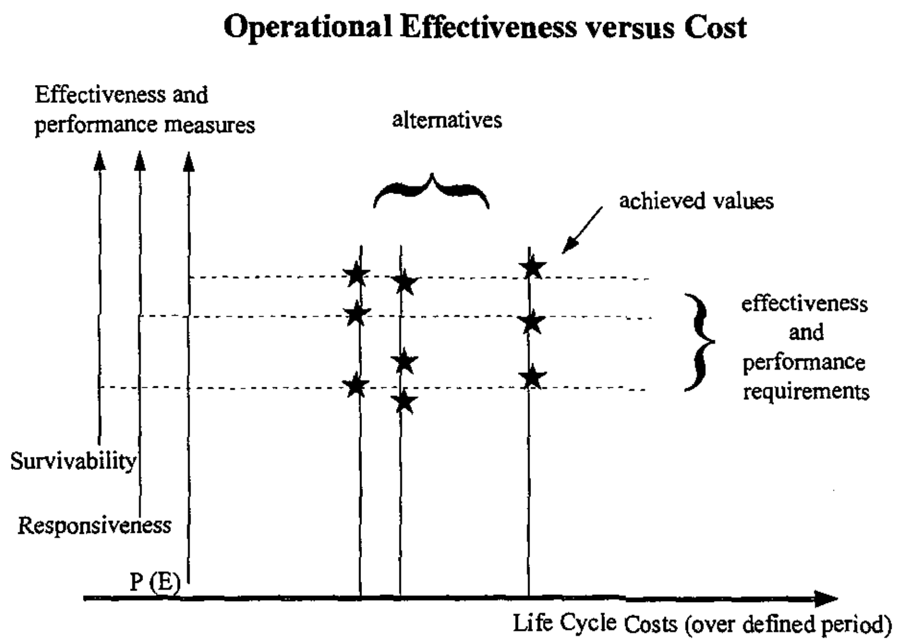

Figure 9.2 Decisions involving Multiple Criteria

While this model is good in providing a simplistic display of the level of capability provided at equivalent life-cycle-costs, where two or more options exist with similar life-cycle-costs and which meet the baseline performance parameters, further evaluation is required against performance priorities. That is, all costs being near-equal, assessment of each option will need to be conducted against individually weighted criteria. Determination of this weighting is based on the judgement of individual specialists and will therefore differ from person to person.

Owing to this dependency on individual judgement, no attempt has been made to place any kind of weighting values to the model. For every force capability and mission type, the weightings against the various criteria are likely to be different. The subjective views of analysts will further differentiate weightings, even for the same mission type.

Regardless, the use of weightings to perform the comparative analysis on competing systems is the only means of reducing the comparison into a mathematical algorithm. As an example, a major aircraft acquisition project used the following model (Figure 9.3[4]) with allocated weightings to compare non-economic parameters.

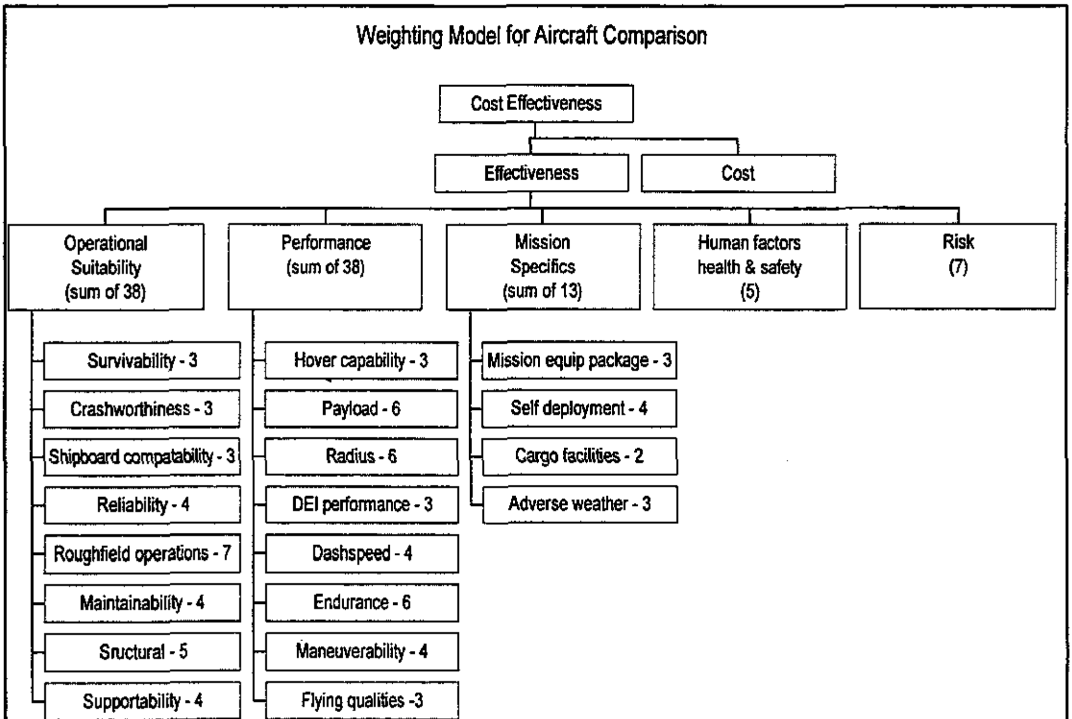

Figure 9.3 Weighted Decision Matrix

[4] Sourced from D. Biedenbender, F. Vryn and J. Eisaman, *The ILS Manager's LSA Toolkit: Availability Engineering*, McGraw-Hill Logistics Series, New York, 1993, p 309.

Using the criteria developed in the previous chapters, a weighted decision matrix can be developed. A model, similar to that illustrated in Figure 9.3, is displayed at Appendix A. The model includes the key elements for comparison as determined in the previous chapters. Weightings against each element will be determined on a project-by-project basis. Also, weightings will vary greatly with the evaluation of different capabilities, likely threat environments and likely employment. These decisions are critically dependent on the provision of clear strategic guidance based on detailed analysis of the prevailing strategic environment.

Following the general organisation of this section, the development of the model is achieved with headings for:

- *Operational Effectiveness*
- Cost
- Utility

The sum of the three major sub-headings is illustrated under the title 'Force Capability'. As with any generic model, a number of criteria specific to certain mission types may be omitted. The purpose of a general model is to provide a basic guideline for conducting a comparative analysis of two or three of the different options. Whether considering surveillance or strike roles, the general principles should remain the same. Weightings and additions of other less generic criteria (such as robust operations for unprepared airfields) will differ for each force capability consideration. This will be particularly true once the form of force capability has been decided. For example, after determining that a surveillance capability will be ground-based rather than space-based for reasons of flexibility in tasking, the criterion of robustness for field operations may be added to the comparative criteria in line with the guidance provided by assessments of the likely threat and employment environments.

Cost of Capability

In the past, the cost of capability has generally been measured in terms of the annual in-service costs to maintain a general level of capability. For example, the in-servicing cost for the Macchi capability was determined by the RAAF as $30 million per year.[5] The difficulty with the current method of determining the cost of capability is that 'capability' is not sufficiently defined. Capability tends to be viewed as something generated by a certain quantity of platforms, but it is rarely detailed in terms of operating hours or the percentage availability for certain tasks. For example, the cost of capability for the F-111 fleet can be determined, but there is no consideration of what percentage of platform hours might be 'available capability' after deducting those used for initial aircrew training and currency requirements. Additionally, where currency training is conducted simultaneously with an operational requirement, how is this attributed? Much of the expenditure of currency hours on manned aircraft can be optimised through a comprehensive examination of issues such as the

[5] *Squadron Leader Howard, Program Management and Budgeting Section, Directorate of Programs - Air Force, Air Force Headquarters, Canberra, July 1997.*

location of the operating base and mission planning. For example, an AEW&C aircraft based in the Northern Territory could simultaneously contribute to on-going peacetime surveillance tasks, whilst conducting aircrew and controller training.

Optimisation strategies for the expenditure of airframe hours need to become a standard workplace practice. This strategy has been adopted by the advocates of the UCAV who predict significant life-cycle-cost reductions through an operating concept involving hangaring the aircraft until it is needed for operations. Though lacking the glamour associated with a flying air force, the concept drives home the issue of the cost in airframe hours through the requirement for initial training and currency hours for a manned fleet.

Cost of capability considerations, therefore, should make some account of useable 'capability' in terms of airframe hours or other measure of capability (eg. number of surveillance hours/year for AEW&C or, number of students trained per year for Lead-In-Fighter). This emphasis is included in the costing model at Appendix A. Much of the other costing issues are already well developed in a number of other models used by other defence forces. Increasingly, however, the consideration of cost-effectiveness between expendable platforms such as cruise missiles and those designed for survivability, such as manned aircraft, will become an important inclusion in costing models. The further development of UAVs in the middle-ground of 'survivable but expendable vehicles' will foreseeably increase their popularity based on their potential cost-effectiveness.

Utility

Before concluding this section, the identification of utility factors should be incorporated formally into the force capability analysis process. All too often, well-meaning but politically naive defence staff forward proposals for improvements to force capabilities which are politically unacceptable or offer limited opportunity for employment. Given the size of the ADF, utility must be given greater attention in the force capability and project definition deliberation processes. This factor will be developed further in Section Three.

Employment of Methodology

Owing to the basic nature of the proposed model, its application in the current form is limited. With minimal development of simple algorithms, however, the model may be applied for developing a Major Capability Submission (MCS). At this level, the MCS defines a preferred solution based on options defined in capability terms. It is entirely appropriate at this level to analyse options in terms of general costs, capabilities, employability and political consequences.

Comparative analysis of unlike systems at the acquisition phase of projects will require use of complex life-cycle-cost (LCC) modelling, with some amendments to incorporate system peculiarities. This is the domain of those LCC specialists having a far greater understanding and experience with complex LCC models.

In summary, this section aimed to develop a generic comparative model which incorporated the main advantages and disadvantages of each system type. As the model is generic, it requires further development to incorporate the special characteristics and needs of different force capabilities.

Section Three

Options for Integration into the Australian Defence Force

Chapter 10

The Applicability of UAVs to ADF Tasks

The general strengths and potential cost-effectiveness of Uninhabited Aerial Vehicles (UAVs) detailed in the previous sections have made them the subject of considerable interest for defence forces worldwide. Over a dozen countries acknowledge operational UAV systems within their defence inventories while a number of others are developing, acquiring or, indeed, already possess them but have yet to publicly acknowledge their existence.

For the majority of nations, the inherent characteristics and attributes of UAVs will ensure their increased popularity, particularly in support of reconnaissance and surveillance tasks involving high risk or long endurance. But the degree of effectiveness and applicability of UAVs to defence forces is dependent on a nation's unique strategic circumstances. Nations with a propensity to operate in foreign theatres, like the US and the UK, are likely to consider the utility of UAVs because of their promise to minimise casualties and political repercussions in both peacekeeping and high-intensity conflict scenarios. This is seen as a driving factor behind the increased acquisition of UAVs by many Western democratic nations. The increased availability and development of long endurance reconnaissance and surveillance UAVs in the US similarly reflects an emphasis for platforms capable of achieving global information dominance through the exploitation of endurance and reach. For other nations such as Israel, the development of UAVs has also been customised to meet specific strategic circumstances. The requirement to perform continuous surveillance of the proximate borders with neighbouring states has seen a focus on the development of endurance UAVs with low daily operating costs. For example, the use of UAVs by Israel as survivable stand-off reconnaissance platforms for monitoring the activities of Hezbollah and other guerilla groups demonstrates the utility and applicability of tactical UAVs in that scenario.

The examples demonstrate the different emphasis on operational performance characteristics resulting from the unique strategic, political and geographic circumstances of a state. Thus the applicability of UAVs to US defence requirements is, for example, fundamentally different to that of the Israelis. This is further evidenced in a comparison of the development of UAVs in other countries. The US has focussed on the development of strategic, long range and long endurance UAVs such as the Global Hawk and the Tomahawk family of cruise missiles. Both these systems have strategic applications and have reach and endurance features to enable the US to employ them some distance from the theatre. Alternatively, the Israelis have concentrated on the tactical and operational level UAVs and shorter-range missiles, as is appropriate for their nation which shares several borders with countries having longstanding grievances with Israel.

These comparisons serve to demonstrate that the applicability and utility of defence systems are determined in the context of their operational environment. The question, then, is how applicable are UAVs to the Australian strategic scenario and what characteristics promote UAVs for Australia's particular circumstances? In which roles, if any, do UAVs offer operationally and financially competitive alternatives to other manned and space-based systems? Section Three explores the applicability of UAVs to the ADF through an examination of their competitiveness in a number of documented ADF roles.

Purpose and Scope of Section Three

The purpose of Section Three is to determine the applicability of UAVs to the ADF and examine potential roles where UAVs present operationally and cost-effective options.

In this section, the first chapter establishes a case for examining UAVs in the Australian context. The chapter develops a rationale for examining UAVs based on the current and future demands on the ADF. Indeed, an appreciation of the contemporary influences on ADF force structure is critical if the study is to retain relevance beyond current defence doctrine. While geography will remain constant, the changes to Australia's strategic outlook, the incorporation of new concepts of warfighting, and the ongoing development of Australia's defence policy will arguably have their effects on the future force structure and employment of the ADF. Acquaintance with the undercurrent of changes to defence thinking will demonstrate the increased potential of UAVs in supporting some of Australia's defence needs into the next century. Influencing those responsible for developing the ADF force structure to consider the applicability of UAVs in the emerging strategic environment is, therefore, considered essential to ensuring an ADF force structure with relevance into the new millennium.

Several interrelated forces are considered relevant in promoting a rational consideration of UAVs in supporting a number of ADF tasks. These forces include a desire to exploit the concepts encapsulated in the so-called Revolution in Military Affairs, the approaching retirement of a number of defence platforms, and the requirement on Defence to structure for operations across the spectrum of conflict, as part of *Australia's Strategic Policy.* The implications of these factors on the ADF force structure are that platforms will need to demonstrate greater utility in delivering information collection and precision engagement capabilities in an integrated manner. UAVs offer a number of attributes which promote them for consideration by defence forces who are developing their force structures for relevance into the next century.

Regardless of how the ADF employs its assets as a result of the changing strategic environment, the general capabilities outlined in *Australia's Strategic Policy* and *Defending Australia 94* (*DA94*) are likely to continue to form the basis for Australian defence. Examination of the potential of UAVs for the ADF will be in accordance with those tasks outlined in *DA94* as representative of capabilities likely to be reflected in later editions of Australian Defence White Papers.

Chapters 11 through 13 examine the suitability and competitiveness of UAVs in meeting Reconnaissance, Surveillance and Target Acquisition (RSTA) roles, other support roles including Electronic Warfare (EW) and communications, and offensive roles. Each chapter considers the comparative suitability of UAVs, manned aircraft and satellites (where applicable) in terms of operational performance, survivability and broad cost implications in the Australian context. The utility of each platform type is considered at the conclusion of each chapter.

Chapter 14 examines the general utility of UAVs across the spectrum of conflict and peace-time tasks. The potential application of UAVs across the Services, other Government agencies and across a number of peacetime and wartime tasks, suggests the need to analyse such platforms in a more holistic manner than has been undertaken in the past. Early consideration of the operating architecture of such systems enables defence forces to negotiate common operating procedures, ground stations and information architectures applicable to the Services and the civilian infrastructure.

Limitations

This section aims to highlight ADF tasks for which UAVs present viable options, with a discussion of general attributes that make these platforms potentially competitive. A detailed analysis of systems has not been undertaken, given the sensitivities in obtaining detailed performance requirements, the variety of options of manned, unmanned and satellite platforms, the array of platform/sensor combinations, and the difficulties associated with accessing sensitive commercial data. Furthermore, a comparison of systems across the number of roles examined in this section, even based on rough estimates, is beyond the scope of this paper. Such in-depth analysis is the domain of those involved in Force Development, Project Definition and Acquisition phases, where sufficient staffing, and access to sensitive capability parameters and commercial data can produce more accurate assessments of the comparative competitiveness of systems.

The ultimate aim of this section, therefore, is to highlight the potential utility of UAVs in supporting documented ADF tasks. Exposure to some of the concepts developed in the section may also serve to modify defence thinking so that a holistic approach to considering the utility of all ADF platforms becomes an automatic activity in the force development process.

Contemporary Influences on Force Structure Determination

In structuring the ADF for relevance in the emerging security environment, defence planners need to consider the likely sources of threats to Australia's security. From this, they must identify the nature of credible conflict scenarios likely to involve ADF participation. Finally, defence planners are charged with managing 'the fundamental changes taking place in technology and warfare'.[1] In simple terms, advanced technology and the concepts of warfighting employed to exploit such technology are significant factors in determining the future force structure of the ADF.

Chapter 10 examines these issues and their influence on force structure determination. The characteristics of UAVs will be critically examined in light of these contemporary influences on ADF force structure.

Concepts of National Security

Australia's concept of national security has undergone an evolutionary change, in recognition of the increased range of potential threats to its national interests. While few would argue that economic and environmental issues, such as illegal fishing, immigration, piracy and drug trafficking, are of such a magnitude as to constitute a threat to Australia's national survival, they are gaining greater political prominence. In the region, these issues have a much greater significance, particularly where nations are dependent on fisheries as a critical food source for their burgeoning populations, and the importation of gas and oils for their sustained economic growth. While these issues are afforded less priority in Australia's assessment of national security, they are becoming more important within the region.

A developing theme in Australian national security deliberations is the perception that Australia's economic and political wellbeing may be jeopardised by conflict or instability within the greater region. The main threats to Australian interests are likely to be activities in another part of the region which disrupt or imperil Australian economic or political interests. In an era of economic interdependence, a threat to one nation's prosperity could equally affect the prosperity of each of its major trading partners. Similarly, tensions or conflict which affect the safe passage of cargo vessels through important sea lanes could dramatically affect trade and, hence, the prosperity of nations within the region. Other nations with trading or passage interests in the region could also suffer from regional instability.

The recognition that regional stability and security is inherently linked to Australian national security has resulted in a greater emphasis and a corresponding allocation of resources for promoting regional stability. In addition, environmental and economic based threats to Australia are gaining increased attention, and will require greater energies as regional access to natural resources diminishes through over-exploitation.

The changing concept of national security is likely to have a reciprocal influence on determining the ADF's force structure. While the physical defence of Australia will always be the primary task of the ADF, other national security tasks may increase in priority, with the corresponding implications for ADF involvement. Consequently, the changing priorities within Australian national security deliberations may have implications for the ADF's force structure. For example, Paul Dibb suggests that consideration be given to 'regional add-ons'

[1] Hon. I. M. McLachlan, 'Defence Challenges in New Era Security', in A. Stephens (Ed.), *New Era Security*, Air Power Studies Centre, Canberra, 1996, p 3.

for contributing better to regional security.[2] Calls for greater participation in protecting the sea-air gap from illegal fishing, refugee flows and other intrusions, similarly indicate the increased likelihood of utilising defence resources in a holistic approach to the range of national security tasks.[3] The ADF, therefore, may be required to incorporate greater adaptability within its force structure to contribute more fully to national security tasks over and above Defence of Australia tasks.

Sources of Conflict

J. Mohan Malik and Paul Dibb, amongst others, have identified a palette of potential threats to security in the post-Cold War era. Changes to the political and military balance since the end of the Cold War have seen the rise of ethnic and religious tensions and a corresponding rise in ethno-nationalism. Arguably, the potential for conflict arising from these unchecked religious and ethnic tensions, is greater within the new strategic environment. Cambodia, Sri Lanka and Bougainville provide reminders that the end of the Cold War has not resulted in an era of enduring peace, particularly in the Asia-Pacific region. While they are examples of localised conflict, they have the potential to threaten the security interests of other nations. The empathy of India's Tamil population for their brethren in Sri Lanka, for example, has the potential to disrupt India's delicate unity of disparate ethnic groups.[4]

In the Asia-Pacific region, the drive to sustain dramatic economic growth has resulted in a renewed focus by nations on access to natural resources. This has seen the re-emergence of tension over resources such as fisheries, gas and oil. Preservation of these resources, particularly in the maritime environment, make environmental and economic issues additional potential sources of tension in the region.

In the current strategic environment, likely sources of conflict may include disputes over resources, ethno-nationalism, ecological disasters and terrorism.[5] What are the implications of these threats for Australian national security priorities? What resources should be allocated to address these security priorities and what role does the ADF have in meeting these security activities?

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[2] P. Dibb, 'International Security and Australia', in A. Stephens (Ed.), *New Era Security,* Air Power Studies Centre, Canberra, p 38.
[3] Air Marshal S.D. Evans, quoted in C. Miranda 'Our defences are down: Drugs, illegal immigrants hop through northern gaps', in *The Daily Telegraph,* 28 April 1997, p 17.
[4] J. Mohan Malik, 'India in South Asia: Relations with Sri Lanka, Nepal and Bangladesh', in J. Mohan Malik (Ed.), *Asian Defence Policies: Regional Conflict and Security Issues*, Book Two, Deakin University, Geelong, 1994, p 242.
[5] J. Mohan Malik, 'Sources and Nature of Future Conflicts in the Asia-Pacific Region', in J. Mohan Malik (Ed) *The Future Battlefield,* Deakin University Press, Geelong, 1997, p 50.

The Changing Nature of Conflict

The emergence of 'a rich new agenda of potential threats' has corresponding implications for the nature of conflict encountered in the region. [6] As the protection of natural resources gains greater importance in concepts of national security, armed forces will play a greater role in related activities. Similarly, as religious and ethnic tensions are seen to threaten the cohesiveness and unity of a nation, armed forces may increasingly be employed on internal security operations. This is already evident in a number of nations within the region including Indonesia, Papua New Guinea and Cambodia. The prediction, however, is that employment of armed forces across the spectrum of conflict will increase for a number of nations. Projections of a reduced incidence of 'conventional wars', a corresponding growth in 'Low Intensity Conflict' and conflict between non-state organisations will require forces that are capable of reacting across many levels of conflict.[7] Anti-terrorism, peacekeeping and peace enforcement activities are likely to demand greater attention by countries such as Australia, particularly where these activities are perceived as critical to regional stability. In developing an ability to operate effectively across the spectrum of conflict, force structures and concepts of operations will need to encompass a greater adaptability.

The Revolution in Military Affairs

Given the changing nature of conflict and the inter-relationships among the national security issues, new, flexible methodologies for applying military force are required. Therefore, development of the ADF force structure will be influenced by the warfighting concepts adopted and capabilities perceived as providing the means for the ADF to operate effectively using these concepts.

The concepts of warfighting espoused in the Revolution in Military Affairs (RMA) arguably enable the application of force across the spectrum of conflict, ranging from terrorism, peace enforcement operations and low intensity conflict to the high intensity conflict of the scale observed in the Gulf War. In essence, the RMA is about the exploitation of technology to reapply the principles of war in an age where the battlefield can extend the length of continents, and the centres of gravity are more likely to be the centres of government with vulnerable lines of command and communications to fielded forces. Manoeuvre warfare and the application of air power across great distances has made it more difficult for commanders to retrieve an accurate and timely picture of the battlespace, as was possible for commanders such as Napoleon who took the high ground to direct the unfolding battle below. After analysing the relative strengths of his forces and weaknesses of his enemy's, Napoleon was also able to communicate his intentions quickly and, in many cases, directly to his commanders. The RMA, therefore, is about retrieving the 'virtual high ground' to provide commanders with timely, relevant and accurate information in order to engage the enemy precisely. Application of these concepts of warfighting also enables the minimisation of casualties and collateral damage and, as such, has increased public expectations that conflicts

[6] Dibb, 'International Security and Australia', p 33.
[7] Martin van Creveld, *The Transformation of War*, The Free Press, New York, 1991, p 20.

can, and should, be conducted with minimal loss to life, and damage to infrastructure and equipment. The cost of war or conflict, therefore, is also an issue, particularly for small nations. Cost, in terms of casualties and equipment attrition, is especially an issue where the conflict is viewed as not directly affecting national interests, such as with peace enforcement operations.

To exploit RMA concepts, there is a need for platforms which provide the commander with target information gathered through surveillance and platforms which enable a commander to engage those targets swiftly and precisely with a minimal loss of life and collateral damage.[8]

Gaining an 'information dominance' relative to one's adversary at the tactical, operational and strategic level is recognised as one of the central tenets of the RMA. The United States armed forces have placed high priorities on acquiring systems that will enable them to dominate the battlefield through the exploitation of information and its denial to an adversary.[9] The development of platforms and sensors indicates the widespread acceptance that continuous surveillance of the battlespace will enable defence forces to reduce the duration of their decision cycles - the Observation-Orientation-Decision-Action (OODA) loop.[10] This reduction can be achieved through the traditional Reconnaissance, Surveillance and Target Acquisition (RSTA) missions. Follow-through support can be provided through Battle Damage Assessment (BDA) which will determine whether a target has been neutralised. Signals Intelligence (SIGINT) and Communications Intelligence (COMINT) payloads are equally important in adding to the collection of intelligence in the battlespace.

Contemporary Influences in Force Structure Determination

The primary role of the ADF is to ensure it 'can prevent or defeat the use of armed force against [Australia]'.[11] It achieves this through the pursuit of national policies which support defence efforts, the establishment and maintenance of relationships with regional and allied nations, and the contribution to global security arrangements.[12] This focus, however, is slowly changing, as planners take stock of the changes in the new security environment. In structuring the ADF for relevance in this environment, the changing nature of conflict, broadening concepts of national security and emerging warfighting concepts need to be considered.

[8] Wing Commander K. Given, 'A Revolution in Military Affairs- The Stuff of Fables?', in *Australian Defence Force Journal*, No 116, January/February 1996, p 7.
[9] J.A. Tirpak, 'Future Engagement', in *Air Force Magazine*, January 1997, p 23.
[10] Colonel B.W. Carmichael et al, *Strikestar 2025*, A Research Paper Presented to Air Force 2025, USAF, August 1996, p 15.
[11] *Defending Australia: Defence White Paper 1994*, Australian Government Publishing Service, Canberra, 1994, p 3.
[12] *Ibid.*, p 3.

The following are the implications of these contemporary influences on the ADF:

- In response to the evolving concept of Australian national security, the ADF may be tasked with more non-defence security activities. These are likely to include augmenting Coastwatch activities to deter illegal fishing, immigration and drug trafficking, and greater regional engagement.

- In response to the changing sources and nature of threats, the ADF is likely to be employed in tasks across the spectrum of conflict, particularly in Operations Other Than War.

- The method of warfighting, encapsulated in the RMA, will enable forces to precisely engage the enemy with minimal casualties and collateral damage. The economy of effort and precise concentration of power made possible through the RMA are applicable at all levels of war. The ADF, therefore, should incorporate the RMA concepts as part of its warfighting concepts with adaptability across the spectrum of conflict.

What does this mean for the force structure of the ADF? Malik suggests that armed forces will need to exploit time, space, information, stealth, reach and precision in a manner that enables interoperability with coalition partners.[13] He amplifies this concept, stating, 'the doctrine of flexible response for multiple missions based on high-technology weapons and a diversified, yet integrated, force structure will be the key principle of defence policies of major powers'.[14]

Characteristics for Adaptable Force Structures

The requirement for the ADF, then, is for platforms which demonstrate flexibility and adaptability in employment, and which exploit the key concepts designed to provide superiority to the commander on the battlefield. Platforms which allow such exploitation generally represent leading edge technology. Such exploitation has been an ongoing component of Australia's defence posture over the past twenty years. During this period Australia has acquired a range of platforms representing leading edge technology that provide both a 'technological edge'[15] over any potential adversaries, as well as using leading edge technology to overcome the disadvantages of defending a continent, characterised by vast unpopulated areas. This concept is reiterated in *Defending Australia 1994* which states:

> The second key element in developing our defence posture is the exploitation of technology. The development of modern defence technology offers important new opportunities for our defence.[16]

[13] Malik, 'Sources and Nature of Future Conflicts', p 81.
[14] *Ibid.*, p 81.
[15] *Defending Australia 1994*, p 27.
[16] *Ibid.*, p 26

Although not directly addressed in *Defending Australia 1994*, there are other issues which impact on the types of platforms considered as appropriate for the defence of Australia. The emphasis on value for money, or cost-effectiveness, is foremost in the minds of those who control the ADF's budget, and such considerations will discount some of the leading edge technologies employed by the United States. Other issues, such as the drive to minimise casualties, were witnessed in the Coalition's conduct of the Gulf War. Wherever the military failed to adequately protect the lives of its Servicemen, for example, dramatic impacts resulted.

An examination is appropriate of the applicability of UAVs, as an example of an emerging technology having the potential to address some of the issues highlighted. In determining the applicability of UAVs to the ADF, they should be examined not only in terms of meeting the operational performance requirements but also in terms of meeting political requirements, such as cost-effectiveness and political utility.

Chapter 11

Reconnaissance, Surveillance and Target Acquisition

Comparison of Platforms for RSTA Roles

Introduction

Two fundamental attributes - the minimisation of casualties and extensive endurance - have seen Uninhabited Aerial Vehicles (UAVs) secure an increased role in performing tactical reconnaissance and surveillance tasks. Their first effective employment in these roles in Vietnam was spurred by the need to address the unacceptably high attrition rates of manned reconnaissance aircraft. Since then, exploitation of UAVs in the Israeli conflicts, the Gulf War and, more recently, Bosnian peacekeeping operations, has justifiably highlighted the utility of these vehicles in Reconnaissance, Surveillance and Target Acquisition (RSTA) roles.

Recognising the utility of UAVs in the RSTA roles has led to the widespread development of UAV RSTA platforms for a growing global market. The UAV customer base is predominantly armies, but is quickly extending to include marines, navies and law enforcement agencies as the attributes of these systems become more widely publicised. With many systems to chose from and an increasing number of operators upon which to draw their experiences in operational environments, consideration of UAVs for RSTA roles is likely to be dominant in the near future. In line with this global trend, Australia is also considering the utility of UAVs in supporting RSTA capabilities in its Joint Project 129 (JP129) - Project *Warrendi*. The Scout UAV Trial revealed, however, that Australia's geographic and strategic environment is unique and the employment of UAVs requires tailoring for Australian use. [1] Therefore, the ADF cannot draw entirely on the experiences of other nations to assess what type of UAV will satisfy Australian requirements.

The purpose of this chapter is to examine those areas where UAVs could be considered as competitive options in delivering surveillance, reconnaissance and target acquisition capabilities in an Australian context. Their specific strengths and limitations in meeting ADF tasks are discussed against those of manned and space-based systems.

[1] *Defence Trial 8/603 - Unmanned Aerial Vehicle Trial*, (DST 92 21640 of 10 Dec 93), Defence Science and Technology Organisation, Department of Defence, July-August 1993.

The Environment

The Australian environment offers a number of challenges to the effective operation of UAVs including the climate and the limited infrastructure across the north of the country. During the dry season, strong winds and the constant presence of dust can have a bearing on UAV operations, whilst the wet season brings with it monsoonal winds and rains which can seriously impede light aircraft operations. More notably, the wet season often removes the use of large parts of the countryside, including its roads and airstrips, due to flooding.

The vast expanse of the continent and the length of coastline provide a daunting defence task, exacerbated by the sparse population of the region and its limited civil infrastructure. While UAV operations have proved extremely successful in the Middle-East and Bosnia, their applicability to Australian conditions must be considered in the context of this operational environment.

The use of tactical UAVs in central Europe and the Middle-East is optimised for operations in those regions given the proximity of national borders to defence positions and an emphasis by these nations for on-going border patrols. Australia has no such land borders with other nations. In addition, the use of UAVs in desert warfare and for traditional European land battles does not translate to a combat scenario on Australian soil. A land battle across the north of Australia could be fought over a much greater area than that of a battle in the Middle-East. The concepts of operation will also have a significant impact on the applicability and employment of UAVs. For example, the Israeli Defence Force has determined that an Army brigade is likely to operate organic tactical UAVs with an endurance of only 4-5 hours, out to a distance of approximately 50 kilometres. In comparison, an Australian Army brigade may be required to cover an area of responsibility of over 300 kilometres. This fundamental difference in operating procedures between the two armies would likely result in the consideration of two entirely different systems for what could be defined as the same basic task.

The Australian emphasis on vital asset protection and small patrols designed to locate and repel incursions on Australian soil represents a vastly different concept of operations than those employed by armies facing conventional land battles or conducting border patrols in landlocked nations. These differences must be considered when analysing the success of UAVs in other conflicts and their applicability to the Australian scenario.

Tasks

The requirement for reconnaissance, surveillance and target acquisition capabilities is evident across a number of ADF tasks, as defined in *Defending Australia 1994*.[2] The Defence White Paper outlines the following core roles which, by their nature, require a level of surveillance, reconnaissance or target acquisition support[3]:

[2] *Defending Australia: Defence White Paper 1994*, Australian Government Publishing Service, Canberra, 1994.
[3] *Ibid.*, p 30.

- intelligence collection and evaluation;
- surveillance of maritime areas and northern Australia;
- maritime patrol and response;
- protection of shipping and offshore territories and resources;
- air defence in maritime areas and northern approaches;
- defeat of incursions on Australian territory;
- protection of important civil and defence assets, including infrastructure, and population centres; and
- strategic strike.

Indeed, all but one ADF role (command, control and communications), have a requirement for some form of reconnaissance, surveillance or target acquisition support. The importance of this form of support cannot be overemphasised, particularly in the modern battlefield where accurate and timely information is critical to effective and efficient military operations. This assessment is supported by the highest priority being given to the 'Knowledge Edge' as part of the ADF's force structure priorities outlined in *Australia's Strategic Policy*.[4]

To simplify the determination of the potential of UAVs to provide RSTA support to Defence of Australia tasks, the RSTA missions will be examined as generic capabilities including maritime, air and land surveillance, reconnaissance and target acquisition. The general suitability of satellites, UAVs and manned aircraft will be examined in each of these missions to demonstrate the attributes as well as the inherent limitations of each system in delivering the capability. It should be stated from the outset that the capability to deliver reconnaissance, surveillance and target acquisition capabilities is predominantly determined by the sensors employed. Manned aircraft, UAVs and satellites are merely platforms and should always be considered as such. Therefore, with the exception of the in-built sensors and computing/analysing capacity of the on-board human operator (aircrew), each platform type is theoretically capable of housing the same sensor capabilities. The differences in performance capabilities exist as a function of the physical characteristics of the platforms including payload capacity, power generation capability, endurance and orbital constraints. All of these characteristics, including orbital movement, can be altered through developments in technology. [5] Whilst some of the platforms are not currently suited to particular roles, theoretically, further development of sensors and platforms could make them competitive in the future.

[4] *Australia's Strategic Policy,* Department of Defence, Directorate of Publishing and Visual Communications, Canberra, 1997, pp 56-57.

[5] For example, development in sensor technology may enable Geostationary satellites to conduct surveillance tasks with resolution comparable to that of LEO satellites. Alternatively, development in fuel technology may enable efficient thrust capabilities for LEO satellites to generate a 'loiter-like' capability for short periods of time.

Surveillance

Three basic forms of surveillance are generally acknowledged: land, sea and air. Each of these environments is dealt with individually due to the variation in sensors required to address the unique environmental features and target characteristics.

Sea Surveillance

Sea surveillance is conducted to detect and monitor the movement of surface and sub-surface vessels off the coast of Australia. A number of different types of vessels may be found including naval surface and sub-surface vessels, merchant ships and ocean-going fishing vessels, as well as less sophisticated wooden-hulled boats.[6]

Several different forms of sensor can be used to detect and monitor surface and sub-surface vessels, including Electro-Optical (EO) sensors to achieve a visual picture of surface vessels, Infra-Red (IR) to detect surface and sub-surface vessels through their heat signature against the relatively stable temperature of the ocean, and radar sensors to detect vessels through motion and surface reflectivity. Synthetic Aperture Radar (SAR) is also widely employed to provide a photo-like picture of the surface, generated through the use of radar. The advantage of SAR is its ability to generate this photo-like image through adverse weather and visibility conditions, enabling all-weather, day/night operations.

Without exception, however, each sensor type has its limitations. For example, IR and radar are not optimised for detecting small wooden vessels, whilst EO sensors cannot operate in overcast conditions or at night. SAR cannot detect fast moving targets. The type of target, requirement for day/night and all-weather operations and the environmental background will largely determine the type of sensor or sensors optimised for the defined task.

Generally, vessels operating on the ocean surface are relatively easy to detect due to their slow speeds. Optical sensors are optimised for the detection of wooden-hulled boats as their low reflectivity makes detection by radar problematic. Sub-surface vessels are best detected through infra-red and sonar equipment: nuclear submarines can be traced through I/R detection of their wake, whilst diesel submarines are best tracked through a combination of under-water and airborne sonar transmitters and receivers.

Most sensor types can be employed effectively in delivering a measure of sea surveillance. The difficulty for most nations, particularly Australia, is in providing sufficient coverage of the ocean surface. For Australia, sensor coverage is a critical consideration in determining the effectiveness of sea surveillance capabilities. Platforms with high altitude operations such as satellites are optimised for the detection of vessels in large expanses of water. Also, the relatively slow speeds associated with sea travel require a relatively low revisit rate sufficient

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[6] Squadron Leader W. Gale, *The Potential of Satellites for Wide Area Surveillance of Australia*, Air Power Studies Centre, Canberra, 1992, p 2-6.

to conduct comprehensive surveillance. In the Australian context, a satellite with a revisit rate of several hours (up to 11 hours), for example, would represent an acceptable sea surveillance capability in terms of coverage.[7]

Satellites for Sea Surveillance

Satellites are capable of employing most of the sensors optimised for the detection and tracking of surface vessels. The detection of nuclear submarines is also achievable and, indeed, currently undertaken by US satellites. The main restrictions to satellite surveillance of maritime activities is associated with the inability to physically drop sonobuoys for the detection of conventionally powered submarines.

Comparatively, the most obvious advantage of satellites over UAVs and manned aircraft is their endurance. Satellites can provide a near-continuous surveillance capability over large areas of the Earth's surface for the duration of their five to seven year life. A constellation of satellites could, therefore, provide on-going surveillance during periods of peace and conflict. Given the correct orbital inclination, a satellite can cover Australia's sea-air approaches, with the potential to provide surveillance information much further afield. Costs are dependent on the sensor types employed, orbital altitudes and the quantity of satellites launched. And while costs are generally considered to be relatively high compared to atmospheric platforms, satellites are highly survivable, providing a continuous surveillance capability with stable operating costs. Satellites reach their life-of-type in accordance with a fairly predictable orbital decay,[8] regardless of their degree of 'employment' during peace and periods of conflict. Unlike atmospheric systems, therefore, preservation of 'platform hours' to extend life-of-type does not become an issue with their employment. The only variable factor with their operating cost might be associated with changes to the numbers of ground-based analysts during periods of increased tension, a feature that would also be equally applicable to both manned and unmanned aircraft.

Manned Aircraft for Sea Surveillance

Manned aircraft have several advantages over satellites in performing sea surveillance tasks. A particular advantage is the ability to carry a greater number of sensor systems and operate them simultaneously. This is largely achievable due to the lower operating altitudes with smaller sensor and power requirements. Manned aircraft can also have significant payload and power capacities, and can operate power-intensive Doppler-based radars. The larger payload capacities of most manned aircraft optimises them for the range of sea surveillance roles, including locating and tracking submarine movements through the employment of sonobuoys and other systems. Manned aircraft employed on maritime tasks are usually capable of remaining on station for a significant number of hours, retaining a flexibility of tasking which provides the capability to closely monitor, track and identify targets. Manned aircraft also project a 'presence' thereby creating a deterrence effect that is not achievable

[7] *Ibid.*, p 2-8. Gale states that after detection, a revisit time of 11 hours is sufficient for ships transiting the sea gap between Australia and the island chain to the north.
[8] *Ibid.*, p 4-7.

with satellite coverage. Their obvious and significant limitation compared to satellites is their reduced coverage due to their lower operating altitude and endurance. Maritime aircraft also attract significant operating costs given their generally large crewing requirements. Additionally, some maritime surveillance missions are both tiring and boring for their crews.

UAVs for Sea Surveillance

The employment of UAVs for maritime surveillance has been limited to date. While their ability to operate EO and SAR sensors enables their employment in detecting most types of surface vessels, their limited payload and power capacity mean they are not optimised for the detection and tracking of sub-surface vessels. Additionally, their operating altitudes result in smaller fields of view than those realised by satellites. In their favour, UAVs have the ability to exert a visible presence where required and are, therefore, a more effective deterrence platform than satellites. UAVs can make significant contributions to the surveillance of surface vessels in the maritime environment. Like manned aircraft, however, UAVs have limited fields of view and limited endurances relative to ground and space-based systems. The employment of UAVs in the maritime environment is optimised where they are utilised as systems which are responsive to other surveillance systems, such as the Jindalee Operational Radar Network (JORN) and satellites, which act as 'trip-wires' for activity in the sea-air gap.

Comparison of Platforms for Sea Surveillance

Each of the three platform types discussed provide useful maritime surveillance capabilities though they all possess some limitations. In the Australian scenario, a satellite surveillance capability would provide national security agencies with a near-continuous picture of the surface activity in the sea-air gap, both during peace and periods of increased tension. The inability to remain on station to further interrogate platforms leaves a gap which must be filled by another platform type. In providing surveillance for sub-surface capabilities, satellites can be used for detection of nuclear powered submarines which exhibit a detectable heat signature. They are not optimised for the detection of diesel-powered submarines which are more prevalent in Australia's strategic environment.

UAVs represent a medium ground between manned aircraft and satellites. They are optimised in one respect, given the 'dull' nature of sea surveillance activities and their capability for greater endurance than manned aircraft. Like manned aircraft, they provide flexibility in tasking and can project a 'presence' to intruders. Their limited payload capacity relative to manned aircraft limits the range of surveillance tasks they can undertake, particularly for those associated with the detection and tracking of submarines.

Owing to their relatively large size, manned platforms offer significantly more utility in conducting maritime surveillance but are limited by their endurance, reach and coverage in comparison to satellite surveillance. Manned aircraft currently represent the most flexible of the three platforms and are likely to dominate ADF maritime surveillance operations in the medium term. UAVs and satellites can both be used to support maritime surveillance operations but their capacity to operate the range of sensors will continue to be limited by limitations in payload and power capabilities in the medium term.

Air Surveillance

Surveillance of the air environment is conducted with the purpose of detecting and monitoring aircraft activity in Australian airspace. The ADF's principal means for monitoring the air gap is through the JORN network, assisted by other ground-based microwave radars such as air defence and civil air traffic control radars. With the extension of the JORN network, coverage of the sea-air gap will correspondingly increase. The JORN network has several on-going limitations which are being partially addressed through the acquisition of an Airborne Early Warning and Control aircraft (AEW&C) capability. Among the more significant limitations of the JORN capability are an inability to accurately locate or identify the target, variations in the period of coverage due to ionospheric conditions, and an inability to interrogate and monitor the incursion. The JORN, therefore, is viewed as a trip-wire capability which must be supplemented by other platforms to provide more accurate identification and interrogation capabilities.

Satellites for Air Surveillance

Satellites represent the least suitable platform type for surveillance of the air approaches to Australian airspace. Owing to the relatively high speeds of aircraft and the continuous orbital motion of LEO satellites, it is impossible for one satellite to continuously monitor an incoming aircraft with EO/IR sensors. The only solution to the employment of this form of sensor is in fielding a comprehensive satellite constellation so another satellite can pick up the aircraft's flight some minutes after the previous satellite has detected its presence.[9] A large constellation would be required even though one LEO satellite at an altitude of 200 km orbits the earth once every 90 minutes. The unique characteristics of a satellite in orbit means it deviates from the previous orbit by a number of degrees.[10] Known as the Apparent Regression of Nodes, it may take a satellite a number of orbits before achieving replication of the original field of view (Figure 11.1 shows the result of the apparent regression of nodes on three satellite passes).[11] Therefore, a number of satellites, known as a constellation, may be provided to increase the revisit rate to any particular point on the earth's surface. For example, estimates are that a constellation of between six to twelve satellites would be required for surveillance with a 90 minute revisit time, depending on the selection of orbital inclination and altitude.[12] This equates to a system which could cost in the order of US $1-2 billion. A fundamental consideration in the cost equation is that this cost figure represents only a five to seven year capability, based on the normal expected life of LEO satellites.[13]

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[9] D.A. Fulghum, 'Flying Slots Disappear, Shift to Ground and Space', in *Aviation Week & Space Technology*, 15 September 1997, p 73.
[10] Gale, *The Potential of Satellites*, p 4-8.
[11] *Ibid.*, p 4-10.
[12] Robert Hughes, Defence Sscience and Technology Organisation Scientist, Directorate of Force Development - Aerospace, Department of Defence, Canberra, August 1997.
[13] Gale, *The Potential of Satellites*, p 6-6.

Therefore, there are two significant constraints to a satellite constellation: an exorbitant cost and the effort required to correlate the images taken by two successive satellites.

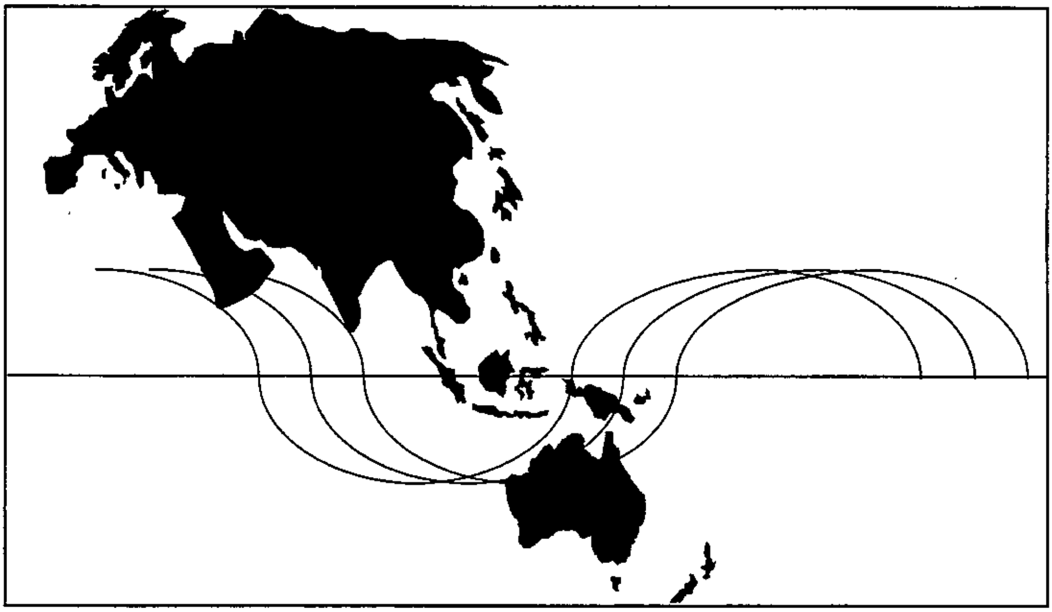

Figure 11.1 Apparent Regression of Nodes

A second sensor type, which is more suitable for the detection of fast moving targets, is the Doppler or active radar sensor, such as the Real Aperture Radar (RAR) system. Satellite mounted RAR systems, however, are costly because they have significant power requirements, dictating the need to mounted on large satellites at high altitudes. Additionally, there still exists 'significant engineering challenges' before satellite-mounted radars of this nature are fielded for military purposes. [14] Therefore, the use of satellites for conducting surveillance of the air approaches to Australia is currently untenable due to cost and technology constraints.

Manned Aircraft for Air Surveillance

The Australian AEW&C program represents the most practical and possibly the most affordable option for fulfilling the gap in Australia's air surveillance requirements. All three contenders for the AEW&C aircraft platform have significant payload capacities and are capable of generating sufficient power to operate powerful Doppler radar systems capable of detecting and identifying aircraft at over 200 nautical miles. Much of the perceived endurance limitation of manned aircraft is overcome through the radar's significant reach. Owing also to

[14] *Ibid.*, p 5-20.

the significant payload capacity of the manned platform, several other sensors may be introduced as required. The aircraft, therefore, offers a flexible and adaptable platform with significant capabilities and reach in locating and identifying aircraft activity in Australia's air approaches.

A critical vulnerability of the manned platform is its high intrinsic value in terms of platform cost and the potentially disproportionate repercussions of its loss. For example, the loss of one AEW&C will have an effect on other capabilities due to its force multiplier effect. Additionally, the loss of the aircraft represents the concurrent loss of large numbers of highly trained crew members, as well as the expensive sensor stations housed on board each platform. As manned platforms of this nature are recognised as high value targets, survivability becomes a key consideration. This attracts costs in terms of self-protection measures and external protection by fighter escorts which may have to be diverted from other tasks. How manned platforms are employed in high threat environments is also likely to be affected by considerations of the impact of their potential loss. Therefore, whilst manned systems are the only systems available for this role, they are expensive and potentially vulnerable. One recent alternative is the Swedish system which limits its on-board crew to pilots, with the AEW data being relayed to ground stations.

UAVs for Air Surveillance

The payload and power generation capacity of current generation UAVs is insufficient to operate radars optimised for detecting fast moving aerial targets in a large field of view. A UAV could, however, be used to identify and follow slow moving aircraft. Given its limited field of view, effective use of UAVs in this role would require tasking through another trip-wire capability such as JORN. Figure 11.2 illustrates an example of a UAV relaying information, on a threat alerted by JORN, to an AEW&C aircraft controlling attack aircraft.

The current sensor payloads for UAVs also are not suitable for the air surveillance role. EO/IR sensors are constrained by environmental conditions such as rain and cloud cover, whilst SAR sensors are not yet capable of accurately identifying fast moving targets. Whilst limited information is available for considering the employment of Doppler type radars on UAVs, their payload and power capacities will continue to restrict them as an option to manned aircraft until either radars are miniaturised or UAVs are developed to accommodate these large, powerful sensor systems.

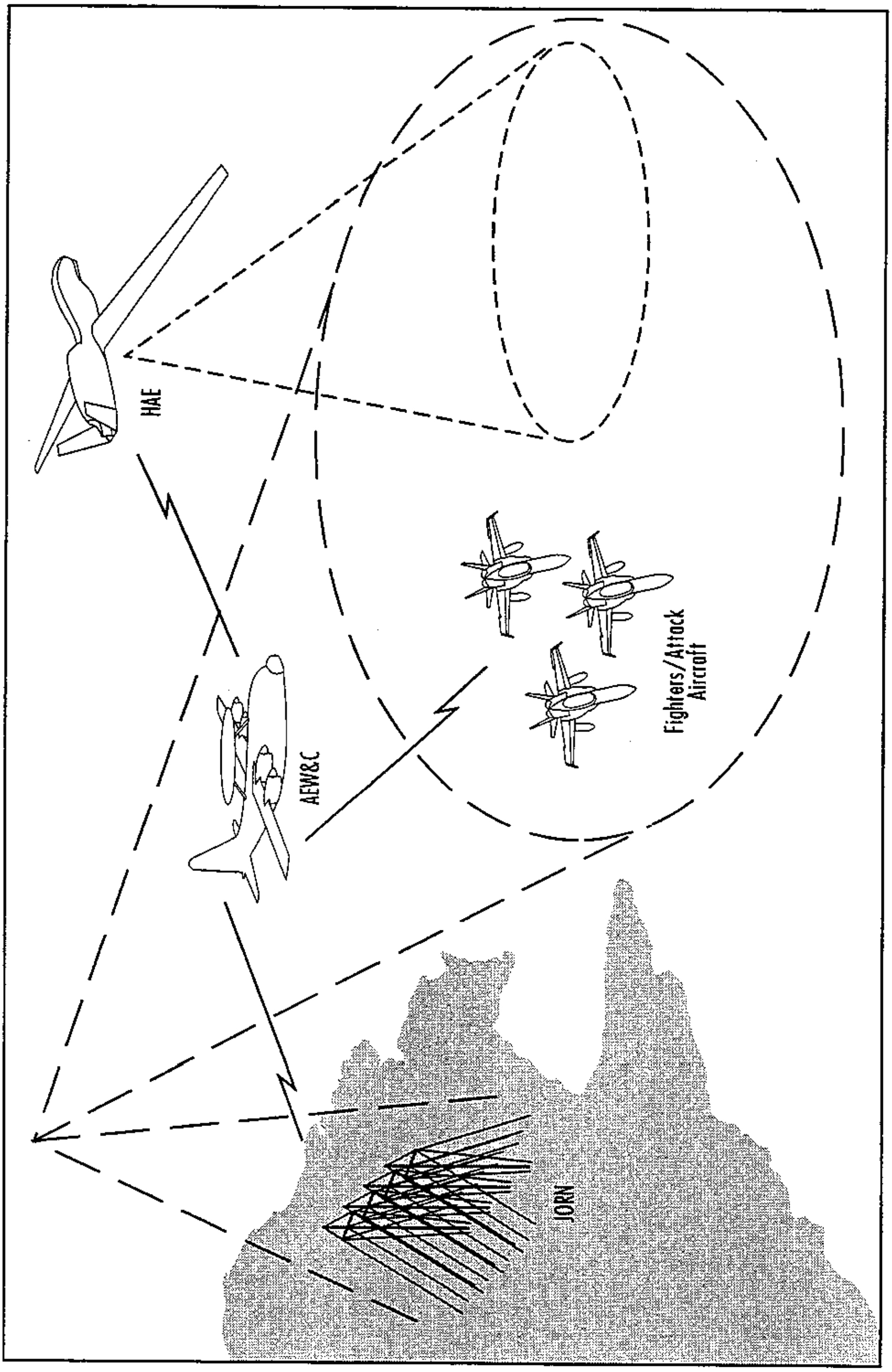

Figure 11.2: UAV Working in Conjunction with JORN and AEW&C Aircraft.

Comparison of Platforms for Air Surveillance

Given the current sensor limitations of UAVs and satellites, manned aircraft represent the most suitable platform for comprehensive air surveillance coverage in conjunction with the trip-wire capability provided by JORN. The limitation to the employment of manned aircraft in environments of medium to high threat are that they are potentially vulnerable and their loss would prove costly in terms of capability and political repercussions. Therefore, while manned systems offer an operationally superior platform, they require a high level of protection, drawing on scarce financial and other resources, such as fighter aircraft for escorts.

Land Surveillance

Satellites for Land Surveillance

By their very nature, satellites offer a unique capability in performing surveillance over land masses. Their orbital characteristics, including altitude, make them capable of unrestricted global access, enabling nations to conduct surveillance of other countries without the restrictions imposed through airspace regulations or the political difficulties associated with unauthorised passage through national airspace. A combination of EO/IR and SAR sensors provides satellites with all-weather, day/night capabilities optimised for land surveillance. Additionally, the orbital altitudes of most reconnaissance/surveillance LEO satellites optimise the resolution/footprint equation. Large surveillance footprints are currently achievable with resolutions of less than one metre. The trade-off for global access is the limited time over target due to the orbital characteristics of satellites. Fast revisit times or loiter capabilities require a constellation with its high costs, inflexible tasking and inability to project a visual presence. Additionally, nations can employ passive defence counter-measures against the easily predicted orbital patterns of satellites.

Manned Aircraft for Land Surveillance

Manned aircraft generally represent reasonably flexible platforms due to their payload and power capacity. Large manned platforms such as the Joint Surveillance, Targeting and Attack Radar System (JSTARS) represent the current pinnacle of manned surveillance and reconnaissance platforms, providing command and control support, target acquisition and coordination support to ground forces. This capability, however, represents an increase in magnitude of cost over standard reconnaissance and surveillance platforms such as rotary-wing and smaller fixed-wing aircraft. As with other forms of surveillance, the task itself is tedious and not particularly popular with aircrew. In comparison, reconnaissance missions offer significantly more interest and involve more specialised forms of flying, particularly low level helicopter operations. The other limitation of manned aircraft for surveillance missions is their relatively low endurance. Compared to UAVs performing similar roles, for example, manned aircraft are limited to about 12 to 14 hours due to aircrew fatigue factors. Rotary wing aircraft are reduced to even lower endurance levels due to their high fuel expenditure. Paradoxically, the greatest limitation of manned aircraft is also currently its strongest attribute. That is, whilst manned aircraft are limited in endurance through the operator requirements, the operator provides the aircraft with the ultimate backup system for redundancy requirements. Operators can provide on-board processing to determine the worth of potential targets, thereby reducing the reliance on vulnerable datalinks, but only where they are required to use visual collection at an altitude suitable to the human eye. The reliance on beyond visual range datalinks can also be reduced where aircrew provide on-board analysis. This positive attribute is only realised where near-real time visual data is not required on the ground. As with all manned aircraft, survivability is also a key issue, particularly where the platform accommodates a number of operators and analysts. The potential loss of a JSTARS-type platform, with 6-8 operators as well as on-board processing equipment, will generally limit its employment to medium to low threat environments.

UAVs for Land Surveillance

Given the miniaturisation of SAR, EO and IR sensors over the past decade, UAVs are capable of undertaking a large range of surveillance tasks within their limited payload capacity. Modern UAV systems, therefore, are potentially comparable with their manned counterparts in conducting most land surveillance tasks. In comparing relatively small unsophisticated fixed-wing aircraft with comparable UAVs, the cost of a UAV system can be contentious. For scenarios where there is no requirement for real-time imagery by personnel on the ground, general aviation aircraft and surveillance helicopters generally represent cheaper systems than UAVs. The cost difference between UAVs and manned aircraft in this scenario is in the requirement for ground and mission control stations for UAVs with all its associated personnel. In comparison, the crew of a manned aircraft can sometimes process the data. However, UAVs offer comparatively greater endurance with potential implications for lower maintenance costs (associated with less take-off and landings) and fewer platforms required to undertake an on-going surveillance mission. In missions where real-time imagery is required, the cost difference between manned and unmanned aircraft decreases.

Comparison of Platforms for Land Surveillance

As evidenced by the widespread acquisition of UAVs by armies, the utility of UAVs for land surveillance has marked them as extremely competitive platforms. This is particularly the case where armies are required to conduct 24 hour surveillance operations in medium to high threat environments. The applicability of these systems to the Australian scenario is slightly different in that the specification for operations beyond line-of-sight requires the use of a communications relay platform for positive UAV control and real-time data transmission. Under the ADF's current parameters, the employment of UAVs will require either the purchase of commercial satellite bandwidth at significant cost or further exploration of the concept of using a second UAV or other airborne platforms for communications relay. Stationary or mobile ground-based relay stations may also satisfy ADF requirements.

Reconnaissance and Target Acquisition

Tactical Reconnaissance

By far the most widely acknowledged role for UAVs is that of tactical reconnaissance conducted in medium-to-high risk threat environments where the timing of information is critical. More than 30 defence forces have acquired UAVs to perform tactical roles in support of land operations. [15] Tactical reconnaissance UAVs are also employed by navies in similar reconnaissance and target acquisition roles.

Satellites for Tactical Reconnaissance

While satellites can provide high resolution tactical reconnaissance data, their inflexibility of tasking represents one of their greatest limitations. Owing to the criticality of the timeliness of information, a large constellation would be required to achieve sufficient coverage. Additionally, satellites cannot be tasked at brigade level for purposes of directing their fields of view.[16] Terrain masking can also occur due to the high altitudes, rendering some areas impossible to view. The final difficulty associated with satellites is the predicability of their orbital paths so that well planned enemy operations will include passive defence against detection when a satellite is overhead.

Manned Aircraft for Tactical Reconnaissance

The primary advantage of manned aircraft for tactical reconnaissance is in the operator's ability and capacity to detect, identify and interrogate potential targets. Ultimately this significantly reduces the reliance on datalinks. Again, however, the operator also represents the most significant weakness of the platform. The requirement to accommodate aircrew results in aircraft of a size that is relatively easier to detect and destroy, especially at low altitudes.

UAVs for Tactical Reconnaissance

UAVs have justifiably earned their accolades in the reconnaissance and target acquisition roles. The size of tactical UAVs is normally dictated by their payload and endurance (fuel) requirements. Usually they are significantly smaller and cheaper than their manned counterparts.

[15] *Shephard's Unmanned Vehicles Handbook 1996*, The Shephard Press, England, 1996.

[16] Given their large field of view, satellites are inherently strategic assets, though their product is becoming available to tactical units in accordance with the principles of the RMA.

The Pointer UAV, as operated by the US Marine Corps, represents one of the smallest operational military UAVs with a wingspan of only 9 feet, an endurance of two hours, and a payload capable of accommodating TV or IR sensors.[17] Whilst only employed at battalion/company level, the UAV provides an 'over the hill' reconnaissance capability, critical to battlefield tactics at that level. In small scale manoeuvres, this capability could prove decisive. For example, the possession of a Pointer capability by one of the entity armies in Bosnia-Hercegovina could have totally reversed the advantages of reverse slope defence tactics which were so widely employed by all sides.[18]

The relatively low cost, low altitude (little risk of fracticide), low detection (due to size) and ability to operate with organic line of sight data links, therefore, has made tactical UAVs a competitive and attractive option for providing organic tactical reconnaissance support. Furthermore, the inclusion of GPS and rangefinders extend the roles of UAVs to one of target acquisition. The Pioneer UAV was used by the US Marine Corps and US Navy to provide target acquisition support to artillery and naval gunfire support respectively during the Gulf War. One anecdote from the war recounted how a US Navy Pioneer UAV had followed the path of an Iraqi delivery van. The van was determined to have been making deliveries to concealed Iraqi military installations, by virtue of the military guards who emerged from the buildings and unloaded their supplies. Once the delivery van had moved on to its next delivery point, a US warship, some 40 kilometres from shore, fired at the installation using targeting data relayed from the UAV to accurately position its guns.

In the Australian context, however, tactical UAVs may be constrained by weather, particularly when operating in northern Australia during the wet season. The aircraft are lightweight and may be subject to buffeting by winds associated with tropical storms. This may impose difficulties in data collection where sensors are not stabilised for significant buffeting. Additionally, for the focal area reconnaissance role, UAVs may not offer the same capability of flight at low level over dense vegetation. In contrast, the manned operator in Kiowa helicopters has a broader field of view and is able to undertake such tasks with little risk, though is also subject to the effect of bad weather. The maturation of foliage-penetration radars will overcome some of the current limitations of UAVs. The trade-off between high resolution sensors and the visual accuracy of observers who are subject to fatigue, also indicates that UAVs have a role in this form of reconnaissance, particularly for operations at night or in overcast conditions. However, the major difficulty with these systems in the Australian context is their cost-effectiveness in the low-threat defence of Australia scenario. The extra cost associated with the mission and ground control stations for the larger UAVs, including the datalink requirements, might appear uncompetitive where the reconnaissance requirement can be satisfied by aircrew operators relying on eyesight to identify the locations of targets and voice communications to relay the information.

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[17] 'Outlook/Specifications, UAVs and Drones', *Aviation Week and Space Technology*, 8 January 1996, pp 88-89.

[18] Observations by Captain S. Yeaman, Operation *Lodestar*, SFOR, Bosnia, March-September 1997.

Comparison of Platforms for Tactical Reconnaissance

Manned aircraft and UAVs are ideal for tactical reconnaissance and target acquisition roles due to their inherent flexibility of tasking. The criticality of information timeliness in tactical reconnaissance renders satellites inappropriate due to their fixed orbital characteristics. The trade-off between manned aircraft and UAVs in tactical reconnaissance roles is dependent on a number of factors including the threat assessment, terrain type, range and endurance requirements, climate, requirement for day/night operations and requirements for real-time optical data on the ground. Each of these factors will influence the relative competitiveness of manned aircraft and UAVs in terms of operational performance, cost-effectiveness and employability (in terms of sensitivity to casualties). Given the varying requirements of armies based on the nature of conflict likely to be encountered, both UAVs and manned aircraft will continue to provide the most competitive platforms for tactical reconnaissance tasks.

Strategic Reconnaissance

Strategic reconnaissance could be defined as the capability to undertake reconnaissance against strategic targets. Given the direction of modern warfighting concepts, this implies that the information must be accurate and delivered to commanders in a timely manner. In an Australian scenario, strategic reconnaissance also can imply a need for long range. In modern warfare, three general characteristics are required for strategic reconnaissance: range, timeliness and accuracy of information.

Satellites for Strategic Reconnaissance

In terms of survivability and access over areas of strategic interest, satellites represent the optimum platform for strategic reconnaissance. The incorporation of SAR sensors now provides an all-weather capability but terrain masking will remain a problem. Satellite reconnaissance can also be easily countered through the employment of passive defence measures, achievable due to the predicability of their flight paths.

Manned Aircraft for Strategic Reconnaissance

The success of the US U-2s, TR-1s and SR-71s in the strategic reconnaissance role demonstrates the applicability of manned aircraft to these roles. There is, however, some doubt as to whether manned aircraft are the optimal platforms for these roles, given the ranges and endurance associated with strategic reconnaissance. Additionally, the political problems associated with the shooting down of manned reconnaissance aircraft is historically acknowledged. Therefore, while manned platforms are equally capable of performing strategic reconnaissance, they are limited by the physiological endurance of their crew and the political repercussions and leverage associated with their loss.

UAVs for Strategic Reconnaissance

Owing to their improvements in range, altitude and endurance, some UAVs offer their greatest potential in the strategic reconnaissance roles. The development of UAVs such as Global Hawk reflects this assessment. Strategic reconnaissance UAVs are considered to offer long-range long-endurance platforms that can be deployed from bases outside an area of operation, thereby reducing deployment costs and minimising casualties. Politically, UAVs are far more appealing, given the examples of limited publicity surrounding those shot down. A negative factor associated with their 'expendability' is that they may be subjected to increased targeting by nations who have not provided airspace clearance for their transit. The destruction of a UAV is far less likely to be considered as a hostile act, and is more likely to suffer a higher rate of attrition than manned aircraft. This raises some interesting issues. For example, could NATO respond with force to the destruction of a UAV by one of the entity armies in Bosnia? Does it legally constitute an act outside the bounds of the Dayton Accord and could it be used as a nuisance tactic?

Comparison of Platforms for Strategic Reconnaissance

Currently, the ADF's strategic reconnaissance capability is provided through four RF-111C aircraft. These RF-111Cs are currently limited to wet film operations, requiring the aircraft to overfly the target area and return to its operating base before the information can be retrieved and processed. Although the RF-111C has significant range capabilities, it is limited in endurance due to fuel and human constraints. Additionally, the RF-111C is crewed with both a pilot and navigator, whose loss would detract significantly from the ADF's strike capability, as well as posing significant political difficulties. In the short term, the procurement of either a stand-off imaging system for the RF-111C or a dedicated UAV or manned aircraft capable of strategic reconnaissance is unlikely given the current strategic environment, access to other forms of information through allies and presence of higher priority projects requiring funding. The importance of timely information in the emerging warfighting concepts will, however, increase the priority for such capabilities. Should the ADF require this capability to be organic to the ADF, an in-depth examination of the effectiveness of UAVs and manned systems will be required. Assuming near-real time sensor information is required (thereby deeming communications relays and Mission Control Stations requirements, hence equal costs, for both systems), the UAV has significant advantages over manned systems. The only advantages of manned systems will be the ability to operate independently of communications links, thereby increasing its chance of survivability should communications be jammed or lost. By virtue of its crew, manned platforms are also more capable of identifying threats and manoeuvring to avoid them. Paradoxically, the advantage provided by aircrew also doubles as their primary disadvantage, particularly given the increased likelihood of detection based on their size. Once detected, survivability measures are limited and/or costly.

Battle Damage Assessment

Battle Damage Assessment (BDA) is considered one of the most dangerous missions performed by manned aircraft due to air defences in the target area being alerted by the initial attack. In the Australian scenario, the RF-111C is the only aircraft capable of performing strategic BDA. The current wet film operation requires the aircraft to directly overfly the target, thereby subjecting the aircraft and crew to extremely high threats over heavily defended targets. Indeed, the threat is generally greater than that of strike missions given that an enemy will usually expect BDA following a strike mission. BDA represents a critical function in the targeting equation, as knowledge of the damage inflicted is required to determine the need for re-strike action. BDA is treated here as fundamentally different to strategic reconnaissance due to the criticality of timing in delivering the BDA information. Successful and timely BDA enables rapid re-strike missions where required, reducing the risk to manned strike packages. It can also reduce the wastage of expensive munitions such as cruise missiles, which are generally employed in packages of two or three missiles to ensure a high probability of target hit. The key to strategic surveillance and BDA missions is survivability. In the case of high value, highly defended targets, survivability should translate to stealth and stand-off capabilities, where the ability to avoid detection or SAM range is paramount to survivability given the density of air defence assets encountered.

Satellites for Battle Damage Assessment

Owing to the requirement for timely BDA information, satellites are not particularly well-suited to the role unless their constellation is sufficiently large to generate near-continuous coverage of the BDA target area. They are, however, the most survivable of platforms and provide good backup information to assets that perform responsive BDA missions. They are also capable of covering a number of BDA target sites each orbit and therefore represent economy of effort.

Manned Aircraft for Battle Damage Assessment

As discussed previously, manned aircraft are placed in extremely high threat environments to perform BDA missions of high value targets. The BDA mission, therefore, represents one of the most dangerous in terms of potential loss of aircraft and aircrew life. Stand-off imaging sensors can be employed to reduce the risks to aircraft but will be dependent on range and the spread of SAM and AAA defences surrounding high value targets.

UAVs for Battle Damage Assessment

DarkStar is the first UAV platform designed to perform high risk reconnaissance missions, including BDA. The UAV employs stealth as its primary survivability measure. As with most other UAVs, the SAR, EO and IR sensors also provide a stand-off capability. In the Australian context a DarkStar does not compare with the RF-111C for operating radius. It is likely, however, to be comparable with most contenders for the F-111 replacement, particularly if the F-111 and the F/A-18 are replaced by a multi-role strike/fighter. UAVs are ideal for these high threat roles and their loss only equates to the replacement cost of the platform. In comparison, the loss of a manned aircraft equals the replacement cost of the platform, the replacement cost of the crew and the political cost of casualties.

Comparison of Platforms for Battle Damage Assessment

BDA requires timely information in order to be of benefit to military commanders. Whilst both UAVs and manned aircraft are sufficiently responsive, the high threat associated with BDA missions make UAVs the option of choice based on factors of cost-effectiveness and political acceptability.

Target Acquisition

Target acquisition has historically been an important role for air platforms and is in fact gaining importance under the RMA concept of warfighting. Target acquisition roles include the detection, identification and location of military targets which can be provided by all three platform types. However, targeting at the operational and tactical levels generally requires platforms which are both responsive and flexible in their tasking.

Satellites for Target Acquisition

Whilst satellites are frequently used for acquiring strategic targets they have limited application for mobile targets. For example, satellites are relatively ineffective for tracking targets like Scud launchers. Due to their fixed orbital characteristics, satellites are generally not suited for operational and tactical level targeting.

Manned Aircraft for Target Acquisition

One of the primary tasks for army aviation assets is to provide targeting information to the ground commander. However, the acquisition of sophisticated ground-based and man-portable AAA has made this role sufficiently dangerous to manned aircraft to prompt the increased use of UAVs for this role.

UAVs for Target Acquisition

A good example of Target Acquisition is artillery spotting and many UAVs, such as the Pioneer, have both range-finders and laser designators, making them ideal for use for indirect fire control, counter battery fire and firing position reconnaissance. Also, their capability to be operated by an artillery battery and therefore be quickly on task increases the responsiveness of fire support.

Many other examples exist of the increased popularity of UAVs for Target Acquisition tasks. The Indian Army, for example, has afforded top priority to the procurement of UAVs to provide better target analysis support to their field artillery.[19] The Pentagon also has

[19] P. Sawhney, 'India's artillery is a force in its own right', *Jane's Defence Weekly*, 9 October 1996, p 37.

considered the use of the Hunter UAV to provide targeting and BDA information in conjunction with the employment of Tomahawk cruise missiles.[20] The Pioneer, as described earlier, has already proven extremely successful in providing targeting and BDA support for naval gunfire. In the UK, the Ministry of Defence has signed a contract for the delivery of 200 GEC-Marconi Phoenix battlefield UAVs to provide target acquisition support for the AS-90 self-propelled 155mm howitzer and other artillery systems, further demonstrating the popularity of UAVs for these roles.[21]

Comparison of Platforms for Target Acquisition

Historically manned aircraft were employed as the primary platform for providing Target Acquisition capabilities. However, as the danger associated with this role escalates, the use of UAVs as a cost-effective alternative will further increase. While all three platforms are suitable for the acquisition of strategic targets, UAVs stand out as the most cost-effective for targeting at the operational and tactical levels.

Communications, Signals Intelligence and Chemical Detection

The previous section dealt with the familiar topic of employing UAVs in the role of providing the 'eyes' to defence forces. Whilst currently limited, the use of UAVs in providing other sensory functions such as capabilities to 'listen' to the adversary through SIGINT and to detect chemical and biological agents through multispectral sensing, is increasing with many UAV platforms employing these sensors in conjunction with those used for 'optical' reconnaissance and surveillance.

Communications

Given the expanse of the Australian continent and the relatively poor communications infrastructure in the north, organic communications are a key consideration in developing robust command and control systems for ADF operations. The ADF relies on a number of different systems, including civil communications infrastructure such as the telephone cable, satellite and mobile phone networks. The ADF also has its own landline system for unclassified communication among major bases.

The ADF operates several tactical systems for secure battlefield communications, including Raven HF systems. These systems, however, are not suitable for the transmission of high quality video imagery. The bandwidth required to transmit quality video imagery for near real-time intelligence analysis requires line-of-sight microwave or VHF transmission. Beyond line-of-sight, either optic cables (as employed for video-conferencing) or satellite bandwidth are required. Relay facilities can be used for communications transmissions but are susceptible to interference if stationed on the ground.

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[20] J.D. Morrocco, 'Hunter to provide data for Tomahawks in test', *Aviation Weeks and Space Technology*, 10 July 1995, p 55.
[21] S. White, *Unmanned Vehicles*, October 1996, p 23.

The US Department of Defense is acquiring the capability of an Airborne Communications Node (ACN) for the Global Hawk.[22] While it is still in early development, the ACN will provide secure battlefield communications for forces deployed in a forward theatre where there is minimal infrastructure, or where secure battlefield communications are needed. This concept could easily be adapted to the Australian scenario where either the infrastructure is limited, or weather and atmospheric changes affect High Frequency (HF) communications. Further, the capability to provide secure battlefield communications through an airborne platform reduces the requirement for landlines or the reliance on HF communications. Another significant advantage over HF communications is the ability to use UAVs as communication relays for the transfer of real-time visual data. Indeed, many believe that UAVs will have a greater role as communications relays, providing communications bandwidth, 'the most precious commodity on the battlefield'.[23] Like communications, EW has similar priority in the exploitation of technology to realise the potential benefits of the Revolution in Military Affairs (RMA) concept of warfighting.

The US concept of operations is to use this ACN as a secure area communications network capable of transmitting high quality imagery, as well as for tactical communications use by army units. Their other concept is to employ the Global Hawk ACN as a communications relay for other UAVs, allowing their use where satellites are not available or otherwise employed. Consideration of such a capability may be warranted in the Australian scenario, given the paucity of communications infrastructure in the north and the redundancy achieved through an additional communications system. Furthermore, should the ADF acquire an organic communications satellite capability, its reach will still be limited. Its placement to optimise communications over the eastern seaboard, for example, most likely would exclude its reach over the north of Australia. Even given a reach over Darwin and surrounding areas, a communications satellite may not enable forces to use the satellite forward of the continental shelf. In all of these cases, communications relay platforms may provide a significant force multiplier capability. For example, how might real-time stand-off imaging on an F-111G be achieved without continental access to communications satellites? There are four options: place a communications satellite for coverage of northern Australia and its approaches, increase the number of satellites to provide comprehensive coverage over Australia and its area of interest, hire bandwidth from other commercial or military satellites (with potential restrictions on use), or employ communications relay platforms. Relay platforms also have the flexibility to be employed offshore. For example, an ACN could be vital for providing a communications capability to troops deployed on peacekeeping missions in a country with limited infrastructure.

Signals Intelligence

UAVs fitted with EW suites have been employed in Vietnam and the Beka'a Valley, with significant effort being directed to further the development in this field. The use of multi-role UAVs to carry ECM, SIGINT and COMINT suites is an essential requirement for

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[22] 'Airborne Communications Node' at http://www.darpa.mil/documents/procure97/iso.html.

[23] D.A. Fulghum, 'Unmanned Strike Next for Military', *Aviation Week and Space Technology*, 2 June 1997, p 48.

information exploitation. This is subject, of course, to the ability of the UAV to provide an adequate power generation capability with which to operate EW systems, particularly ECM. The IAI Pioneer and Mastiff, for example, were originally designed to carry Electronic Counter Measures (ECM) and Electronic Support Measures (ESM) suites, laser designators or TV camera payloads.[24]

The US Department of Defense (DoD) also has had considerable experience in utilising UAVs for EW roles, developed during the Vietnam War. Owing to the high losses of manned aircraft, the Teledyne Ryan 147E drone was adapted for ELINT missions. In 1966, a 147E drone was successful in transmitting details of a North Vietnamese missile guidance radar and proximity fusing arrangements. The data was collected by on-board ESM systems and then retransmitted to either an RB-47 aircraft or direct to a ground station.[25]

The loss of 31 crew on an EC-121 EW countermeasures aircraft which had been collecting the data on North Korean radar emissions in April 1969, prompted the use of a Teledyne Ryan 147T drone as a relay for such transmissions.[26] Ten EW receivers fitted to the high altitude 147TE drone were proven capable of collecting and retransmitting large amounts of electronic intelligence. The capability provided ground stations ELINT on targets some 600 miles from their location.

The US Department of Defense has now endorsed the development of a SIGINT (COMINT) system which can intercept low-power 'walkie-talkie' field radio and cellular phone conversations.[27] This SIGINT capability was envisaged for use in Bosnia where potentially disruptive plans by any of the entities could be intercepted and countered. Recent testing of the COMINT system required that the aircraft fly to within one mile of the signal emissions.[28] In such scenarios, the relatively small size of UAVs aids their ability to operate undetected, making them ideal for such roles. In contrast, risks to manned aircraft may be unacceptable for performing the same mission.

Nuclear, Biological and Chemical Detection

The suitability of UAVs to perform missions for detecting emissions from industrial plants suspected of producing nuclear, biological or chemical (NBC) weapons has prompted further research into appropriate sensors. Using these sensors, UAVs could perform NBC monitoring operations through the direct overflight of suspected NBC weapon production facilities or testing sites. Similarly, battlefield employment of UAVs with NBC sensors where the use of NBC weapons is suspected removes the hazards to personnel associated with such missions.

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[24] Air Chief Marshal Sir M. Armitage, *Unmanned Aircraft*, Brassey's Air Power: Aircraft, Weapons Systems and Technology Series, Vol 3, Brassey's Defence Publishers, London, 1988, p 82.
[25] *Ibid.*, p 74.
[26] *Ibid.*, p 76.
[27] D.A. Fulghum, 'JCS Lowers Priority for UAV Spy Payload', *Aviation Week and Space Technology*, 7 April 1997, p 39.
[28] D.A. Fulghum, 'U.S. Navy Reconnaissance Crucial in Albania, Bosnia', *Aviation Week and Space Technology*, 31 March 1997, p 30.

Applicability of UAVs to Australian RSTA Requirements

The general suitability of UAVs in performing various RSTA tasks has been dealt with in the first half of this chapter. In applying these findings to the Australian scenario in order to determine their level of competitiveness, a more complete knowledge of operational parameters is required. For example, satellite surveillance is the only practicable alternative in terms of affordability should the ADF determine that there is a requirement for maritime surveillance of the sea-air gap, covering an area extending from Broome to Weipa and the island chain to the north, with a revisit rate measured in hours. Alternatively, should the capability be used to perform more detailed interrogation of targets in response to JORN detection, then manned and UAV platforms offer more flexible and competitive options. The relative competitiveness of each system is fundamentally dependent on the defined operational parameters. The derivation of these parameters comes from strategic guidance and calculations of the capability levels the ADF can afford. However, the operational parameters are frequently of highly classified and are subject to change as strategic guidance evolves. For this reason, specific judgements are difficult on where UAVs are the most competitive options for the performance of ADF tasks. Given this limitation to performing an in-depth analysis of UAVs, this half of the chapter will look at the competitiveness of UAVs against other platforms, based on differing assumptions. As assumptions change, so will the competitiveness of various platforms. Dealing with the competitiveness of platforms in this manner will ensure the study is not dated by a dramatic change in strategic thinking but, rather, the principles can be applied to encompass any changes to Australia's defence posture.

As detailed previously in this chapter, the operational effectiveness of UAVs across a range of RSTA missions promotes them for consideration by the ADF in the following roles:

- Maritime surveillance - as part of a larger surveillance architecture
- Land surveillance
- Tactical reconnaissance and target acquisition
- Strategic reconnaissance
- Battle Damage Assessment
- Other roles including artillery spotting and target designation

Indeed, the only mission currently not suitable for UAV operations is the air surveillance mission due largely to the inability to generate sufficient power for the effective operation of large Doppler radars. This judgement has, however, been based on the assumption that the UAV would compete with aircraft of the magnitude of the AEW&C competitors to undertake air surveillance out to 200 nautical miles. In satisfying a navy requirement for airspace surveillance, a much lesser capability could suffice with opportunities for UAVs to fulfil these roles.

The utility of UAVs in the listed roles will be analysed against a number of assumptions. The resultant matrix demonstrates the combination of assumptions where UAVs offer highly competitive systems, as well as those where UAVs represent less cost-effective options than satellites and manned aircraft.

Assumptions Underlying the Measurement of Platform Suitability

Threat Environment

Defining the threat environment is a key consideration in determining the cost and viability of platforms in undertaking their defined missions.

High

A high threat environment is defined as one where all survivability measures are likely to be employed to evade imminent and effective threats to the platform. High threat environments pose substantial risk to platforms and a level of attrition is considered likely. An example of a high threat environment would be one with a comprehensive concentration of anti-air capabilities such as Anti-Aircraft Artillery, Surface-to-Air-Missiles and Air-to-Air-Missiles covering a range of altitudes. This could be encountered over high value targets such as air bases, a naval task force, an army field headquarters and the national political and defence force headquarters. The lethality of a high threat environment is relative to the capabilities of the platform. UAVs are optimised in high threat environments due to their relatively low cost compared to equivalent manned platforms and the absence of aircrew. Satellites are also optimised through their exploitation of altitude.

Medium

A medium threat environment is defined as one where the probability of threat to the platform is considered likely. The type, volume and success of the threat is variable. Attrition of platforms is dependent on survivability measures, tactics and good training. Satellites, manned aircraft and UAVs are all suitable for employment in medium threat environments. Other factors are likely to dominate a comparative analysis where the threat is assessed as medium.

Low

Most 'Defence of Australia' scenarios would pose low-to-medium threats. Small groups of insurgents are unlikely to have sophisticated AAA and SAM systems but are capable of carrying shoulder or vehicle launched weapons that could pose a threat to aircraft operations, particularly at low levels. The likelihood of attrition in these cases, given accurate intelligence and the employment of self-defence measures is determined to be low. Manned aircraft, UAVs and satellites are all suitable, though satellites are the more costly option.

Range

Range is also relative but is defined for the purposes of this paper in air force rather than army terms. This accounts for the ranges experienced across the continent as well as over the sea-air gap, which is the current focus of the Australian defence posture.

Short

In the Australian context, short-range aircraft would normally have an operating radius of about 500 kilometres. Caribous, PC9s and rotary wing aircraft are considered short range.

Medium

Few aircraft fall into the medium range category but this can be fulfilled by aircraft with longer ranges. A radius of action of around 1,000 kilometres would define the outer limit of medium range aircraft. The F/A-18s and HS748s fall into this category.

Long

For the purposes of this analysis, long range is defined as aircraft capable of a radius of action of 3000 kilometres. These operating radii equate to ranges enabling aircraft to travel from Sydney or Weipa to Darwin without refuelling. The ADF's long range aircraft include F-111s, C130s, P3Cs, B707s and Falcon 900s.

Endurance Over Target

For reconnaissance and surveillance missions, endurance is critical to the cost-effectiveness of the mission. For example, given the requirement for 24 hour operations, the task may be undertaken by two aircraft capable of 12 hour operations, or three aircraft capable of 8 hour operations. If both aircraft types have similar maintenance and acquisitions costs, the aircraft with the greater endurance represents a cheaper maintenance system overall.

Low

Most aircraft are capable of low endurance over targets. While dependent on the requirements, an endurance of minutes to a few hours would normally be defined as low endurance operations. Owing to their orbital restrictions, LEO satellites are only capable of low endurances, but are capable of short revisit times, enabling reasonable surveillance of stationery targets.

Medium

In RSTA terms medium endurance is generally accepted as ranging from 8 to 12 hours at the limit of the platform's radius of action. Obviously, a trade-off on operating range in a particular scenario will equate to longer time on task but this figure is used as a defining guide for most reconnaissance and surveillance platforms.

Long

Given the previous emphasis on manned operations, understanding of long endurance has normally been associated with flights of 12 to 16 hours duration. With the emergence of long endurance UAVs, endurances in excess of 24 hours at operating radii of over 5,000 kilometres are achievable. For the purposes of this study, long endurance is defined as over 12 hours.

Coverage

The type of coverage required will have significant impact on platform quantities and the cost of capability. Coverage is a function of both time and space and must be carefully defined. For example, continuous coverage of an area implies an on-going surveillance of every point within the defined area. Few systems offer such capabilities, other than tethered balloons which have an extremely small surveillance footprint. Manned aircraft and UAVs are similarly capable of such coverage but are not cost-effective compared to other systems, such as tethered balloons, and are also incapable of covering large areas.

Responsive

UAVs and manned aircraft are optimised in providing responsive reconnaissance and surveillance coverage. In comparison, satellites are bound by their orbital characteristics and offer far less flexibility in this area.

Programmed/Continuous

Programmed coverage implies a set area of coverage with defined revisit times. The larger the area and the lower the revisit time, the more aircraft required. Alternatively, the size of the area has little effect on a satellite's ability to provide repetitive coverage. The number of satellites required to perform programmed coverage is dependent on the revisit times. Simplistically, satellites are optimised for continuous surveillance of the entire sea-air gap where a low revisit rate is required. In comparison, manned aircraft and UAVs are more cost-effective where the revisit rate over a small operational area is high.

Type of Data Transmission

The type of data to be transmitted also has a significant impact on the competitiveness of the three platform types.

Verbal

Where verbal confirmation of the target suffices, manned aircraft are likely to represent the most cost-effective platform. This can be demonstrated in a simple comparison of the system costs of a general aviation aircraft with two aircrew and their maintenance support. An equivalent UAV system, such as the Pioneer or Hunter, utilises five to seven operating staff, and requires Mission Control Stations and Ground Control Stations. Should the UAV be required to operate beyond line-of-sight the cost of a communications relay, whether it be another UAV, an aircraft or a satellite, must be considered. Consequently, sophisticated UAV systems are not very competitive compared to aircraft performing basic reconnaissance tasks, particularly when operating beyond-line-of-sight.

Delayed Sensor

Many UAVs and manned aircraft can store information gathered on operations beyond line-of-sight and hold that information until the aircraft is within range of the communications link. While basic UAV systems rely on continuous datalinks for control, greater automation of UAVs can enable them to perform their mission beyond the communications link.

Real-Time Sensor

The requirement for real-time sensor data is increasing in priority as many defence forces recognise its importance in reducing their decision cycles. All three platform types are equally capable of providing real-time information. Such provision is based on the availability of a communications relay capability, or the ability to operate within line-of-sight of the Mission Control Station. The requirement for real-time data has significant implications on the competitiveness of UAVs in that it makes the cost associated with their operation in terms of cost of bandwidth and requirement for Mission Control Stations commensurate with that for manned aircraft. All things being relatively equal in terms of maintainability and operating costs, the cost of trained aircrew then becomes the biggest drawback for the competitiveness of manned aircraft.

Suitability of Platforms Based on Varying Operational Assumptions

Following the previous discussion, the suitability of each platform type in meeting each of the assumptions is displayed at Table 11.1. The table is simplistic and should not be used to discount any particular option but is useful in demonstrating which platforms may be most appropriate in performing defined tasks.

Three scenarios listed at Enclosures 1 to 3 demonstrate how variations in assumptions dramatically effect the competitiveness of particular platforms. While flexibility across the high range of performance characteristics comes at a cost, the acquisition of a platform type based on assumptions at the lower end of the scale can greatly affect the utility and flexibility of the platform in performing tasks outside those for which it was acquired.

In line with the previous reasoning, proponents of UAVs could argue a case for long-endurance long-range aircraft such as Global Hawk to conduct a range of surveillance tasks whilst offering the operational flexibility of deployment off-shore but launched and controlled from the continent. Short-range surveillance aircraft have to contend with deployment costs and the cost of long logistics chains, making them less cost-effective than aircraft with greater ranges and endurance. Alternatively, manned aircraft with long range and endurance capabilities, such as JSTARS, AP-3Cs and AEW&Cs, also attract significant costs in terms of large operating crews. Manned aircraft of this type are also less likely to be employed in high threat environments due to their high unit cost and large number of on-board operators.

Summary

This chapter has examined the comparative ability of three platform types to conduct Reconnaissance, Surveillance and Target Acquisition roles in support of ADF tasks. While dependent on particular assumptions for threat, range and other requirements, UAVs offer a competitive platform option for a number of ADF roles. Their inclusion in ADF force capability considerations is therefore warranted.

ASSUMPTIONS	UAVS	MANNED	SATELLITES
THREAT - LOW	N	S	N
THREAT - MEDIUM	S	S	S
THREAT - HIGH	O	N	O
RANGE - SHORT	S	S	S
RANGE - MEDIUM	S	S	S
RANGE - LONG	O	S	S
ENDURANCE - LOW	S	S	S
ENDURANCE - MEDIUM (Time on Target)	S	S	N
ENDURANCE - LONG	O	N	N
COVERAGE - RESPONSIVE	S	O	N
COVERAGE - CONTINUOUS/SMALL AREA/HIGH REVISIT	S	S	N
COVERAGE - CONTINUOUS/MEDIUM AREA/MEDIUM REVISIT	S	S	S
COVERAGE - CONTINUOUS/LARGE AREA/LOW REVISIT	N	N	O
TYPE OF DATA - VERBAL	N	O	N
TYPE OF DATA - DELAYED SENSOR	S	S	S
TYPE OF DATA - REAL-TIME SENSOR	S	S	S

Key:

N - Not suitable based on cost or operational factors

S - Suitable

O - Optimised

Scenario 1

<u>Defence of Australia</u>

Task: Tactical Surveillance

Threat:	Low
Range:	200 kilometres
Endurance:	8 hours
Coverage:	Continuous/small area/high revisit
Data:	Verbal/Delayed sensor

Assumptions	UAVs	Manned	Satellite
Threat - low	N	S	N
Range - short	S	S	S
End - medium	S	S	S
Cover - cont/small/high	S	S	N
Data - verbal/delayed	N/S	O/S	N

Key:
N - Not suitable based on cost or operational factors
S - Suitable
O - Optimised

Using the methodology employed in Table 11.1, manned aircraft present themselves as the most suitable candidate for operations in the Defence of Australia. Satellites are an expensive option given the threat is low and the coverage over a small area is required at high revisit rates. The task is also likely only to be conducted during periods of increased tension. Additionally, in this case verbal information would suffice.

UAVs may also provide less attractive options based on cost. Given that verbal data will meet the minimum requirement, the employment of sophisticated Mission Control equipment with its associated communications links forms a costly addition to the task.

Scenario 2

Services Protected Evacuation

Task: Pre-deployment Surveillance

Threat:	Medium to high
Range:	7,000 kilometres
Endurance:	12 hours
Coverage:	Continuous/small area/high revisit
Data:	Real-time

Assumptions	UAVs	Manned	Satellite
Threat - medium/high	S/O	S/N	S/O
Range - long	O	S	S
End - medium/high	S/O	S/N	N
Cover - cont/small/high	S	S	N
Data - real-time	S	S	S

Key:
N - Not suitable based on cost or operational factors
S - Suitable
O - Optimised

In this scenario manned aircraft and satellites are not very competitive. The cost and risk of attrition is high and aircrew would have difficulty ferrying some 3,000 kilometres before commencing a 12 hour surveillance task. Satellites may provide a suitable option if sufficient exist in a constellation to overcome their limited time on target. For this reason, satellites represent an expensive option.

UAVs are optimised for most parameters in this type of scenario. Their main cost, the requirement for communications relay to achieve real-time data transmission, is similarly shared by manned aircraft in this scenario.

Scenario 3

Defence of Australia

Task: Surveillance of Sea-Air Gap (monitor increased surface activity)

Threat: Low
Range: 7,000 kilometres
Endurance: minutes
Coverage: Continuous/large area/low revisit (5,000 x 500 km)
Data: Delayed sensor

Assumptions	UAVs	Manned	Satellite
Threat - low	N	S	N
Range - long	S	S	S
End - low	S	S	S
Cover - cont/large/low	N	N	O
Data - delayed	S	S	S

Key:
N - **Not suitable based on cost or operational factors**
S - **Suitable**
O - **Optimised**

In this scenario UAVs provide an expensive option in the quantities required to cover such a large operational area. The cost associated with fielding a number of systems would be prohibitive. For much the same reasons, manned aircraft are also not suited to the coverage of such a large area. In this case, satellites provide the most effective system, even though they are expensive and do not exploit their high survivability in this scenario.

Chapter 12

Offensive Roles: Strike and Suppression of Enemy Air Defence

Introduction

In line with many other defence forces, the ADF is likely to consider the acquisition and employment of UAVs for offensive roles with a degree of scepticism and reserve. This general aversion to the concept is based on a number of factors, including culture and the correlation of the technical sophistication of UAVs with tactical reconnaissance drones. The argument against offensive UAV systems, generally proffered by aircrew, is that UAVs are generally unsophisticated, unable to replicate the 'situational awareness' of aircrew and incapable of correct target discrimination. This belief is naive and based on a narrow appreciation of the UAV family tree. Additionally, the subscribed view tends to be held by those who have little understanding of the sophistication and variety of UAVs already in existence and to clearly disregard a recognition that cruise missiles are an operational example of an offensive UAV.

This chapter provides an appreciation of the potential of UAVs in offensive roles, based on their historical development, current technology and attributes which promote them as cost-effective options. The utility and applicability of various offensive UAV systems in development will be discussed with relation to the ADF.

Background to Offensive UAVs

The story of the development of the cruise missile from its crude origins as a flying bomb is the story of the initial development of UAVs for UAVs were first developed as offensive weapons. The first notable operational system was the German-developed V1 'Flying Bomb', which went into production for use against the United Kingdom during World War II.[1] The rationale behind the V1 and every offensive UAV since, has been to address the attrition of manned aircraft through an alternative cheap, unmanned, hence expendable, system.

While reconnaissance UAVs were later developed, these offensive flying bombs attracted far greater interest than that of reconnaissance drones, predominantly because of their cheapness and reduction in aircrew attrition as a result of their employment. Unfortunately, the further development of cruise missiles, given the extent of the topic, has generally been considered as

[1] Air Chief Marshal Sir M. Armitage, *Unmanned Aircraft*, Brassey's Air Power: Aircraft, Weapons Systems and Technology Series, Vol 3, London, 1988, p 7.

a distinct subject in its own right and its association within the UAV family tree has tended to be overlooked. The failure to recognise the similarity between the cruise missile family and that of other offensive UAVs has enabled critics to write-off the potential for re-useable offensive UAV systems as technically unachievable. Exclusion of offensive UAVs from serious consideration for further development and incorporation into air power doctrine has also resulted from the high level of secrecy that surrounded the use of UAVs in Vietnam and other wars. The lack of publicity and the plethora of manned systems in operation during the Cold War meant that the successes of such trials were lost within a generation.

During the Vietnam War period, the development of re-useable offensive UAVs for use in high-threat environments reached impressive states of advancement. Their development was largely driven by the impetus to address the unacceptable levels of attrition encountered by manned aircraft as a result of the conflict. This led to the adaptation of UAVs, such as the Teledyne Ryan Aeronautical Firebee, for use as weapons carriers for anti-ship, anti-surface and anti-radiation missiles. Successful trials were completed using the Firebee to deliver two 500 lb bombs at an attack altitude of 25 feet and a speed of 400 knots.[2] A trial to defeat SAM sites was undertaken in December 1971 using the Teledyne Ryan Model 234 carrying an AGM-65 Maverick missile. The air-launched drone was guided toward the SAM site by an operator on-board the DC-130 launch aircraft using a nose-mounted TV camera. As the drone approached the target the operator switched to the optical seeker of the Maverick and guided the pair to within two miles of the target before firing the Maverick. The missile hit its target while the drone was recovered.[3]

Re-useable offensive UAVs were therefore reasonably advanced by the end of the Vietnam conflict. However, the ready availability of manned systems and the secrecy surrounding the development and use of experimental systems during the Vietnam era, meant the lessons learned, with regard to the operation of re-useable offensive UAVs, were lost. Cruise missiles, however, continued to receive development funding due to their symbiotic partnership with manned platforms.

Lethal Roles

As an example of the only offensive UAV to receive further development after the Vietnam War, the technologies and employment of cruise missiles is worth closer examination. Cruise missiles incorporate the inherent strengths of UAVs to provide a precision strike capability in a high threat environment to a commander sensitive to aircrew attrition. By virtue of being unmanned, cruise missiles are expendable. While cruise missiles are not considered cheap, they offer a cost-effective form of firepower in high threat environments against high value targets. Their operating range also offers a significant stand-off capability to the launch platform, thereby further reducing the risk of attrition to personnel.

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[2] *Ibid.*, p 78.
[3] *Ibid.*, pp 79-81.

The success of cruise missiles during the Gulf War has increased their popularity for strike against high value and highly defended targets. A man-in-the-loop employment strategy has been incorporated into the Block IV Tomahawk cruise missiles to address some of the inaccuracies experienced through the reliance on TERCOM (terrain profile matching), and DSMAC (terminal guidance based on digital images), guidance systems.[4] The successful adaptation of the man-in-the-loop concept for cruise missiles addresses one of the few concerns surrounding the employment of UAVs in offensive roles - that of target discrimination and authority to fire. This development paves the way for the acceptance of re-useable strike platforms as a cost-effective alternative to the cruise missile. Re-useable combat UAVs, or UCAVs, are proposed to fill the gap between expensive single-use cruise missiles in high threat environments and manned aircraft in lower threat environments.

A Lockheed Martin study concluded that UCAVs would provide the cost-effective strike option where platform survivability ranged from 0.75 to 0.98. Given a cost-effective window for re-useable offensive UAVs, Lockheed Martin has undertaken an ambitious program to convert an F-16A to an unmanned aircraft. This conversion will be used as a technology demonstrator to convince sceptics that mature technology is available to make the concept achievable, and to make progress into addressing some of the limitations and weaknesses associated with UCAV operations. The first F-16A is likely to be manned in order to provide feedback on the aircraft's operation and provide the ultimate form of redundancy in initial test stages. Their second program will be to fit extended wings to an F-16A, remove aircrew life support systems, and test the resultant endurance. This second program will be designed also to test the cost-effectiveness potential of UCAVs in performing Combat Air Patrols (CAPs) and other tedious but necessary roles. Lockheed Martin has estimated that converted F-16As could perform a standard CAP function at 60 per cent less cost than a manned squadron of F-16s.

As stated earlier, the technology is currently available and in operation for offensive UAVs in the form of cruise missiles. Theoretically, little is involved in taking cruise missiles to their next progression and using the smart cruise missiles as the vehicle to carry and deliver smaller, less expensive munitions. From the other direction, reconnaissance UAVs are maturing to a point where they are also being increasingly utilised for more offensive roles, including laser designation of targets. In the medium term, it is foreseeable that organic Army UAVs will be used for CAIRs and other roles which are considered a high risk to expensive manned platforms.

A number of offensive roles, therefore, are being considered for UAVs including strike, CAP, Suppression of Enemy Air Defence (SEAD) and Theatre Ballistic Missile Defence. Whilst some of these roles are unachievable in the near to medium term, there is little doubt given their history, that all of these roles are achievable eventually. How will and should the ADF approach UAVs for offensive roles? In answering this question, several factors should be considered: regional capabilities, likelihood of survivability based on regional air defence capabilities, utility, and cost-effectiveness. Few offensive systems offer a high degree of

[4] Wing Commander P.A. Hislop *Employment of Cruise Missiles by the ADF,* Paper No 57, Air Power Studies Centre, RAAF, Canberra, August 1997, p 13.

utility, given the very narrow use of these systems. Other than their utility in providing deterrence and potential for use in gunboat diplomacy, submarines, F-111s and other predominantly offensive platforms have fairly limited scope for peacetime use.

Whilst the ADF has limited capabilities in some of the offensive roles discussed, such as SEAD, the potential for using UAVs in these roles will be examined, given the likelihood that the ADF will give greater priority to these missions as regional capabilities in these areas improve over the next two decades. Additionally, while there appears little likelihood that combat UAVs will have achieved sufficient operational maturity to be considered for the up-coming ADF requirement to replace the aging F-111 strike aircraft and F/A-18 fighter fleet by 2020, there is a high probability that they will represent competitive options for the following generation. The potential for offensive UAV systems to complement the employment of manned aircraft in offensive roles in the near future will be discussed. Acknowledgment that offensive UAV systems can provide viable alternatives to manned aircraft in specific support roles lays the foundation to their acceptance for more demanding roles. Finally, the exploitation of offensive UAVs will be premised on the ability and dedication of resources to address some of the challenges to their operation in the near to medium future. Resolution of these issues will be fundamental to the ADF's ability to include offensive UAVs within the list of credible options.

Potential to the Australian Defence Force

The Strategic and Geographic Environment

Australia's geography has a significant effect on the determination of force structure for offensive platforms. Given the vastness and expanse of the country, platforms require mobility and range on a scale similar to that of the United States and other large countries. The alternative to systems which offer significant range and endurance capabilities is the option of increasing unit numbers and locations. For example, with their short range, the F/A-18 requires a number of bases to enable operations across the north of Australia. Alternatively, the range of the F-111 enables it to conduct operations from a single base. Systems without the range or endurance to operate across the expanse of the continent therefore attract the costs associated with the requirement for deployment to bare bases. The high personnel and infrastructure costs associated with this form of operation is difficult to support given Australia's small defence force. In order to satisfy the requirements for the defence of Australia as well as having sufficient regional reach to use the ADF as a deterrent; range, mobility, deployability and endurance become important factors in the selection of hardware for the ADF.

Should the Australian government decide that strategic strike continues to retain relevance as the ultimate deterrent, strike platforms will require a similar reach to that of the F-111. Acceptance of this assumption is critical to the further discussion of the suitability of UAVs in offensive roles, given their strategically 'offensive' nature. That is, should Australia concentrate on defensive counter air and naval support, the value of offensive UAVs to the ADF is limited. The decision to retain offensive counter air and strategic strike capabilities into the next century opens discussion on the suitability of UAVs in offensive roles.

Tasks

The force development priorities identified in *Australia's Strategic Policy* outlines several tasks where UAVs can potentially contribute in offensive roles. These include:

a. **Defeating Threats in Our Maritime Approaches.** Stand-off weapons are currently stockpiled by the ADF for defeating hostile shipping.[5] The Harpoon anti-ship missile (ASM) provides stand-off capability to their F-111, F/A-18, P3C Orion, surface and sub-surface delivery platforms.

b. **Strike.** Cruise missiles have been suggested as an option for enhancing Australia's strategic strike capability. Furthermore, submarine launched cruise missiles are being considered as an alternative to replacing the F-111 strike platform upon its retirement in 2020. Another role that aligns with strategic strike is SEAD where control of the air is required for effective strike operations. Given the high risk associated with the SEAD role, the task is well suited to UAV operations.

Strike

Arguably, the capability for strategic strike has represented the foundation to Australia's deterrence capability. This is achieved through the Collins submarine fleet, the F-111 strike aircraft and the Special Forces. The F-111 can be fitted with precision guided munitions and stand-off missiles such as the Harpoon anti-shipping missile, the Rockwell AGM-130C and the recently acquired AGM-142 Popeye for air-to-ground strike capabilities.[6] Coupled with the significant range of the F-111s, these missiles enable these aircraft to conduct retaliatory strikes with a significant stand-off capability.

Manned Aircraft

The pending retirement of the F-111 in the 2010-2020 period has already highlighted the challenges to Defence replacing this impressive and flexible strike capability. There is currently nothing on the market that will deliver the range and payload capacity of the F-111, other than the B-1B which is decidedly offensive in nature and unaffordable for the ADF. An alternative to seeking a replacement strike aircraft such as the F/A-18D Hornet or F-15E Strike Eagle, is to replace the F-111 and F/A-18 with a multi-role strike/fighter. Range and payload will be sacrificed if this option is chosen and the ADF will need to consider air-to-air

[5] Differentiation of cruise missiles and stand-off weapons is based on range. Arguably, the ADF already employs offensive UAVs in the form of 'short-range cruise missiles' or 'stand-off weapons'.

[6] G. Ferguson 'Options for ADF's next big stick: Strategic Strike', *Australian Defence Magazine*, March 1996, p 34.

refuelling platforms, combined with the employment of medium to long range ASMs or cruise missiles to provide a satisfactory range.

Cruise Missiles

Cruise missiles are likely to be given serious consideration in the near to medium term in addressing Australia's requirement for a deterrent strike capability. The retirement of the F-111 will remove the significant Australian capability and will be difficult to resolve. An option being given considerable attention for providing this strike capability is to outfit Australia's Collins class submarines or one of the Navy's surface ships with cruise missiles, such as Tomahawks. Such a capability could reduce the need to replace the F-111 in terms of its reach and payload capacity, enabling a single multi-role platform to compete for the replacement of both the F-111 and F/A-18. Surface ships also have the benefit of exerting a presence and substantial political pressure where required. The argument against surface ships is their vulnerability as well as the cost in terms of life and equipment should the ship be sunk. Another consideration is that of weapons resupply to vessels where supply lines are vulnerable and slow.

The consideration of cruise missiles has already received some support. This is likely to increase as the F-111 approaches retirement or if other nations in the region consider or add cruise missiles to their arsenals.

UCAVs

Reusable combat UAVs, termed Uninhabited Combat Aerial Vehicles (UCAVs), have also generated significant interest through their promised cost-effectiveness over expendable versions. The USAF StrikeStar paper for the Air Force 2025 study indicated that, with sufficient funding and DoD support, a UCAV could be fielded by 2015-2020. Lockheed Martin's UCAV team believe they can have their unmanned F-16A demonstrator flying by around the year 2000. Successful conversion of the aircraft will open the way for further development of a purpose-built UCAV. Given the concurrent success with the DarkStar reconnaissance UAV, the first UCAV demonstrator could be operating around the 2005-2010 period.

Considering the current time-line, UCAVs are unlikely to be sufficiently mature, even as demonstrators, to place them as realistic competitors for the F-111 replacement, given that the year of decision is likely to be some five years before the F-111 retirement. UCAVs, however, do have a number of attributes that recommend them for this role, and the UK Ministry of defence has commissioned a study to determine their viability as part of the Future Offensive Aerospace System (FOAS) which would be fielded around the same time that the F-111 is retired. Therefore, the ADF would be wise to closely follow the study and consider the recommendations, with due regard to the Australian context.

Suppression of Enemy Air Defence

UAVs have been used on several occasions in supporting SEAD missions. The first use of drones in this role was in Vietnam where Teledyne Ryan Aeronautical 147F reconnaissance drones were deployed over North Vietnamese SAM sites to undertake photographic reconnaissance. Outfitted with ALQ-51 ECM defensive packages, a single drone succeeded in drawing fire from up to 11 SAMs.[7] Whilst the drone was eventually destroyed by a SAM, it demonstrated potential cost-effectiveness in this mission type. The concept was later exploited using cheaper modified BQM-34-A target drones to serve as decoys to the more expensive reconnaissance drones flying at higher altitudes.

Cheap UAVs such as the Teledyne Ryan Aeronautical 124R drones were employed by the Israelis in the Yom Kippur War of October 1973 to draw enemy SAM fire away from attacking manned aircraft. Expensive SAMs from a limited arsenal were expended in attacking these relatively cheap UAVs, with a report that some 32 missiles were directed at a single drone which was recovered unscathed.[8]

The Israelis continued to use UAVs in this role, most notably in air operations over the Beka'a Valley in 1982. First, the UAVs were used to collect intelligence and test Syrian air defences. Samson drones were then employed to simulate the radar return of F4 Phantom aircraft and were sent over the valley, followed by aircraft carrying anti-radiation missiles. When the Syrians activated their SAM radars, they were neutralised by the incoming radiation missiles.[9] As decoys, they were also used to draw SAM fire to allow manned aircraft to attack SAM sites during reloading.

The SEAD role has been one largely neglected by the ADF. And while F/A-18s and F-111s are capable of performing offensive counter air roles through ground attack of enemy airfields and assets, little is practised in the way of defeating SAM and AAA capabilities. As demonstrated in the 1991 Gulf War, this capability was essential for creating a safe environment for subsequent strike missions over Iraq. Expendable decoys provide a cost-effective method of activating SAM radars which can then be targeted by anti-radiation munitions. Further development of this concept could see the decoys used as an integral anti-radiation system or UAVs could carry expendable decoys as well as anti-radiation missiles.

This concept is being realised through the Harpy anti-radar UAV, one of IAI's most successful drones. Harpy has generated sales of over US$200 million with its customers which include Israel, South Africa, South Korea and India.[10] The concept of operations for Harpy is based on a 'fire and forget' system with the expendable UAV exploiting a two hour loiter capability over potential radar sites. The UAV employs a passive anti-radiation homing seeker to detect and attack the source of radar emissions.[11] With a length of 2.5 metres and

[7] M. Armitage, *Unmanned Aircraft*, p 74.
[8] *Ibid.*, p 85.
[9] *Ibid.*, p 85.
[10] *Unmanned Vehicles*, August 1997, p 32.
[11] 'In HARM's way', *Flight International*, 2-8 July 1997, p 36.

with a take-off weight of only 100 kilograms, the weapon is difficult to detect. At approximately US$50 million for a system of 16 (which presumably includes their mobile launchers), they may be considered an expensive weapon, with each missile costing in the order of hundreds of thousands of dollars. In comparison to the loss of a fighter aircraft at $30 to $40 million, however, these weapons are generally considered cost-effective in high threat environments.

While Australia is likely to acquire anti-radiation missiles in the near to medium term, no thought appears to be given to the use of either decoys or autonomous Harpy-like missiles to reduce the threat to manned aircraft. Given the critical role of strategic strike in Australia's defence posture, the lack of importance attached to the SEAD role is indeed curious. As regional air defence capabilities improve, however, the ADF will need to address the SEAD role if it is to ensure sufficient levels of survivability to successfully undertake the strike missions. The decoy/ARM partnership or the Harpy concept should both be given greater consideration in structuring the ADF for operations beyond 2000.

Summary

The potential use of UAVs in offensive roles is obvious from their ability to accurately strike targets whilst reducing the probability of attrition to manned aircraft. While cruise missiles have been technically accepted as operationally successful for over a decade, the psychological barrier to the acceptance of re-useable platforms has yet to be overcome. Regardless, within ten years, UCAV platforms will be operating as technology demonstrators, with operational systems achievable by about 2015. Consideration of these platforms by the ADF will depend on their maturity at critical decision points and, of course, their availability to the Australian market.

As previously discussed, UAVs unlikely to replace the F/A-18 or the F-111. As the year of decision for their replacements will be approximately the 2010-2015 period, it is unlikely that UCAVs will be either operationally mature or available for procurement outside the US within that time-frame. However, Australia may consider the acquisition of cruise missiles to provide sufficient strike capability, given the range and payload limitations of most replacement candidates and the cost and political impacts of the F-111's nearest contender, the B-1B.

Chapter 13

The Potential Utility of UAVs in the ADF Force Structure

Utility for the ADF

While *Australia's Strategic Policy* emphasises that 'Defending Attacks on Australia is the core force structure priority, Operations Other Than War (OOTW) and peacetime tasks are far more likely to involve ADF participation. The utility of UAVs and other defence platforms in performing these other tasks arguably warrants some consideration. While a platform must predominantly satisfy the requirements for national defence, its contribution to other roles should also be considered a measure of its total worth to Australian national interests and security.

Utility Across the Spectrum of Conflict

United Nations Activities

Over the past two decades, the ADF, like other defence forces, has been predominantly employed in Operations Other Than War (OOTW), consisting primarily of peacekeeping and peace enforcement operations. Military forces worldwide have dedicated enormous resources to these operations, directed at alleviating human suffering and promoting peaceful outcomes to conflict. As participation in these activities is seen by many nations as their contribution to global security and one of moral necessity, it is accordingly considered an important military activity. While the trend for Operations Other Than War activities appear to be increasing, few military forces use these activities as a basis for force structure.[1] Fortunately, balanced force structures enable significant contributions to these operations. Even platforms normally associated with medium to high level conflicts are useful, such as the tactical strike aircraft used in Operation *Deliberate Force* over Bosnia.[2] While it is fitting to build force structures appropriate for the ultimate defence of the nation, there is a need to achieve a flexibility for employment across the spectrum of conflict. Hence, consideration should be given to the utility of platforms and weapons systems in OOTW, given the frequency with which these operations arise.

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[1] *Peacekeeping Policy: The Future Australian Defence Force Role*, Department of Defence, Canberra, 1993, p 3.

[2] Air Vice-Marshal T. Mason, 'Air Power in Operations Other Than War: The Case for Involvement', in A. Stephens (Ed.), *New Era Security*, Air Power Studies Centre, Canberra, 1997, p 122.

As demonstrated in Bosnia, UAVs provide a useful reconnaissance platform for those missions posing considerable risks to manned aircraft. Low tolerance to the loss of life in United Nations (UN) missions has increased the utility of UAVs.[3] These platforms provide valuable information to troops on the ground and can be used to monitor activities at a significant distance, obviating the need to risk manned aircraft.[4] Additionally, their operating altitude and sensor range enables UAVs to gather information without alerting those on the ground to the fact they are being monitored.[5] In conflicts such as that recently waged in Zaire, the UAV could be instrumental in tracking small bands of refugees, thereby reducing the exposure of patrols to the risks of potential rebel activity and land mines. UAVs also have the potential to act as communication relay stations, which are useful in providing cost effective communications to UN forces in areas with a limited communications infrastructure.

Figure 13.1 illustrates an example of the utility of UAVs. In this figure Global Hawk is shown on a surveillance task over Cambodia. The aircraft is capable of flying from Darwin to Cambodia return, with over 20 hours on task.

Paramilitary Activities

The South Africans have used UAVs very successfully to conduct border patrols and to undertake other paramilitary activities, including surveillance of rebel groups.[6] While these activities are not currently applicable in the Australian context, other paramilitary activities including counter-terrorism responses may be supported by UAVs. Hostage scenarios on oil rigs, for example, could be monitored by UAVs operating at high altitudes to reduce the risk of detection or loss.

Peacetime Roles

The perception of Australian national security is evolving to incorporate issues beyond the traditional concept of the physical defence of the nation. In particular, Buzan identifies five major dimensions to national security: military security, political security, economic security, societal security and environmental security.[7] Economic and environmental security are fast gaining acceptance as issues which require more immediate attention. The utility of various platforms within the ADF in contributing to these non-defence security tasks, therefore, warrants some consideration.

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[3] Fulghum, 'Unmanned Strike Next for Military', p 48.

[4] D.A. Fulghum, 'Predator to Make Debut Over War-Torn Bosnia', *Aviation Week & Space Technology*, 10 July 1995, p 47.

[5] A. Venter, 'Hide and Seek', *Flight International*, 11 February 1997, pp 31-32.

[6] *Ibid.*, pp 31-32.

[7] Buzan, quoted in J. McFarlane and K. McLennan, *Transnational Crime: The New Security Paradigm*, Working Paper No 294, Strategic and Defence Studies Centre, Australian National University, Canberra, May 1996, p 4.

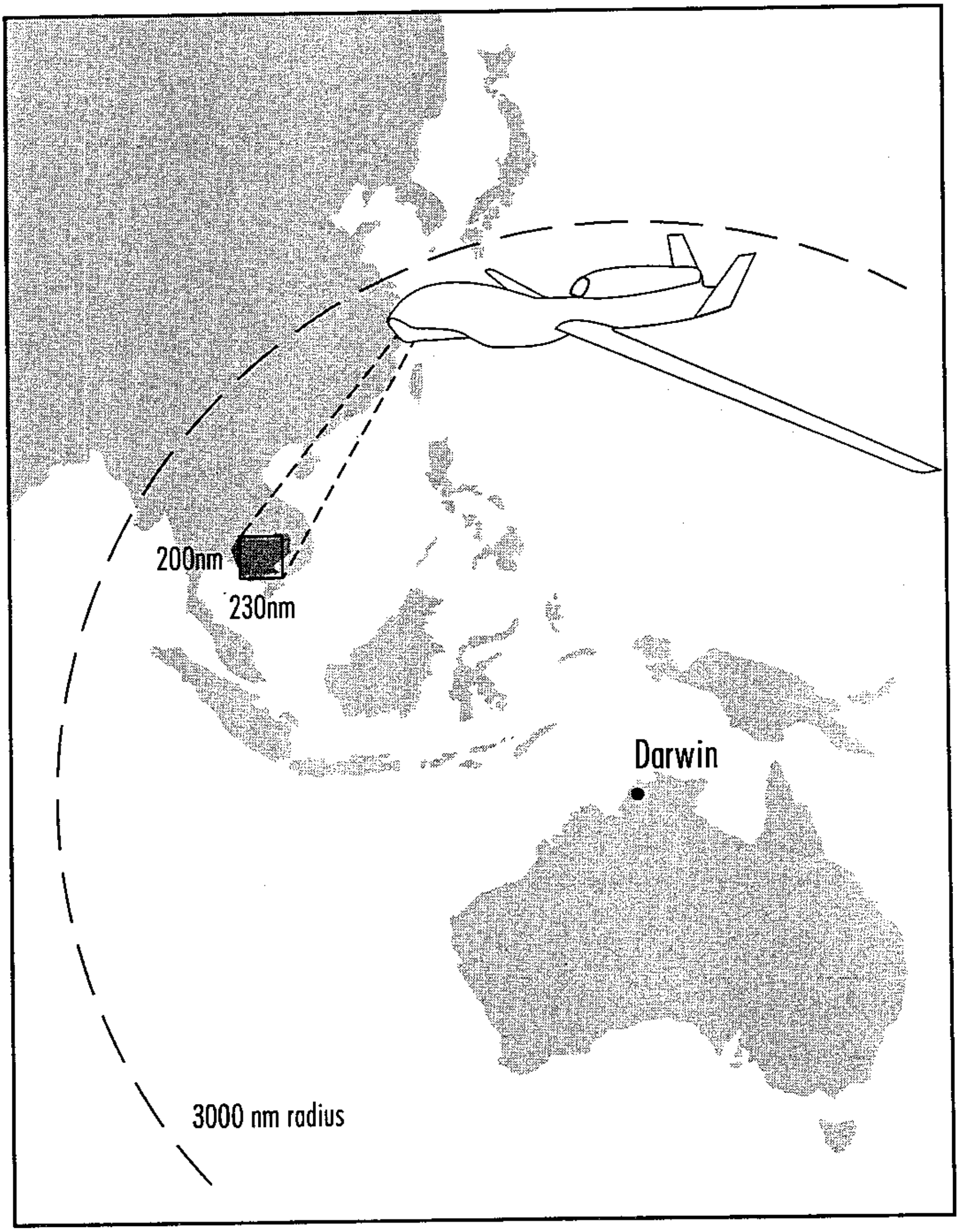

Figure 13.1: Global Hawk employed in support of peacekeeping operations over Cambodia.

Illegal Fishing and Illegal Immigration

The Australian Prime Minister's announcement that the government will develop a strategy, using satellite imaging, to address the issue of illegal fishing reveals the importance the Australian government places on the protection of Australian resources.[8] Indeed, the protection of marine resources within national EEZs is an issue gaining increasing global attention. Some consider it an issue linked to the defence of sovereign territory. This is particularly evident in archipelagic and littoral Asia-Pacific nations, where fishing resources provide a major proportion of their food source.

As an indication of the incidence of illegal fishing and immigration activities in Australia, Coastwatch made 105 arrests of fishing vessels and detected 16 illegal entry vessels within the eight month period up to February 1995. These figures are double the number of such incidents from previous years.[9] There is difficulty in determining whether these figures represent an increasing trend in the incidence of illegal fishing and illegal immigrants or results of more effective surveillance methods. However, it would be true to say that, given the limited Coastwatch resources, the detection figures represent but a portion of activity occurring in the sea-air gap. Indeed, notable examples exist of Australia's failure to detect incursions. The arrival of Chinese refugees in Western Australia in 1992 highlighted the inability to comprehensively protect Australian shores from intrusion. Other incidents included the arrival of vessels in Broome and Darwin in 1994 and the abduction of the Gillespie children.[10] Air Marshal Evans (Retired) also pointed to the gap in surveillance coverage, stating, 'Illegal immigrants and drug couriers already [enter from the north], and in the dry season they can land just about anywhere'.[11]

Like satellites, UAV technology can be applied to monitor incursions into Australia's EEZ. The broad area sweeps are capable of covering large surface areas whilst spot targeting will enable sensors to focus on surface activity and provide greater detail on vessels. Drug trafficking activities can be monitored or deterred through airborne platforms. UAVs can either covertly monitor activities or project a presence, thereby deterring illegal activities. Manned or unmanned airborne surveillance aircraft would work closely with Coastwatch and naval vessels in these activities.

Defence Assistance to the Civil Community

Environmental monitoring is another role which is suited to UAV platforms due to their ability to attain high altitudes. Research on bush fires, cyclones and other environments which endanger manned aircraft, through smoke inhalation, heat or high winds, are a further application for UAVs. Israel Aircraft Industries (IAI) has recognised this commercial

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[8] J. Woodford, 'Satellite imaging to counter illegal fishing', *The Sydney Morning Herald*, 4 March 1997, p 6.
[9] G. Giles, 'Coastwatch - The Surveillance Task', in Bergin, A and Osman M.S.S., (eds), *National Coordination of Maritime Surveillance and Enforcement*, Australian Defence Studies Centre, Canberra, 1996, p 25.
[10] *Ibid.*, p 25.
[11] C. Miranda, 'Our Defences are down: Drugs, illegal immigrants hop through northern gaps', *The Daily Telegraph*, 28 April 1997, p 17.

application and has employed tactical UAVs for bush fire monitoring in the United States. Similarly, the Australian Bureau of Meteorology employs UAVs to monitor and research cyclones and other weather phenomena.

Owing to the relatively limited market for UAVs, however, an excess ADF UAV capacity could be hired out to other agencies when it is not being tasked for military purposes. Alternatively, UAVs can perform both military and civil functions during a single mission. During bush fires or other emergencies the UAVs could similarly provide assistance to the civil community. While these incidents occur infrequently, the public relations coverage resulting from the employment of ADF resources generates valuable public support for defence activities.

As demonstrated by the 1996-97 rescues of British and French yachtsmen in the Southern Ocean, defence assets provide an important contribution to search and rescue operations. The endurance of contemporary UAVs, coupled with sensors capable of day/night and all-weather operations, lend themselves to this type of activity.

Regional Engagement

The increased importance of the region to Australia's security interests is acknowledged throughout *Australia's Strategic Policy.* Under this policy an increasing emphasis has been placed on Defence becoming more active in shaping the strategic environment to Australia's best advantage. Australia has embraced a theme of strategic engagement, establishing closer defence relations through collaborative industry ventures, joint exercises, attachments and an exchange of visits. This approach further develops bilateral and multilateral relationships, contributing to interdependence and, hence, the stability of the region. Additionally, combined exercises with other nations in the region ensure Australian '...forces can operate jointly in support of regional security'.[12]

The policy of increased regional engagement has come about with the recognition that the security of the region directly affects Australia's security. Group Captain S. Gray clarifies this posture:

> The primary objective of Australia's regional defence engagement is not to defend the region, but to use defence relationships with regional countries to contribute to our own security. This approach also enhances the security of the region as a whole.[13]

In determining the activities that can contribute to regional stability and security, there is a need to identify first the nature of threats that may emerge to upset the security of the region.

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[12] *Ibid.*

[13] Group Captain S. Gray, 'Royal Australian Air Force Regional Defence Engagement', in Wing Commander K. Brent (Ed.), *Regional Air Power Workshop - RAAF Richmond, 17 to 19 September 1996,* Air Power Studies Centre, Canberra, 1996, p 15.

Regional Strategic Environment

In the post-Cold War period, the Asia-Pacific region continues to be characterised by high economic growth. The booming Asian economies are generating better standards of living, greater political influence, and more substantial Gross Domestic Products (GDPs) with which to further develop national infrastructures and economic capacities. The protection and maintenance of continued economic growth has therefore become the primary focus of many of the nations in the Asia-Pacific region. In pursuing strategies to sustain this economic growth, the protection of, and greater access to, natural resources have been emphasised. In particular, there is evidence that off-shore resources are being given increased attention by nations in the region.[14]

The potential wealth offered by maritime resources including fisheries, oil and gas deposits, therefore, has the potential to increase tension within the region, particularly in the South China Sea. As a case study, the dependence on fishing activities and seaborne trade by the Association of South-East Asian Nations (ASEAN) nations for sustained economic growth has resulted in concern over China's proclamation of the South China Sea as an inland lake of Chinese sovereignty. Competition for marine resources is likely to increase as stocks reduce due to over-fishing and pollution.[15] Illegal fishing and pollution, as well as aggressive military actions, are therefore issues of significant concern within the region.

Disruption of sea trade is also an issue of concern, given that most nations are dependent on safe and open sea lanes of communication for export purposes, as well as for the importation of energy resources. Singapore and Japan both depend on trade by sea for their requirements for oil and other energy resources.[16] Sea Lanes of Communication (SLOCs) are vulnerable to threat by military force and piracy, particularly where they converge or pass through choke points. Maintaining safe and open SLOCs, therefore, is a security issue for most nations within the region, as well as being a concern to others transiting through such choke points to Asian and other export markets. The security of SLOCs is vital to Australia's economic interests because over 90 per cent by weight of its exports are sea-borne.

There are several points of tension which have the potential to introduce conflict into the region. Many of these have an economic basis or are bound up with economic interests. Greater economic interdependence, therefore, is seen by many as a means of reducing the potential for conflict. Where nations depend on others for their own economic prosperity, it is unlikely they will threaten this prosperity by increasing the level of friction through military or other activities. The general approach to increasing regional security is based on strengthening political, military and economic relationships on bilateral and multilateral levels. These are further developed through the establishment of collaborative and cooperative arrangements which provide mutual benefit to participants, whilst further

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[14] J. Mohan Malik, 'Sources and Nature of Future Conflict', in Malik, J. Mohan (Ed), *The Future Battlefield*, Deakin University Press, Geelong, 1997, p 61.

[15] Wing Commander R.W. Grey, *A Proposal for Cooperation in Maritime Security in Southeast Asia*, Working Paper No 274, Strategic and Defence Studies Centre, Australian National University, Canberra, July 1993, p 5.

[16] Malik, 'Sources and Nature of Future Conflict', pp 61-62.

increasing the economic prosperity of participating nations in achieving economic prosperity. In this regard, Australia's initiative to form the Asia-Pacific Economic Cooperation forum has received wide support.

Australia's Approach to Regional Engagement

In contributing to regional security and stability, Australia's approach to regional engagement necessarily focuses on activities aimed at providing collective security through mutual benefit. The level and form of these activities vary with each nation, according to the characteristics of each bilateral relationship. In general terms, however, Australia has adopted two forms of contribution, based on sub-regions: one is a strategy of Constructive Commitment with nations of the South Pacific while the other is Comprehensive Engagement with South-East Asia.

Constructive Commitment in the South Pacific

Australia's contribution to the maintenance of security in the South-West Pacific is based on the awareness that any perceived threats to national livelihood differ from those of South-East Asia. The level of infrastructure and associated defence capability to protect national interests also differs significantly from that of the rest of the region. Accordingly, Australia's commitment to the South-West Pacific nations focuses on building the defence capabilities and protecting natural resources for those nations. Under the Pacific Patrol Boat (PPB) project, for example, Australia has provided patrol boats to the island nations enabling them to enforce their 200 nautical mile Economic Exclusion Zones (EEZ).[17] These boats are vital in protecting the economic interests of the South Pacific nations, while concurrently benefiting Australia by reducing illegal activities in the respective areas through their surveillance activities. In a similar fashion, RAAF AP-3C Orion patrols and other Defence Cooperation Program (DCP) initiatives serve both the receiving nation's interests, whilst providing Australia with intelligence information and contributing more generally to the overall security and stability of the region. The potential to employ UAV platforms for undertaking similar tasks is substantial. Surveillance can be undertaken to detect illegal fishing, drug trafficking and to provide scientific data on environmental conditions. In addition, UAVs can be used to monitor environmental degradation, thereby facilitating planning for sustainable, environmentally friendly industries.

Comprehensive Engagement with South-East Asia

Australia's involvement in South-East Asia and the methods of contributing to regional security are less tangible. Relationships with South-East Asian nations are increasingly based on mutual participation and equality, rather than on client/provider arrangements. Activities in this region are, therefore, more focussed on strengthening bilateral and multilateral ties between Australia and nations within the region. Australia hopes to further develop collective

[17] Desmond Ball, *Building Blocks for Regional Security: An Australian Perspective on Confidence and Security Building Measures (CSBMs) in the Asia/Pacific Region*, Canberra Paper on Strategy and Defence No 83, Strategic and Defence Studies Centre, Canberra, 1991, p 3.

and collaborative security arrangements through participation in political, economic and security forums. In pursuing a military contribution to regional security, Australia has adopted a strategy of incremental steps, known variously as Confidence and Security Building Measures (CSBMs) or Trust Building Measures (TBMs).

Incremental Steps to Regional Engagement

Any substantive Australian contribution to regional security will need regional acceptance. Such acceptance will come about only after the development of mutual trust and confidence. Therefore, the potential role of UAVs in regional security should be examined in light of documented TBMs. Assuming these TBMs have some acceptance within the region, they will be considered here as likely activities that Australia may undertake.

Paul Dibb has proposed a number of TBM activities, beginning with increasing contacts with regional nations through exchange postings, high level visits, seminars, workshops and exercises.[18] Areas for future cooperation may incorporate activities such as increased dialogue on regional security and an exchange of information, including information on piracy and drug control.[19] Long term activities, which will only be possible once a level of trust has been achieved, may include developing zones of cooperation, notification of military deployments, conventions on the maritime environment and maritime surveillance proposals.[20] Potential UAV roles might include combined exercises, peacekeeping activities, participation in non-defence related surveillance, and military surveillance.

In particular, the potential employment of UAVs in an Asia-Pacific maritime surveillance regime, as proposed by Dr Noordin Sopiee, will be examined. The scope of this paper is insufficient to speculate on the likelihood or nature of a regional surveillance regime. However, the proposed surveillance regime provides a means of evaluating Australian participation in a scheme. Indeed, analysts believe the concept has substantial merit, given that maritime surveillance activities can be tailored to suit the requirements and sensibilities of the region.[21] Surveillance over international airspace can effectively be used to detect illegal activities, violations of agreements and treaties and to monitor environmental degradation. In summary, a maritime surveillance regime could achieve the following:[22]

- monitor the region for violations of the Zone of Peace, Freedom and Neutrality (ZOPFAN) and deter state-sponsored threats through the provision of a visible demonstration of strength, determination and unity of purpose;
- provide capabilities for protecting the maritime interests of participating nations;
- detect and monitor intrusions to the region by external interests;

[18] P. Dibb, *How to begin implementing specific trust-Building Measures in the Asia-Pacific Region,* Strategic Defence Studies Centre, Working Paper No 288, Canberra, July 1995, p 13.
[19] *Ibid.*, p 13.
[20] *Ibid.*, p 13.
[21] Grey, *A Proposal for Cooperation in Maritime Security*, p 17.
[22] *Ibid.*, p 18.

- monitor the region for violations of the South-East Asian Nuclear Weapon Free Zone (SEANWFZ) and assist with its enforcement;
- help preserve the SLOCs from interference by military forces, pirates, pollution or accidents;
- contribute to the protection of the environment and resources;
- contribute to transparency through information sharing;
- establish and practice a regime for avoidance of accidents at sea; and
- establish a working base to build more comprehensive joint capabilities for peace enforcement if required.

The contribution that UAVs could make in these roles will be discussed in further detail.

Military Surveillance

Owing to the sensitive nature of military surveillance, or surveillance for military purposes, limited opportunities exist for contribution within the region. A notable exception is the combined Malaysian and Australian maritime surveillance, based on missions conducted in South-East Asian waters from the Royal Malaysian Air Force base at Butterworth.[23] These military surveillance operations are conducted within the parameters of strictly defined areas of operation for mutually agreed surveillance objectives.[24] Within predefined parameters, UAV operations could possibly complement the surveillance activities currently performed by Australian AP-3C Orions.

Similarly, where joint military surveillance activities are impractical or improbable, the possibility exists of contributing to regional security through intelligence sharing. This concept has already been proposed by senior military officials and academics who have suggested that access could be provided to information collected by the JORN system.[25] Likewise, information collected from UAV surveillance operations in international airspace could be provided to enhance transparency and contribute to regional security. Owing to national sensitivities to military surveillance, the greatest potential for this activity lies with the less intrusive forms of maritime surveillance.

Surveillance of SLOCs

The security of safe passage of merchant ships through sea lanes of communication has been given increased focus with the globalisation of the world economy.[26] Areas of particular concern include straits and other choke points. In the Straits of Malacca, for example, there

[23] R. Swinnerton, 'The Role of the Australian Defence Force in Maritime Surveillance in Southeast Asia', A. Bergin and M.S.S. Osman, *National Coordination of Maritime Surveillance and Enforcement*, Proceedings of a Joint Workshop organised by the Australian Defence Studies Centre and the Maritime Enforcement Coordinating Centre at Lumut, Perak, 29-30 May 1995, Australian Defence Studies Centre, 1996, p 93.
[24] *Ibid.*, p 93.
[25] Interview with Air Marshal S.D. Evans (Retired) suggested this was an area which should be given further consideration by Australia.
[26] B.A. Hamzah, 'The Security of Sealanes: The Search For An Equitable Straits Regime', *Asian Defence Journal*, 6/93, p 6.

are significant environmental problems arising from the increased accident rate between seagoing vessels, particularly, when they result in the spillage of oils or other hazardous goods.[27]

In response to worsening conditions, Malaysia, Singapore and Indonesia have undertaken research into establishing a surveillance system to enable better control of traffic within the Straits.[28] The current proposal is to establish radar centres to monitor traffic with the funding for this venture to be met in part by other user nations.

Monitoring of trading activity and increased military activities is beyond the surveillance capabilities of any one nation but may be addressed through a collective approach. An Australian contribution to this tripartite arrangement could be an acceptable form of engagement.[29] Indeed, the RAAF already conducts limited surveillance of shipping routes. Operation *Burbage* patrols involving AP-3C Orions, for example, overfly the major shipping routes in the Indian Ocean. Similarly, *Gateway*, a joint Australian-Malaysian surveillance program, covers the Indian Ocean and the South China Sea from Sri Lanka to the Spratly Islands.[30] Exercises *Kakadu, Starfish, Penguin* and *New Horizon* represent further vehicles for regional cooperation through maritime air operations. There is great potential, therefore, to include UAV operations which are tailored for long endurance maritime surveillance.

Joint surveillance activities need to be encouraged to enable the protection and further development of collaborative projects and agreements. For example, the Zone of Cooperation between Australia and Indonesia in the Timor Sea allows for joint surveillance and economic exploitation; however, this has not yet been realised to full potential due to sensitivities by both countries.[31]

Piracy

In the ASEAN 53 point communique of the 29th Annual Ministerial Meeting, members agreed to 'focus attention on such issues as narcotics, economic crimes (including money laundering), environmental protection and illegal migration which transcend borders and affect the lives of the people in the region'.[32] This statement reflects the increasing focus ASEAN places on non-defence security issues.

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[27] *Ibid.*, p 10.
[28] J. Fernandez, 'KL, Singapore, Jakarta Study Surveillance System in Strait', *Asian Defence Journal*, 4/93, p 80.
[29] Interview with Wing Commander I. MacFarling, 19 June 1997.
[30] Group Captain S. Gray, 'RAAF Aspects of Regional Engagement Policy', in J. Harvey & M. Lax (eds.) *Regional Air Power Workshop - Townsville, 4 to 8 September 1995*, Air Power Studies Centre, Canberra, 1995, p 68.
[31] Desmond Ball, *The Joint Patrol Vessel (JPV): A Regional Concept for Regional Cooperation*, Working Paper No 303, Strategic & Defence Studies Centre, Australian National University, Canberra, October 1996, p 2.
[32] M. Brooke, 'ASEAN's 29th Annual Ministerial Meeting Welcomes Myanmar as an Observer', *Asian Defence Journal*, 9/96, p 11.

While cooperative efforts between South-East Asian nations have reduced the incidence of piracy in particular areas, criminal activity continues to threaten the safe passage of merchant ships through the region. The International Maritime Bureau indicated that Indonesian waters were the location of the greatest number of incidents in 1996; the waters off Thailand held the second highest figure. In all, 45 piracy attacks were reported in South-East Asian waters in 1995.[33] Efforts to address the increased incidence of piracy in the region have led to bilateral agreements between ASEAN nations. Grey argues, however, that 'Piracy may only be deterred by a patrol and surveillance program',[34] and proposes joint maritime surveillance and information sharing as the best means of counteracting this problem.

Illegal Fishing

Australia currently operates AP-3C aircraft around Papua New Guinea, the Solomon Islands, the Cook Islands, Tonga, Kiribati, Vanuatu and Western Samoa in the *Solania* patrols designed to support the Foreign Fisheries Regime.[35] The use of UAVs to complement AP-3C operations could greatly enhance the effectiveness of the Foreign Fisheries Regime, given their capability to remain on station for longer periods than manned platforms. While Australia does not contribute to fisheries surveillance in South-East Asia due to 'the complexity of EEZ claims, the fishing vessel density, and the complexity of the general shipping plot',[36] UAV operations could possibly complement other forms of surveillance, where required.

Regional Cooperation and Interoperability

The sum of these activities provides tangible results, builds trust and increases regional cooperation and interoperability. Further, Australia currently engages in between 20 and 30 exercises a year involving one or more ASEAN nations. These exercises are an important contribution towards developing regional cooperation and increasing the level of interoperability between forces. Desmond Ball notes that the exercises have increased in scope and sophistication, as well as regularity, involving '... some of the most sophisticated capabilities in the respective defence forces, and the exercise scenarios have generally become more fruitful with respect to the promotion of closer cooperation and confidence building'.[37] The exercises help to increase the level of interoperability of common platforms and the mutual understanding of operational doctrine, and command and control systems. This interoperability is of significant importance in any future peacekeeping effort or operational activity involving a regional coalition force.[38]

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[33] 'Piracy on the Rise', *Asian Defence Journal*, 9/96, p 73.

[34] Grey, *A Proposal for Cooperation in Maritime Security*, p 3.

[35] Group Captain G.W. Waters, 'Regional Air Power Cooperation', in G.W. Waters & M. Lax (eds.), *Regional Air Power Workshop - Darwin, 23 to 25 August 1994*, Air Power Studies Centre, Canberra, 1994, p 20.

[36] Swinnerton, 'The Role of the Australian Defence Force in Maritime Surveillance in Southeast Asia', p 96.

[37] Ball, *The Joint Patrol Vessel (JPV)*, p 9.

[38] Hon I. McLachlan, *Defence Policy and Regional Cooperation with Asia,* Address presented to the Government Defence, Trade and Foreign Affairs Committee, Canberra, 3 December 1996, pp 1-3.

Peacekeeping Operations

As Australia views regional peacekeeping activities as a means of contributing to regional stability, it actively seeks to participate in such operations. The use of UAVs to support peacekeeping forces as communication relays, or for reconnaissance and surveillance will become more common after the success of the Predator system in Bosnia. Peacekeeping activities, whilst not always dangerous, often involve continuous observation and monitoring. Given these types of roles, Australian peacekeeping contributions may see an increased use of such systems and a concurrent reduction of personnel required on the ground. This is in keeping with Australia's emphasis on providing units with relatively superior technical capabilities, rather than units with more basic skills.[39]

Any plan to employ platforms such as UAVs in a regional peacekeeping activity should take into consideration their acceptance by regional nations. The development of a regional understanding of UAVs through their visible employment in combined exercises, therefore, is fundamental. Furthermore, given that regional peacekeeping scenarios such as Cambodia, are likely to involve participation from a number of regional nations, familiarity with UAV operations will enable ground forces to access operational products. This concept may even be extended to 'handing over control' of the platform for a given time and space. This 'sharing' arrangement was considered by the US armed forces, where the USAF would control Predator's take-off and landing, but could hand over to the Army at a given rendezvous point (command and control disagreements have prevented this from occurring).[40] Consideration by regional nations of establishing a level of commonality through the acquisition of common Mission Control Stations would further enhance interoperability. This consideration points to the need to develop familiarity with UAV operations for furthering interoperability and developing regional acceptance of the platforms.

Limitations to Regional Engagement

While there are many activities where Australia can contribute to regional security, there are limitations. Even for activities considered to be mutually beneficial and non-defence related, difficulties can be encountered. For example, Australia has experienced significant difficulty in conducting land and mapping aid projects, such as a recent refusal for an oceanographic study in Indonesian waters on the effects of the Java current and its contribution to the El Nino effect.[41] The study was to be conducted from the *Franklin*, a civilian research vessel with Australian, US and Indonesian scientists. However, Indonesian authorities are said to be sensitive to oceanographic research as it can have significant military applications, such as mapping passages for submarines to avoid detection.

The preceding examples demonstrate that, despite the potential for UAVs and other surveillance platforms to contribute to the protection of economic and environmental security interests, national sensitivities to these capabilities are, and will remain, strong. The utility of

[39] *Defending Australia 1994*, p 105.

[40] Anecdotal evidence provided by Wing Commander S.W. Filmer, 6 May 1997.

[41] 'Indonesia Stops Foreign Oceanographic Study', *Asian Defence Reporter*, 1/96, p 66.

UAVs in contributing to regional security will be dependent on regional perceptions of their capabilities, Australian sensitivity to their employment outside the Australian EEZ, the level of access given to their product, and affirmative steps to promote them as platforms to enhance regional security.

Summary

UAVs are readily seen to be capable of providing suitable reconnaissance and surveillance capabilities for the ADF. Additionally, their capability for endurance addresses the particular requirement for surveillance in the Australian context. The potential utility for employment in non-defence roles further promotes UAVs as cost-effective and flexible platforms that can be employed across a spectrum of conflict increasing in the post-Cold War era. In particular, UAVs offer capabilities for monitoring operations for peace enforcement and peacekeeping operations, with minimal risk to Service personnel.

Furthermore, UAVs may be utilised during peace to contribute to non-defence security tasks, greatly enhancing existing capabilities for the protection of Australian fisheries, detection of illegal activities and provision of assistance to the civil community. Arguably, maintaining a valid and responsive surveillance capability in peace through complementary tasking with Coastwatch activities, better prepares the ADF for responding swiftly to the potential occurrence of short-warning conflict.

While these tasks should not determine ADF force structure, platforms which contribute to other elements of national security, particularly through peacetime roles, may represent more cost-effective force structure options. Furthermore, UAVs can be useful as part of Australia's contribution to regional security.

Given the emphasis for an integrated approach to force capabilities, reconnaissance and surveillance platforms that contribute to national security should be given a weighting for capabilities where they complement rather than duplicate. For example, a surveillance UAV will tend to be more cost-effective through widespread use of the system. Should Project JP129 acquire a UAV platform for airborne surveillance of land operations, it will most likely be employed in the role for major exercises, contingencies and possibly peacekeeping roles. Overall, the system could effectively be employed for as little as 40-50 per cent of the year. The alternative for a UAV platform is to view it as an ADF asset, and employ it for coastal and maritime surveillance. The asset, therefore, would be contributing to national security tasks as opposed to being treated as an organic asset for a Service in roles where the sensor package may possibly be under-utilised.

Section Four

Challenges to the Introduction of Uninhabited Aerial Vehicles

Introduction

From the previous sections, UAVs have been demonstrated as cost and operationally effective platforms for undertaking a number of ADF missions. With advances in technology and improvements in reliability, UAVs are becoming increasingly competitive alternatives to manned and space-based systems for a growing number of missions. But the introduction of UAVs into the ADF faces several significant challenges. At the forefront is the issue of culture, the 'pro-pilot' bias, which exists across the three Services, but predominantly in Air Force. This bias is considered by the US to be one of the primary reasons for the slow development and acceptance of UAVs into their armed forces, but most particularly the USAF.[1] Overcoming the pro-pilot bias is key to enabling an unbiased analysis of UAVs as options in meeting various ADF force capability requirements.

Cultural acceptance of UAVs by Australian community in general will also be an issue requiring early resolution. If UAVs are to provide utility in peacetime and low level operations, flexible airspace regulations must be developed to enable regulated UAV operations for performing ADF tasks. Cooperative development of airspace regulations, including benchmark standards for navigation systems and civil accreditation of engines, between the authorities and operators will be critical to the widespread acceptance of UAVs by the larger community. Public demand for accountability is also likely to influence the type of UAV systems deemed acceptable for operations in civil airspace. Those UAV systems required to overfly or transit controlled airspace are likely to require, for example, 'man-in-the-loop' functions to satisfy public accountability.[2] These legal requirements will extend to UAV employment in both controlled and uncontrolled airspace. Resolving airspace control issues will be one of the greatest challenges to UAV operations over the battlefield and in civil airspace.

These challenges to the effective introduction and optimisation of UAVs as defence assets are examined in the following section. While comprehensive solutions to these challenges are not offered, this section focuses on issues requiring further research and development by agencies both within and outside the defence organisation. Inadequate resolution of these issues prior to the acquisition of UAV systems may result in the development of ineffective, ad hoc procedures, with a consequent under-utilisation. Alternatively, UAVs may be rejected as competitive options in force capability considerations due to the belief that these challenges represent insurmountable barriers to their effective employment. In truth, most of these challenges, such as security of datalinks and legality of stand-off weapons, will become increasingly applicable to manned systems using advanced technologies. Resolution of the issues for unmanned systems, therefore, will also resolve similar issues affecting manned operations.

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[1] B.W. Carmichael, T.E. DeVine, R.J. Kaufman, P.E. Pence, & R. Wilcox, *Strikestar 2025: A Research Paper Presented To Air Force 2025*, US Department of Defence, August 1996, p 21.
[2] *Ibid.*, p 28.

Chapter 14

Political Factors

One subject given little formal consideration in force capability proposals is the potential political ramifications that may be associated with the employment of the various weapons systems options. In considering the introduction of UAVs to the ADF, two political factors should be examined. The first is the greater potential offered by UAVs to enable governments' political freedom of action. The ability to employ unmanned systems without risking loss of life has been recognised at the highest levels of government.[1] Unfortunately, the advantage offered by this attribute may be counterbalanced by the negative effect of these systems resulting from a possible escalation of the conflict. As an example, the employment of cruise missiles may escalate a crisis, where a 'display' of force may have achieved the desired political outcome. More generally, the benefits obtained through the acquisition of UAVs for the ADF may be offset by the widespread introduction of similar capabilities across the region. Regional implications of ADF acquisition of UAVs, especially those with strategic application is, therefore, an issue worth further examination.

Regional Implications

Australia is increasingly sensitive to the effect on regional stability and security resulting from a change to ADF force structure. Force capability improvements are comprehensively justified in terms of the defence of national interests. Regional reactions to new systems, particularly those representing capability improvements, will have some weighting on the relative competitiveness of systems in providing such capabilities. Any acquisition with the potential to ignite a regional arms race or disrupt the current balance of power, is seen as contradictory and counterproductive to Australia's desire for regional stability in Asia-Pacific.[2] Given the prevailing absence of long-range cruise missiles in South-East Asia and the South Pacific, the potential introduction of such weapons by Australia could encourage the acquisition of similar systems by other states in the region. While this may not directly affect Australia's security, it could threaten the security of other nations, thereby disrupting the relative stability that currently exists within the region.

The use of cruise missiles as a 'force projection' capability is by now well established among defence commentators. Similarly, aircraft carriers, nuclear submarines, air-to-air refuelling aircraft and long range ballistic missiles all represent force projection capabilities which are

[1] Cruise missiles were employed over Iraq in mid-1990s to send political messages to the government of Saddam Hussein. It is unlikely the US would have risked manned crews in these political manoeuvring.
[2] L. Murdoch, 'Split over plans for missiles', in *The Age*, Saturday, 23 August 1997, p 1.

difficult, though not impossible, to justify within the context of a defensive posture. Well-argued cases for these types of systems are fundamental to general regional acceptance of the potential acquisition of these capabilities by Australia. Regional reactions to the possible acquisition of non-lethal UAVs and to UAVs with the potential for lethal and non-lethal payloads are important to Australia.

The presence of several tactical UAV systems in South Korea, India, Thailand and Singapore indicates a high level of acceptance of these systems in support of ground forces. Such acceptance to UAVs with strategic applications is, however, a little more difficult to gauge. This is complicated, for UAVs fitted with hard-points, by the potential to utilise these for lethal payloads, thereby representing a system with capabilities similar to long-range cruise missiles.

In determining the regional reaction to the acquisition of new lethal and non-lethal capabilities with strategic reach, the reactions to Australia's F-111 fleet and the more recent purchase of 15 F-111G aircraft should provide some insight. Other examples are the JORN and AP-3C capability. As the platform representing the manifest capability for force projection operations, Australia's F-111 fleet represents the far end of the scale. Consideration of the regional acceptance of the F-111 capability should be tempered by the understanding that it is an inherently offensive platform and should not be taken as a direct indication of the reaction to a platform utilised for defensive purposes. Since its acquisition, the F-111 fleet is now generally well accepted by most regional countries due to the passage of time since its procurement. Indeed, it may be argued that except for Indonesia, the region was relatively agreeable to the acquisition decision in 1963 due to the tensions surrounding 'Konfrontasi'. The 1992 purchase of an additional 15 F-111G aircraft did, however, draw some comment from the region. The Indonesian ambassador to Australia, Sabam Siagian, indicated the purchase could 'raise possible scepticism (in Asia) about Australia's seriousness in security cooperation'.[3] Gary Brown also saw the acquisition as sending confusing signals to the region.[4] Regional acceptance of Australia's JORN capability is more difficult to gauge, particularly as its capabilities and reliability have been developing at what can only be described as an evolutionary pace.

Australia's concern about regional reactions to such acquisitions may, however, be more an indication of Australia's reluctance to put its regional relationships at risk. Many nations in the region have increased their maritime forces with little comment from their regional neighbours. Indeed, as all nations are becoming more aware of the need to defend their maritime interests, there appears to be a level of acceptance of each nation's requirement to modernise their forces in line with the growing responsibilities associated with the adoption of a 200 nautical mile EEZ.

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[3] C. Klassen, 'F-111G Deal at Final Stage', *Asian Defence Journal*, 3/93, p 100.

[4] G. Brown, *Australia's Security: Issues for the New Century*, Australian Defence Studies Centre, Australian Defence Force Academy, Canberra, 1994, p 205.

Worthy of consideration is the region's reaction to acquisitions by some of its members. For example, the *Asian Defence Journal* reported that 'Thailand ... surprised its regional neighbours by suggesting that it should allocate US$1 billion to the acquisition of a 'spy' or reconnaissance satellite to monitor the country's borders with Myanmar and Cambodia'.[5] While the article does not provide the reaction from the rest of the region, the tone and title of the article, 'And Perhaps a Spy Satellite Race as well?', reflect a level of concern.

Any consideration given by Australia to acquiring UAVs should also be based on the regional acceptance of these platforms generally. For example, as other nations in the region acquire similar capabilities, there is less likelihood these platforms will be viewed with undue concern. Australia would be merely one more country with this capability. India, Pakistan, Thailand, South Korea and Singapore all boast UAV systems either in operation or development. A summary of the regional UAV systems is provided at Appendix C.[6] The absence of literature reflecting concern for the growing UAV capability in the region is noteworthy, indicating a level of acceptance for surveillance and reconnaissance platforms as justifiable to national defence requirements. Additionally, the increasing level of interest in UAVs evident in regional newspapers and journals reveals that these platforms are becoming more prominent as force structure options.[7] To date, however, most nations have concentrated on developing or acquiring UAV systems of limited endurance for battlefield reconnaissance and border patrols. The limited payload and endurance capabilities of such UAVs arguably have much to do with their current acceptance.

The key to regional acceptance of any UAV acquisitions will invariably lie in the ability of the Government to justify the capability in terms of the requirement for the defence of Australia. This will involve continued transparency through publication of defence white papers and strategic reviews. An increased emphasis on peacetime operations provides further justification for assets which provide a continuous capability in contributing to the protection of Australian national interests. Regional acceptance of Australia's ownership of UAV technology will also largely depend on the understanding and experiences other nations have of the operational capabilities of such platforms. This can be achieved through exposure to UAV operations and their products through exercises and other regional activities. This will both increase the level of interoperability and provide tangible benefits for regional security.

Political Benefits

On the positive side, UAVs enable greater political freedom of action resulting from their unmanned status. The loss of US operated reconnaissance UAVs over China in the 1960s and 1970s raised little more than a few eyebrows, where the loss of a manned aircraft became a

[5] 'And Perhaps a Spy Satellite Race as well?', *Asian Defence Journal*, 1/96, p 69.

[6] The table was developed from a number of sources extending over five years. Consequently, some information may be dated.

[7] Regional articles on UAVs include 'Looking at the other side of the hill', *The Straits Times*, 5 February 1997; 'UAV: A New Philosophy in Asia-Pacific', *Asian Defence Journal*, 12/92; and 'The latest in defence technology', *Asian Business Review*, December 1996.

major political embarrassment.[8] In peacekeeping and peace enforcement operations, the use of UAVs will reduce the likelihood of political immobility as a result of large Australian casualties. Both in the air and on the ground, UAVs can reduce the threat to the lives of uniformed personnel through its optimal employment in support of the ADF. This will, however, require a shift in thinking by the Australian Army, in particular, with development of concepts of operations designed to exploit the characteristics of UAVs in supporting the forces on the ground.

Summary

Any analysis of UAVs within defence capability considerations should include comment on the potential political acceptability of the systems within the region. UAVs considered as offensive or intrusive systems are likely to attract some level of adverse reaction by other nations within the region. The costs of any reaction, which may range from negative public comment to weapons proliferation, must be squarely weighted against the perceived benefits of the system. The establishment of a profile on regional UAV capabilities and perceptions could assist defence analysts in this task.

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[8] Air Chief Marshal Sir M. Armitage, *Unmanned Aircraft*, Brassey's Air Power: Aircraft, Weapons Systems and Technology Series, Vol 3, London, 1988, p 78.

Chapter 15

Concepts of Operations

> By 2020, [US] Air Force planners believe that UCAVs will have taken over much of the air defense suppression mission and even some strike missions. Technology will be less of an obstacle than the maturation of military concepts of operations.[1]

The traditional time lag between the development of military technologies and the maturation of concepts of operations developed to exploit those technologies equally applies to UAVs. Until concepts of operations are developed to fully exploit the employment of UAVs, their utility will fall short of their potential. Furthermore, their competitiveness against other platform types is likely to be hampered by comparisons based on concepts of operations optimised for other platforms. For these reasons, the development of concepts of operations is required to demonstrate and extract the optimum value of UAVs to defence forces.

Timely development of innovative concepts of operations is also important in the emerging security environment. Given the widespread proliferation of advanced technologies across the globe, military advantage is far more likely to depend on superior concepts of operations over a pure technological edge. Maintaining a military advantage also requires the development of concepts of operations designed to counter or limit the effectiveness of military technologies employed by an adversary. Therefore, even if a nation chooses to leave UAVs out of its force structure, it should develop concepts of operations designed to protect the force against their use. Given the growing number of nations in the Asian region who operate UAVs, this is particularly important for the ADF.

Owing to the significant differences in the way in which the ADF is likely to operate compared with that of the armed forces of other nations, the direct transfer of US or Israeli concepts of operations (CONOPS) for UAVs would be inappropriate. [2] Australia's unique strategic circumstances demand Australian-developed concepts of operations so as to exploit the employment of UAVs within the Australian strategic environment. While CONOPS employed by the US, Israel and other defence forces serve to provide a foundation for the development of CONOPS and doctrine, Australian development should not become bound by the parameters of other doctrines. The development of uniquely Australian CONOPS for both

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[1] D.A. Fulghum, 'Flying Slots Disappear, Shift to Ground and Space', *Aviation Week & Space Technology*, 15 September 1997, p 74.

[2] A concept of operations (CONOPS) defines the scope of UAV usage within the intended operational environment.

their effective employment and the defeat of UAV capabilities which may be used against the ADF represents another challenge to those charged with examining the viability of UAVs for the ADF.

General Concepts of Operations

Currently, the typical employment of UAVs is in support of infantry units. As a concept of operations, UAVs are used to provide an 'over-the-hill' reconnaissance capability. The battlespace imagery collected is used by these units to plan tactical courses of action. Depending on the size and endurance capability, UAVs are employed at platoon, battalion and brigade level. As the payload capacity and endurance of UAVs increase, they will be employed at higher levels of command and may aid in strategic level planning. Regardless of who operates the UAV system, the information collected is generally fed into the command decision architecture at the most appropriate level for the detail and footprint of information received.

The concept of operation based on infantry unit operations generally assumes 'traditional' methods of fighting in high intensity conflict, where units are required to seize and hold ground. While this method of warfighting readily applies to European and Middle Eastern theatres, its relevance to the Australian scenario is less easily accepted. However, an emerging concept which exploits the endurance features of UAVs may have greater applicability to defence of Australia and other ADF tasks.

Dictating the Nature of Low Intensity Conflict

Recent Israeli experience with UAVs has seen them employed as a two-pronged weapon. UAVs are being used not only as reconnaissance platforms, but also to directly influence the conduct of battle. In Operation *Grapes of Wrath* against the Hezbollah in April 1996, the use of UAVs by the Israeli Defence Forces was seen to have a direct effect on the conduct of enemy operations by virtue of its 'presence'. The UAVs dictated the nature of war by forcing the Hezbollah to adopt a 'hide and seek' strategy, with limited time to arrange accurate fire on Israeli positions. This was attributed to Hezbollah wariness of the continuous surveillance provided by the reconnaissance UAVs overhead. The Israelis ascribe the failure of the Katyusha rockets to hit their targets partly to the presence of UAVs causing rushed launchings. Furthermore, the UAVs flew some 1,200 hours without loss to enemy fire.[3]

NATO's use of Predator in Bosnia can similarly be seen as repressing any overt action by the three Bosnian factions by virtue of its 'presence'. Activities in Sarajevo, for example, can be continuously monitored, whilst specific events with potential flare-ups, can be monitored at a distance, with quick reaction forces on stand-by. In comparison, AH-64 Apache helicopters are used where there is a requirement for a more overt and aggressive stance by the United Nations Stabilisation Force (SFOR).

[3] Summary of Air Power Conference, UK, Spring 1997

UAVs have also proved their usefulness in missions requiring continuous monitoring such as during the elections in South Africa. They could have similarly been used to monitor the elections in Cambodia, perhaps reducing the requirement for large numbers of armed personnel on the ground. Any sign of unrest or illegal activities can be quickly identified and dealt with (through accurate identification of the perpetrators). Moreover, the presence of UAVs or other aircraft at lower altitudes is readily observable, producing a deterrence effect. UAVs, therefore, can be employed overtly as a method for positive crowd reinforcement.

In South Africa, the endurance of the Kentron Seeker UAV was used to monitor the working routine and security systems of guerrillas operating in the south coast area of Natal. The mission to capture the group leaders was successful following observation by the UAV, where previous missions had failed to pass the guerilla observation posts without detection.[4]

While the preceding examples demonstrate the successful employment of UAVs in unique political and geographic environments, the general concepts can be used as a foundation for the development of concepts of operations for the Australian environment. The nature of conflict involving sizeable ADF participation is far more likely to parallel the types described in the preceding paragraphs than the likes of the 1991 Gulf War.

The Australian Environment

The vast distances and dispersed population of the north represents a significant defence challenge for the limited resources of the ADF. Locating and containing an adversary who mounts surprise attacks at isolated locations is considered a possible defence scenario on the Australian mainland.[5] In contrast to nations like Israel, the size of the Australian continent poses significant difficulty in actually locating the insertion or departure of small units of enemy forces. Much of the intelligence collection relies on local community support, ground reconnaissance units and aircraft with limited endurance capabilities. The use of endurance aircraft to locate and monitor enemy forces until ground forces arrive, represents a capability with unique application to Australia's geographic environment. This concept also requires consideration of who might be best placed to operate UAVs in a Defence of Australia scenario. Unlike European and Middle Eastern theatres, the infantry are not necessarily poised on the opposite side of the hill.

In the Australian scenario, the employment of reconnaissance UAVs by units other than infantry may therefore represent better utilisation of their capabilities within the Australian environment. For example, the use of UAVs as forward scouts for the Light Armoured Vehicles (LAVs) would enable more accurate tasking for cavalry units. The ability for UAVs to cover relatively large areas within short periods of time with the flexibility for retasking at short notice can provide a significant force-multiplier to a cavalry squadron which takes significantly longer to manoeuvre than air platforms. By virtue of their perspective and pervasiveness, air platforms are able to provide timely information covering a proportionally

[4] A. Venter, 'Hide and Seek', *Flight International,* 11 February 1997, pp 31-33.

[5] *Defending Australia: Defence White Paper 1994,* Australian Government Publishing Service, p 21.

large area of the battlespace. Air platforms are becoming critical enablers of manoeuvre warfare. The development of CONOPS enabling ADF units to exploit time and space for accurate engagement with the enemy represents a critical formula in the emerging warfighting concepts.

Concepts of operations for UAVs with applicability to Defeating Attacks on Australian tasks therefore, could include the following:

- the use of UAVs to extend the 'eyes and ears' (reconnaissance and EW) reach of the ADF's rotary wings (Army and Navy);
- the employment of UAVs as forward scouts for Army cavalry units;
- target acquisition and designation support to armour and artillery by UAVs;
- the employment of UAVs to provide Battle Damage Assessment of both tactical and strategic targets;
- submarine and ship controlled UAV reconnaissance in support of Special Forces missions;
- naval controlled UAV reconnaissance in support of general amphibious landings;
- area surveillance by UAVs preceding insertions by paratroopers;
- littoral patrols by UAVs controlled from Headquarters Northern Command (HQNORCOM) (with information fed directly to their operations centre); and
- support to Combat Search and Rescue (CSAR).

Employment of UAVs for other potential ADF Tasks

In developing CONOPS for UAVs, the ADF would also be wise to examine the other tasks in addition to Defending Attacks on Australia. This would enable defence personnel to formulate opinions on the utility of platforms across the spectrum of conflict. Therefore, development of CONOPS for the employment of UAVs in tasks more likely to involve the deployment of the ADF, such as peacekeeping and coalition activities, should be conducted.

The use of UAVs in Services-protected-evacuation, peacekeeping and peace enforcement operations requires the development of different CONOPS in accordance with the geography, climate, Rules of Engagement (ROE) and threat level. Furthermore, the employment of ADF assets may be in paramilitary roles which are little practised in Australia due to the absence of a requirement for such missions. With changes in the strategic environment and greater emphasis on the protection of natural resources, however, the ADF may increasingly be called upon to assist Australian customs, immigration and state and federal police in paramilitary roles. The possible increased threat of terrorist activities associated with the 2000 Olympic Games is but one example where the ADF may need to become more familiar with other types of operations. Many of these methods of employment and tasks are unlikely to be familiar to the majority of ADF units. Consideration of the types of tasks required suggests an increased utility for UAVs as shown by the following examples:

- The requirement to detect refugees in guerrilla held territory in Zaire could see the use of UAVs to reduce the danger to foot patrols. Heavily mined areas can also be overflown by UAVs to monitor the activities of groups using mined areas to prevent ground forces from interference. The use of air platforms including UAVs and helicopters in Bosnia has increased the transparency of faction activities in areas inaccessible to ground forces.

- The requirement for continuous surveillance at 'arms-length', such as required for Bosnian war criminals, could be optimally provided by UAVs with links to operations' centres.

- Stand-off surveillance of demonstrators and massed rallies can allow paramilitary forces to detect personnel wanted for questioning or identify troublemakers in riot situations. This capability was employed in both Bosnia during anti-Plavsic demonstrations and in South Africa for their first democratic elections.

These examples demonstrate the need for different CONOPS for conducting low-level operations. Aircraft operations, generally, will have both different strengths and vulnerabilities to those in open-plain, high-level conflict scenarios. The employment of UAVs in these examples would represent optimisation of their attributes of relative size, cost and 'expendability' compared to manned aircraft.

In low-level operations, an adversary can generally inflict politically unacceptable operational losses through targeting high-value targets such as manned aircraft. The loss of a single Australian aircraft, for example, could cause a significant military and political setback, particularly in activities where national survival is not at stake. Such examples have led to the increased use of UAVs in peacekeeping scenarios. The use of Predator in Bosnia, for example, has enabled NATO forces to maintain vigilance over medium-threat areas without great concern for its potential loss. The development of concepts of operations for these scenarios demonstrates the greater utility afforded by UAVs based on exploitation of their unmanned status, range and endurance.

ADF Exploitation of UAVs

ADF employment of UAVs as force-multipliers across a number of missions is limited only by the imagination of those developing CONOPS. Through exploitation of attributes of 'expendability', range and endurance, the ADF can significantly extend the 'eyes' and 'ears' of its forces. Exploitation of UAVs is particularly achievable in high-threat environments.

As one example of how the ADF could incorporate UAVs into its CONOPS, the Navy and Army could employ UAVs to further extend the reach of their helicopters in the reconnaissance, surveillance and Electronic Warfare (EW) roles. A UAV could be controlled out to some 300 nautical miles from the lead helicopter. The Australian Army could also use UAVs to extend the reach of their reconnaissance Cavalry units by scouting large areas and providing direct feedback to the reconnaissance squadron. Areas of interest can be further interrogated by ground units. This concept of operation exploits the manoeuvrability of air platforms which can more accurately direct the tasking of slower ground forces. Artillery and armour can likewise employ UAVs for target acquisition, target designation and battle damage assessment roles which would otherwise involve the use of forward scouts and observers. Similarly, the RAAF can employ UAVs in target acquisition and designation roles but the Battle Damage Assessment role represents the optimal employment of UAVs in support of the RAAF. The use of decoys, anti-radiation missiles and the range of cruise missiles are other UAV systems which are being given increased consideration by air forces worldwide.

The question of how the ADF might employ UAVs if they were to become part of its inventory is worthy of consideration in the near term. The opportunity to exploit UAVs in a different manner to that of manned aircraft may provide the ADF with a system offering greater relative utility, worthy of detailed examination. Finally, the ADF must gain sufficient knowledge of UAVs to enable the development of counter-concepts of operations.

Counter-UAV Concepts of Operations

Concepts of operations must be developed to counter the advantages provided through UAVs operated by a notional adversary. As demonstrated by the Hezbollah reactions to the Israeli use of UAVs, they can seriously affect the conduct of operations through their very presence.

The effect of UAVs on the conduct of warfighting was also found in the annual US Army Warfighting exercises which pitch regular 'Blue force' units against the elite 'Red force' training unit.[6] For the first time in the history of the exercises, the competition was declared a 'draw'.[7] The previously undefeated Red forces were found to be thoroughly agitated by the use of UAVs against them. They reacted by moving high-value equipment more frequently and changing their plan of attack on a number of occasions. Furthermore, Red forces increased their radio usage and time on air to discuss the location of the UAVs overhead, providing Blue force with significant opportunities for intelligence collection. Red force also expended a significant amount of anti-aircraft artillery rounds in an attempt to physically neutralise the UAV threat. Even their special reconnaissance unit mission to break into the enemy camp was monitored by a UAV employing an infra-red sensor. The reconnaissance team was neutralised before reaching the Blue camp.

[6] Colonel M. Howell, 'You can run, but you can't hide', *Unmanned Vehicles*, August 1997, pp 6-7.

[7] D.A. Fulghum, 'New Control System Sparks UAV Success', *Aviation Week and Space Technology*, 19 May 1997, p 40.

These examples demonstrate the effectiveness of UAVs in disrupting the warfighting procedures of forces who are aware of their general presence but unable to effectively neutralise their effect. For the ADF, at absolute minimum, the development of concepts of operations and capabilities to counter the disruptive influence of UAVs (and the value of the intelligence collected) must be undertaken in earnest if it is to maintain its defence posture of developing counter-capabilities to those emerging within the region. This will require some experience on how the vehicles operate and how their limitations might be exploited. The need for familiarity with UAV systems is an issue also identified by the UK where a tri-Service steering group has been established. The UK MoD spokesman for operational requirements, Wing Commander J. Plumb, stated 'The UK needs experience ... It is important we gain experience of high-altitude, long endurance UAVs.'[8]

Developing Australian Concepts of Operation

This chapter has argued the importance in developing concept of operation for both the use and defeat of UAV capabilities by the ADF. The challenge to military analysts is to gain sufficient knowledge of their operations without necessarily acquiring the capability. Developing concepts of operations is possibly best done initially through an analysis of the unique Australian operating environment. Using their knowledge of the strengths and limitations of UAV operations, analysts can then develop concepts which apply to the ADF's method of warfighting. These theoretical concepts can then be tested through exercises and trials using UAVs against Australian units. While this was done in the 1993 Scout Trial[9], its value was limited because insufficient consideration was given to the differences between Israeli and ADF operations. Arguably, significant effort should be made to develop Australian operating concepts before further trials are undertaken.

Challenges to exploiting concepts of operations for UAVs

The greatest challenge in realising the potential of UAVs in the ADF is the development of an operating architecture with sufficient flexibility to allow for multiple tasking of the same platforms across a number of units. Even for tactical UAVs organic to the Army, there will be a requirement to centralise command at the highest practicable level. This will enable the UAV to be tasked in accordance with the commander's priorities and will ensure the UAV transcends the boundaries of ownership by a particular Corps or a unit. Control of the UAV platform and, more importantly, its product, must be placed at the level which can best exploit it. This may equate to an artillery battery, the company commander of a LAV unit or the squadron commander of a helicopter unit. These units may be given direct control of the UAV for a defined time and space in the battlefield with control handed over mid-flight or they may be allocated a UAV detachment for control for a certain phase of the conflict. Resolution of these management issues is an essential consideration in the development of operational procedures and will be dealt with in the following chapter.

[8] D. Barrie, 'UK MoD considers long-endurance UAV options', *Flight International*, May/June 1997, p 20.

[9] Department of Defence, *Unmanned Aerial Vehicle Trial Team Report - Defence Trial 8/603*, 1993.

Summary

Early consideration of Australian CONOPS is important for two reasons. Firstly, UAVs represent a new type of platform with characteristics that are yet to be exploited in current Australian doctrine. The utility 'value' or 'weighting' of UAVs can be quantified through the development of notional operating concepts in support of a number of ADF missions. Secondly, Australia must develop CONOPS to counter the advantages accrued to an enemy employing UAVs against the ADF.

Chapter 16

Management of UAV Systems

The management of UAV systems is an issue which has already seen fierce debate between surface and air forces in both the US and Israel. The rationale behind these debates is based on the competition for control of airspace and air tasks. Anecdotal evidence, for example, suggests that the USAF's bid for control of the Predator UAVs was based on the belief that they needed to 'draw a line in the sand' on the demarcation of tasks among the Services.[1] With the potential development of UCAVs for close air support (CAIRS), battlefield air interdiction (BAI) and combat air patrol (CAP), armies could field organic combat UAV forces, simultaneously decreasing the role of the USAF and their claim to airspace over the battlefield. The potential development of combat UAVs is viewed by many as constituting a similar threat to the USAF's role to that posed by the concurrent development of long-range ground-launched cruise missiles, such as the Army Tactical Missile System (ATACMS). The USAF, therefore, has 'claimed' endurance UAVs, and by association, their developing combat counterparts, in an effort to retain control over activities on the battlefield.

In contrast, the Israeli Defence Forces have developed an ownership policy based on the launch method; if the UAV uses a runway, the Air Force is the operator, if no runway is used the Army is the operator.[2] This method recognises the division based on methods of operations rather than along functional lines. This policy works well in the Israeli case where the Air Force is viewed as an important support arm to predominantly operational and tactical level operations. The Army, therefore, is generally satisfied that the assets are appropriately tasked in support of its operations where required. In armed forces where there is less cooperation between the services, such as in the US, this method of management might not prove as successful.

Debate of this nature is both fruitless and counterproductive in the ADF context. By virtue of their supporting role, tactical UAVs should be operated and maintained by the Army and Navy where applicable. Systems with requirements for sealed runway operations can likewise be fielded by any of the three Services provided the expertise is present to undertake operational level maintenance of the assets and to manage the logistic requirements. Heated argument on which Service should assume command and control of UAV systems is contrary to an ADF which must focus on integrated operations across the defence force. Thus, if the three Services had a requirement for Predator UAVs, for example, the force acquisition process should include the coordinated requirements of all three Services. One Service may be nominated as the logistics manager with responsibilities for coordinating deeper level

[1] Discussions with Wing Commander S.W. Filmer, Project Manager, Project *Warrendi*, DAAPROJ, May 1997.
[2] Summary from Air Power Conference, UK, Spring 1997.

maintenance contracts and providing other integrated logistics support. The three Services may be provided with detachments of Predators in accordance with their requirements which are operated and operationally maintained by the host Service. Alternatively, systems such as Global Hawk may be operated by one Service and tasked in support of the other Services as with strategic airlift assets. Unlike manned aircraft, however, training and currency hours are not available for the host Service to use in concurrent tasking. This availability issue is the cause of much chagrin with other Services.

A major thrust of this argument is that, regardless of which Service or which Army corps is selected as the logistics manager of the systems, UAVs represent platforms with significant utility and should be managed as such. The ADF should give detailed consideration as to how it might ensure the utility of UAVs is exploited in a holistic manner for the benefit of the ADF as a whole. More detailed examination of this topic, therefore, is warranted.

ADF Management of UAVs

Given the assumption that the ADF introduces one or a number of UAV systems into its inventory, how best would they be managed to provide support across a range of ADF and non-defence tasks? The age-old debate of who should command and control the assets is one that should be discarded in favour of a more contemporary form of management. The maintenance manager of UAV systems should be capable of maintaining them at a level which optimises their operational potential. Tactical UAVs with ranges of 50 to 300 kilometres, for example, are best maintained at the nearest operating base, whether it be a dirt strip or sealed runway. More sophisticated UAVs with the capacity for greater ranges might be better maintained at established bases. Consideration of the type of facility required for operational maintenance should be one consideration as to by whom and at what level UAVs are maintained.

In the ADF case, it is quite justifiable and foreseeable that tactical UAVs will be maintained by the primary users, whether Army or Navy. UAVs with strategic capabilities could well be managed by Army, Navy or the Air Force given that they may provide support to all three Services. Given the RAAF's current concentration of maintenance personnel familiarity with highly sophisticated aircraft and, its ownership of the majority of air bases around Australia, it appears the most suitable service to maintain and manage UAVs with strategic capabilities. The tasking, and command and control of major assets such as Global Hawk should preside, however, at a more centralised level such as at the Headquarters Australian Theatre (HQAST). The centralised command of UAVs is necessary to ensure that assets are assigned in accordance with ADF priorities.

For the ADF, its three Services will have to overcome their individual biases towards the acquisition of organic assets because of their lack of faith in receiving appropriate support from one another. The ADF cannot afford to operate three separate UAV systems providing the same capabilities. At the same time, the Services need to be more openly supportive of each other, particularly where one Service takes the lead role in an operation. Air forces, for example, have a particular limitation in that their thinking may be so focused on achieving strategic outcomes that they are unwilling to commit platforms to support tactical objectives which may involve greater risk to aircraft. Also, air forces need to examine whether they should undertake dangerous missions, such as CAIRS, and determine how they can best be achieved. If crewed aircraft are too rare and valuable to risk in high-threat missions, particularly in small air forces, combat UAVs and other alternatives need to be considered.

Centralised Command and Decentralised Control

The key to the exploitation of unmanned platforms in the ADF will be through the centralised command and decentralised control. Centralised command appears most appropriate at the HQAST or at the Joint Force Headquarters level such as Headquarters Northern Command (HQNORCOM) with decentralised execution by the units using assigned UAVs. A platform such as Global Hawk could foreseeably be operated by the Army for land surveillance, the Navy for maritime surveillance, and the Air Force for BDA, strategic reconnaissance and surveillance. Management and maintenance of the assets, along with training operators and analysts would logically sit with one Service, with the assets being allocated to the various users as required or on a semi-permanent basis. Alternatively, the assets could be operated by a single Service, with down-links to various agencies who could then request further interrogation of a target where required. For example, HQNORCOM would be well placed to operate a fleet of Global Hawks over the maritime approaches to Australia. Mission control stations (or monitors) could be placed with Coastwatch, and at HQNORCOM, as well as one feeding directly into the HQAST Air Operations Centre.

In order to exploit surveillance and reconnaissance platforms sufficiently, a networked national system is required, similar to the system the US Armed Forces are developing. The concept of organic assets for the individual Services, particularly air platforms, risks an under-utilisation or inappropriate utilisation where the asset is not employed in its primary role. To extract the most effective use of the platform, a method for employing the asset in its primary role for the maximum period is required. This involves a 'cost-sharing' concept where each agency might contribute to the operating costs of the platform.

To achieve a holistic ADF operating architecture for UAVs, a high level of command is required. Considering such assets as inherently ADF, rather than single Service assets, will promote joint development of concepts of operations, communications protocols and airspace management procedures. Though currently lacking, the joint development of these operating parameters is fundamental to exploiting joint operations. The development of a holistic ADF airspace management procedure will also be critical in forming the basis of development and acceptance of airspace regulations enabling UAVs flight in civil airspace without the requirement for waivers constrained by defined time and space parameters.

Joint Doctrine and Joint Operations

Early development of concepts of operations for UAVs will provide defence doctrine writers with clear guidance on the potential employment of UAVs in the ADF and how best to address the doctrinal framework. Initial steps have been taken by the Australian Defence Force Warfare Centre (ADFWC) by incorporating UAV operations within their airspace control doctrine. The development of joint doctrine for the employment of UAVs needs to be further expanded with their inclusion where appropriate across the doctrine series.

Consideration of how UAV assets can be employed within a joint operations scenario is also worthwhile. Surveillance and reconnaissance activities are usually constrained by limited asset availability, thus needing to be coordinated across environmental, geographic and command boundaries to ensure comprehensive coverage.[3] This is emphasised by Anderson and Dibb who state:

> The growing need for real-time information is leading to an increased interdependence of operational defence units and a blurring of the traditional distinctions between Navy, Army and Air Force operations.[4]

Hence, UAVs and other reconnaissance and surveillance assets must be sufficiently coordinated to ensure the optimal utilisation by ADF customers, whether Army, Navy or Air Force.

Common Communications Protocol and Architecture

Identification of the joint requirement for reconnaissance and surveillance products can enable early development of common communications protocols and supporting architecture. The US has already identified the importance of integrating the Services requirements for data and are investing in an integrated network system which will tie all Common Ground Stations together. These stations will be capable of providing units with real time data from reconnaissance and surveillance platforms operating in their area of interest.[5] Manned and unmanned platforms such as JSTARs, Predator, Apache and Hunter, will feed directly into the ground stations where the information will be interpreted and analysed by the intelligence community. The Common Ground Stations can send requests to the operating agencies for further exploitation of an area of interest through a centralised command system.

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[3] *Australian Defence Force Publication,* Operations Series, ADFP 29, Surveillance and Reconnaissance, 1st Edition, May 1995, p 2-5.

[4] K. Anderson & P. Dibb, *Strategic Guidelines for Enabling Research and Development to Support Australian Defence,* Canberra Papers on Strategy and Defence No 115, Strategic and Defence Studies Centre, Australian National University, Canberra, 1996, p 24.

[5] Discussions with S.W. Filmer, Project *Warrendi,* DAAPROJ, May 1997.

Management of Bandwidth

The development of common communications protocols and architecture will also aid in ADF management of the limited bandwidth available to defence. A coordinated approach by the ADF will also ease transition into global conventions on the use of bandwidth. An Australian lead in this area could provide the foundation for the development of protocols within the Asia-Pacific region. This type of leadership within the region might also be applicable for the development of protocols governing airspace use by UAVs.

Airspace Management

The adoption of a holistic management system for the employment of UAVs in the ADF will also ensure positive steps are taken to develop common airspace management procedures which will enable the use of UAVs in the battlespace, and controlled and uncontrolled civil airspace. This in turn will provide the foundation for civil agencies to develop national procedures on UAV flight through non-military airspace.

Summary

While the issue of the management of UAV systems represents one of the least challenging obstacles to their effective employment, ineffective resolution can result in their under-utilisation by the ADF. In considering the management of UAVs at a centralised level within Defence, force structure analysts can better address other related issues including the development of common communications protocols, the management of bandwidth within the ADF, the development of joint doctrine and the requirements for airspace management procedures. Accordingly, while particular UAV systems are likely to be managed by a single Service, some consideration should be given to the establishment of a joint agency which oversees their effective tasking and development of associated operating protocols.

Chapter 17

Management of Airspace

Introduction

The exploitation of UAVs across the spectrum of conflict, including peacetime operations, is critically dependent on the resolution of airspace management issues. If the ADF is to consider the inclusion of UAVs within its inventory, the development of airspace regulations to enable the operation of UAVs within both the military and civil airspace environments should be given priority. This will be particularly important for UAVs which require the use of sealed runways at airfields which require transit through controlled airspace.

Definitions

In the military context, airspace control is defined as:

> A service provided to increase combat effectiveness by promoting the safe, efficient and flexible use of airspace. Airspace control is provided in order to permit greater flexibility of operations ...[1]

The management of airspace in the civil domain is similarly important to ensure the safety of airspace users whilst permitting the efficient and flexible use of airspace.

Airspace control is achieved through positive or procedural methods, or through a combination of both.[2] The management of airspace is also effected through the partition of airspace into various sectors based on the concentration of air traffic, use and associated hazards. Simplistically, airspace is separated into controlled and uncontrolled airspace where controlled airspace represents a portion of airspace subject to positive or restrictive procedural air traffic control. While controlled airspace, in Australia is generally associated with major airports and air routes, it is divided into four classifications: A, B, C and D.[3] Class A represents transoceanic airspace between 24,500 and 46,000 feet while class B represents Australian continental airspace between 20,000 and 60,000 feet. Class C airspace surrounds major radar-controlled airports and generally extends to the 120 mile limit of radar coverage

[1] *Australian Defence Force Publication (ADFP) 13 - Air Defence and Airspace Control,* Operations Series, Headquarters Australian Defence Force, Canberra, April 1997, para. 202.
[2] *Ibid.*, para. 203.
[3] Definition provided by M. Walker, Flying Operations Inspector, Flying Operations Branch, Civil Aviation Authority Australia, Canberra, November 1997.

with a ceiling of 20,000 feet. Class C airspace may also be extended to cover busy air routes such as those along the eastern seaboard. Class D airspace surrounds major non-radar airports out to 30 miles where it is adjoined by Class C. Operation in any of this controlled airspace requires a clearance from air traffic control and compliance with standard procedures.

Uncontrolled airspace is that portion of airspace where aircraft are not subject to positive control but operate in accordance with general rules and procedures. Use of this airspace for a special purpose would generally require the issue of a Notice to Airmen (NOTAM) indicating the area, nature and timing of the activity, in order to alert other potential users of the airspace.

Restricted airspace is another type of airspace that is often used by the military when conducting operations. Restricted airspace can be permanent to prevent overflights of sensitive military installations or high-use military ranges. For the purposes of this paper, airspace restricted for use by military forces, such as airspace over a defined area of operations, will be referred to henceforth as 'military' airspace. The challenges and potential solutions for regulating the flight of UAVs through these airspaces is discussed hereafter.

Management of UAVs in Military Airspace

Airspace Management in an Area of Operations

The control of airspace over the battlefield is necessary to provide freedom of action to exploit its advantages for the movement of objects, be they platforms or projectiles, whilst maintaining procedures to ensure the safety of airspace users. US Army doctrine states that the purpose of controlling airspace over a battlefield is to 'provide a framework for the synchronization, coordination, integration, regulation, deconfliction, and identification - through both positive and procedural control methods - for the land component commander's (LCC's) airspace requirements.'[4] Battlespace management of airspace seeks to increase flexibility for airspace users within a 'semi-controlled' environment through apportioning operating envelopes which are limited in time and space.

Generally, difficulties arise when airspace becomes congested over battlefields. Conflicting Service priorities become major challenges to airspace managers who are required to juggle the airspace requirements for artillery and other missiles, tactical transport aircraft including helicopters, tactical attack aircraft, longer range BAI aircraft, and strategic strike platforms. The main source of the problem is determining safe corridors for aircraft, which becomes particularly difficult where two or more Services are operating aircraft in, or projecting missiles through, common airspace. This problem has tended to become more complex with the use of longer range, higher altitude missiles by ground forces. Dividing airspace into

[4] TRADOC Pamphlet 525-72, *Army Airspace Command and Control (A2C2), Operations Concept*, US Army, 1 June 1996, para 1-1.

altitudes and time limits or 'slots' is more difficult in scenarios which require constant transit over the battlefield while ground operations are in progress. The Gulf War provides a point in case:

> Timing was everything. Force packages were sent in waves, with critical adherence to flight paths, altitudes and airspace boundaries.[5]

Given the prevailing difficulties in managing airspace in the battlefield, the introduction of another airspace user with limited ability to 'see' other users will further complicate the task of airspace managers. Furthermore, given that UAVs are likely to be airborne for long periods, restrictions based on time limits significantly reduces the utility of the UAV. Alternatively, airspace use by other systems is severely restricted.

In developing regulations for the employment of UAVs in the battlefield airspace architecture, planners should consider whether they wish to exploit the advantages of UAVs through the precision of relative flexibility of operations, or whether they wish to introduce regulations which may be prohibitively restrictive. The resultant method of dealing with UAVs in the airspace over the battlefield can have a large influence in the definition of requirements for what type of navigation and identification systems should be present in ADF procured UAVs.

The importance of the navigation and identification systems of the UAV was reinforced to the Australian Army in 1993 when they conducted trials with the Israel Aircraft Industries' (IAI) Scout UAV. The lessons learnt provide some insight into the current restriction to UAV operations both in military and civil airspace, resulting predominantly from an absence of regulations covering UAV flights. Limitations in the navigation and identification systems of the UAV also presented difficulties with regard to its management in controlled airspace.

Results of Scout UAV Trial in Australia[6]

Reports of the trial with the Improved Scout UAVs in northern Australia in 1993 indicated that the management of airspace encompassed significant demands on the operators. Regular reports on the position and intention of the UAV were required on the Mandatory Traffic Advisory Frequency (MTAF) whilst the UAV flew in unrestricted airspace. This required the semi-permanent placement of an Air Traffic Controller from 1 Aviation Regiment with the Ground Control Station. Additionally, a minimum of 12 hours notice was to be provided to the Notice to Airmen (NOTAM) office and a qualified pilot had to maintain a listening watch on civil air-ground frequency and make normal pilot reports on the UAV's course. To add further to safety procedures, an Army helicopter was employed to escort the UAV within the five nautical mile boundary of the civilian airport used.

[5] Gary Waters, *Gulf Lesson One - The Value of Air Power: Doctrinal Lessons for Australia*, Air Power Studies Centre, Canberra, 1992, p 125.

[6] Findings summarised from Department of Defence, *Unmanned Aerial Vehicle Trial Team Report - Defence Trial 8/603*.

The resource costs associated with meeting current civilian airspace requirements during the trial were demonstrably high. Should the regulations remain unchanged, the potential cost-effectiveness of UAVs is unlikely to be realised. Furthermore, the current requirement for the notification of the UAV flight and associated reporting procedures would not be suitable during actual operations. Adherence to such procedures would entail updates to the UAV's position over insecure frequencies, thereby threatening the success of its mission. The difficulties associated with operations in civilian airspace would therefore need to be overcome if UAVs were to be effectively employed on tasks involved with Defeating Attacks on Australia.

The limitations to the Scout's operations, even in military airspace, were also demonstrated when the trial at RAAF's Tindal air base was confined to specific time windows due Exercise *Pitch Black* being conducted at the same time. The trial report stated that the team found it difficult to determine accurate timings for RAAF aircraft movements, indicating the complexity of operating UAVs in areas with significant aircraft activity.[7] Operations at RAAF Tindal also highlighted the difficulty of identifying the UAV on radar due to its small cross sectional area and radar absorbent material. As a result, the report recommended that UAVs should be fitted with Indication Friend or Foe (IFF) transponder to provide positional information to the relevant Air Traffic Control agency and identification to air defence assets.[8]

In summary, the trial brought out a number of lessons for the ADF. Navigation and identification systems are required to provide airspace managers with a method of accurately identifying the location and status of UAVs in military airspace. This is particularly important for small UAVs which are not easily located by radar. Also, the trial highlighted the requirement to develop operating procedures for the employment of UAVs in conjunction with more sophisticated aircraft such as the F/A-18. Development of operating procedures catering for the range of different aircraft operated by the ADF is required. This will be critical to successful ADF air operations given the limited number of sealed runways available in the north of Australia. The main challenge in developing these procedures will be to account for aircraft of varying speeds in the runway approach and departure paths. While basic UAV operating procedures have already been incorporated into ADF doctrine, further development will be required if UAVs are to share major operating bases with other aircraft types. A number of other limitations to current ADF doctrine will also require resolution if the utility of UAVs is to be fully realised.

ADF Airspace Control Doctrine

In recognition of the increased likelihood for UAV operations by the ADF, an ally or a coalition partner, the 1997 edition of *Australian Defence Force Publication (ADFP) 13 - Air Defence and Airspace Control*, has included guidance on the integration of UAV operations within the battlefield airspace control architecture. The ADFP states:

[7] Department of Defence, *Unmanned Aerial Vehicle Trial Team Report - Defence Trial 8/603*, para 33-35.
[8] *Ibid.*, para 40.

> The principles of airspace management used in manned flight operations will usually apply equally to unmanned aerial vehicle (UAV) operations.[9]

The publication further defines specific procedures for UAV operations, to be used during launch and recovery, en route travel and operations in the mission area.[10] The ADFP recommends the establishment of a restricted operations zone (ROZ) for the mission area, launch and recovery, while en route travel is generally to be effected through the provision of a UAV 'blanket'.[11] Figure 17.1 represents the ADFP concept for a UAV flight profile.

Unmanned Aerial Vehicle Flight Profile

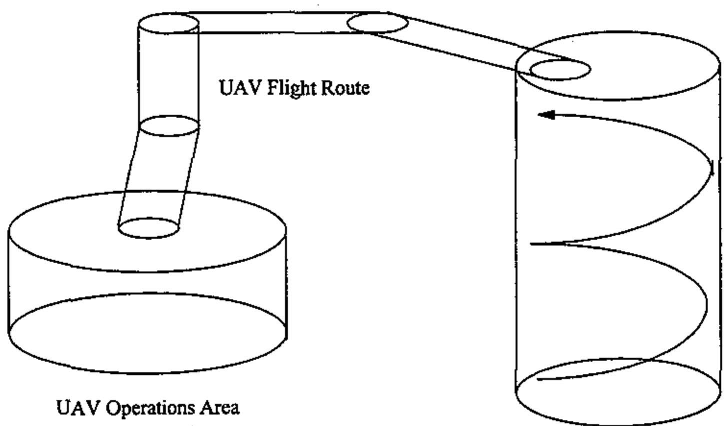

Figure 17.1

An ROZ is airspace reserved for an 'operation which requires isolation from other airspace users. ROZ procedures restrict some, or all, airspace users from an area until the particular activity is completed.'[12] While guaranteeing the safety of other airspace users, this method is restrictive and somewhat in opposition to the aspiration to maintain flexibility for battlefield operations. Additionally, the employment of ROZs for UAV operations is likely to be achievable only for missions of short duration. The development of alternate procedures providing greater access of airspace to other users may be required for endurance UAV operations.

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[9] *ADFP 13 - Air Defence and Airspace Control*, para. 271.
[10] *Ibid.*, Annex 2D-9, paras. 29-31.
[11] *ADFP 13*, Annex 2D-9, paras. 29-31.
[12] *ADFP 13*, Annex 2D-5, para. 14.

The requirement for flexible operations has partially been addressed in the doctrine which states that en route travel may be effected via established flight routes and transit altitudes, and UAV operations may be isolated from other airspace users by means of an airspace coordination area (ASCA).[13] This area ensures aircraft are safe from friendly surface fire through the establishment of a block of airspace. Although not stated, a reasonable assumption is that the ASCA may be used by a number of aircraft. Like an ROZ, however, the ASCA is subject to lateral and vertical boundaries and is limited in time.[14] The development of procedures which removes the requirement to 'parcel' airspace would result in increased flexibility to all airspace users. This concept lies behind the US development of a network mission planning system. The system will enable flight planners to input mission details and the system software will amend flight paths for deconfliction. In comparison to the inflexible system employed in the Gulf War, this system would enable individual units to plan and task their missions with awareness of other aircraft in their area of operations. As such systems would allow for more flexible battlefield operations, they are worth consideration.

The current doctrine promulgated in ADFP 13 represents a significant step on behalf of the ADF. Such doctrine recognises the potential for UAV operations to become an inherent element of future ADF exercises and operations. This is true, regardless of whether UAVs are included within the ADF's inventory. The increased likelihood for one of Australia's coalition partners to employ UAVs during combined operations warrants further development of flexible airspace procedures for UAV operations.

Airspace Management in OOTW and Low-Intensity Operations

While the development of procedures for the employment of UAVs in military airspace is critical to their exploitation by armed forces, the issue of their employment in civil airspace is equally important. In most defence of Australia scenarios, civil traffic is unlikely to cease during periods of increased tension. The development of regulations that enable UAVs to operate across the country is therefore critical to their effective employment as ADF assets. Furthermore, the use of UAVs in peacekeeping and other scenarios, where civil air traffic proceeds as normal, must be addressed. The requirement to account for ongoing civil air traffic was experienced by the Coalition forces in the Gulf War:

> The ATO did not provide airspace management, and a separate Airspace Coordination Order (ACO) had to be developed which had to cope with routine civilian traffic as well.[15]

[13] *ADFP 13*, Annex 2D-9, paras. 29-31.
[14] *ADFP 13*, Annex 2C-3, para. 13.
[15] Waters, *Gulf Lesson One*, p 225.

Even though NATO effectively controlled the airspace over Bosnia, the decision to maintain normal civil air traffic meant there was a requirement to synchronise military and civil air activities. These examples demonstrate the increasing likelihood of the dual use of airspace by military and civilian platforms. Therefore, the requirement to develop regulations for UAV operations in civil airspace is gaining momentum.

Management of UAVs in National and International Civil Airspace

National Airspace Management

In developing detailed procedures for UAV operations in civil airspace, a number of associated issues must be considered. Foremost is the need to satisfy legal requirements for public safety. At minimum, UAVs will be required to guarantee an equivalent level of safety to that of manned aircraft. This requirement will significantly influence the design of UAVs for flight in civil airspace. For example, UAVs may be required to have redundancies in some or all of their systems, as well as civil certification of their engines. The development of UAV operating procedures for civil airspace will therefore dictate the system features required of UAVs. Consequently, early ADF involvement is considered essential if it is to have some influence on what type of UAV is acceptable for operations in civil airspace. Correspondingly, knowledge of civil requirements will assist the ADF in producing benchmark specifications for any future acquisition of UAVs.

The issue of operating UAVs in airspace with other manned and unmanned aircraft, poses the one of greatest challenges to realising their utility. For manned aircraft operations, the most basic guiding rule in unrestricted airspace is the capacity to 'see and be seen'. UAVs offer a significant challenge in this regard as not all are necessarily equipped with nose-cameras to provide ground operators with real-time images (the 'see' capability) of their flight. Furthermore, they present difficulty in being seen due to their comparatively small size. Various remedies have been employed by UAV operators. The United States Air Force has mounted a video camera in the nose of the Predator UAVs operating in Bosnia so that ground operators can see to the front of the aircraft.[16] Identification Friend or Foe (IFF) transponders have also been incorporated into the Predators to assist air traffic controllers to determine their position with respect to other aircraft.[17] However, officials have indicated an intention to upgrade the IFF system to Traffic Alert Collision Avoidance System (TCAS) 2 standards which will actively interrogate radar transponders of other aircraft in the vicinity and take evasive action if a collision is threatened.[18]

[16] Interview with Wing Commander S.W. Filmer indicated that this was the method for 'seeing' other aircraft.
[17] D.A. Fulghum, 'Predator to Make Debut Over War-Torn Bosnia', *Aviation Week & Space Technology*, 10 July 1995, p 48.
[18] *Ibid.*, p 48.

In controlled airspace, UAV operators converse with air traffic control staff to indicate the altitude and position of the UAVs.[19] The USAF currently takes a further precaution by employing a chase aircraft for UAV flights through controlled airspace.[20] These procedures are resource intensive and restrictive in periods of conflict. In order to address these limitations, further development of UAV safety features is required. To date, only the South African Kentron Seeker UAV is legally permitted to operate independently in restricted and unrestricted airspace.[21] Closer examination of its features is therefore considered worthwhile.

The South African Experience

The Denel Kentron 'Seeker' UAV has been operated successfully in South African civil airspace on a number of occasions since its first employment in April 1994 during the national elections. Over the election period, 'Seeker' flew 17 hours in the congested controlled airspace over Johannesburg.[22] To meet the safety and reliability requirements of civil aviation regulations, the UAV's systems incorporated a number of modifications which enabled it to operate similar to manned aircraft. This experience led Kentron to incorporate a number of modifications to what may be regarded as a relatively sophisticated UAV in terms of in-built safety and redundancy features. As an indication, the following Seeker features were regarded as important in gaining its approval for flights in controlled airspace:[23]

- Electrical power is provided by an alternator with battery backup.
- Stable flight in pitch and bank is provided by the autopilot.
- The autopilot can maintain selected airspeed, altitude and heading or bank angle.
- Accurate flight and engine instrumentation is provided.
- The UAV is fitted with standard VHF AM radio for air traffic communications.
- The control and speech link between the ground station and the VHF AM radio is provided by UHF radios.
- Frequencies between 118 MHz and 136 MHz can be selected in-flight.
- A standard transponder is fitted to the aircraft which can operate in OFF, MODE A, MODE C, squawk code, IDENT and TEST modes.
- Two radio command links are used - microwave and UHF - providing redundancy.
- The UAV automatically returns to recovery location if total communication loss occurs.
- The UAV is tracked in range and azimuth from ground station, providing a real-time position within 100 metres accuracy in Latitude and Longitude and the local Grid system.
- Standard altimeter subscale setting procedures are followed to enable the UAV to fly on altitude (with the local QNH) or on Flight Levels.
- A 'black box' recorder located at the ground station logs all command and status data, including communications between ATC and crew conversations.

[19] Interview with Denel Kentron, Mr A. Phillips, Avalon Airshow, 20 February 1997.
[20] Interview with Wing Commander S.W. Filmer, 6 June 1997.
[21] P. La Franchi, 'Lessons from hot skies: The Kentron Seeker', *Australian Defence Magazine,* May 1996, p 25.
[22] P. Muir, *Certification Standards and the Integration of UAVs in Air Traffic - The South African Experience,* Kentron, Division of Denel (Pty) Ltd, South Africa, 1996, p 3.
[23] Muir, *Certification Standards and the Integration of UAVs in Air Traffic,* pp 3-4.

Despite the ability to conform with most airspace regulations, the Seeker has not achieved civil certification. It has been certified by the South African Air Force (SAAF) after extensive consultation with the South African Civil Aviation Authority (CAA). The current military 'certification' of the Seeker System is '... authorisation by the SAAF for military flight operations according to the UAV system documentation package'.[24] This 'documentation package' incorporates extensive safeguards through the documentation of all operating procedures, maintenance standards and requirements, crew training and certification requirements. Missions in civil airspace continue to require prearranged approval with CAA, the issue of NOTAMs and lodgement of flight plans, and detailed briefings with civilian ATC personnel.[25]

While the Seeker UAV is still constrained by restrictive airspace procedures, it provides a good example of the type of system features which will be required for UAVs designed to operate in civil airspace. Unfortunately, the development of airspace regulations concerning UAV operations in controlled and uncontrolled airspace is ad hoc and lacks uniformity across countries. This will not only impact on the variable suitability of UAVs from one country to another, but also will pose a significant issue to the employment of UAVs in international airspace.

International Airspace Management

The development and acceptance of an international procedure for the operation of UAVs outside national airspace is crucial to realising the utility of UAVs. International regulations will enable UAVs to be employed beyond EEZs and more importantly, will stipulate the basic navigational and identification systems, and procedures to ensure the adequate safety of all airspace users. Owing to the significant variations in UAV systems and national operating procedures, however, the development of internationally accepted UAV specifications and operating procedures will be difficult to achieve. With the development of long endurance UAVs such as Teledyne Ryan Aeronautical's Global Hawk, this issue will gain increased priority.

Establishing UAV Protocols

As indicated in previous paragraphs, in order to ensure the safety of other airspace users, both national and international airspace regulations are likely to detail minimum basic requirements for UAV systems. Legal requirements are likely to include measures of reliability, standards of navigational and identification systems, and the nomination of responsibility for the UAVs flight path. They will set common standards for safety whilst providing accountability for UAV operations. The likely requirements for UAV systems will be discussed under two categories: Accountability and UAV safety & reliability. The subjects

[24] *Ibid.*, p 9.
[25] *Ibid.*, p 9.

covered in the ensuing discussion are by no means comprehensive, nor conclusive. The following section merely indicates the types of issues which will require further consideration in the development of national regulations on UAVs. Adherence to the regulations developed will in most cases be ensured through the process of seeking civil accreditation of the UAV systems.

Civil Accreditation

Owing to the general absence of national regulations on UAVs, no system has yet attained civil accreditation. However, several UAV manufacturers have forecast the importance to achieve civil accreditation of their systems and have designed their UAVs accordingly. IAI, for example, has a stated aim to achieve a level of civil accreditation for their UAVs. The company recognises that it is imperative to demonstrate an equivalent level of safety and reliability to manned aircraft if their UAV systems are to gain widespread acceptance by the civil community. This acceptance will both increase the utility of UAVs for paramilitary roles, and expand the market for civil and commercial applications.

The primary purpose of civil accreditation is to ensure that the minimum safety specifications for aircraft systems are met, thereby satisfying legal requirements for public safety. Civil accreditation of UAV systems is therefore likely to demand the incorporation of emergency procedures and redundancy features which replicate those available for manned aircraft operations. Several manufacturers have already included emergency features where a UAV can be destroyed in flight or returned to base through a backup program.[26] The requirement to protect other airspace users and population centres along UAV flight paths has reinforced the need to develop complex decision system algorithms or re-introduce the man-in-the-loop requirement. For the Block IV Tomahawk cruise missiles, military planners have opted for a man-in-the-loop to address deficiencies in navigation and targeting systems, and to provide the authority for self-destruction where the missile threatens to malfunction. These type of emergency features are likely to be required for any civil accreditation of UAV systems. However, civil accreditation is also likely to require compliance with a number of other specifications which influence the safety and reliability of the UAV system.

UAV Safety and Reliability

To satisfy the requirements of civil aviation regulations, aircraft must generally satisfy the guidelines with relation to safety of other airspace users, and persons and property under flight paths. This general guidance extends to the range of aerial vehicles, including balloons, kites, rockets, manned aircraft and UAVs. The US Department of Transport Federal Aviation Administration (FAA) has stated:

[26] The option to destroy the UAV in flight is usually undertaken as the last resort due to the danger posed to population centres through falling debris.

> UAV operations should be as safe as manned aircraft insofar as they should not present or create a hazard to persons or property in the air or on the ground *greater than that created by manned aircraft of equivalent class or category.*[27]

This requires general adherence to the principles behind manned aircraft design such as the inclusion of system redundancy and/or independence. The US FAA has developed draft 'Advisory Circulars' specifying the requirements for UAV operations in civil airspace. The Circulars cover four integral components of UAV operations: design criteria, operations, pilot qualification and training, and maintenance. To these, a number of specific features are considered worthy of examination, including collision avoidance measures, weather avoidance and system robustness, datalinks for command and control, and system redundancy.

Design Criteria

The FAA considers that the basic guiding criteria for the design of UAV systems is that they should have 'A demonstrated means to comply with the equivalent level of safety afforded by the "see and avoid concept" applied to manned flight operations'.[28] The UAV is also to include 'the minimum equipment required to operate in the desired class of airspace'.[29] The implication of this design criteria is that most UAV systems will need a significant level of sophistication in order to operate in civil airspace. This will be particularly true for UAVs which are designed to operate beyond-visual-range. The onus will be on the manufacturer to demonstrate that the system design provides the 'equivalent level of safety' required.

Operations

The development of regulations for UAV operations in national airspace is likely to follow an evolutionary process based on incremental experience accumulated from civil UAV operations. The FAA has stated, however, that UAV operations will be expected to conform with '... the existing air traffic control (ATC) system without adversely affecting manned aircraft flights'.[30] The onus will be on UAV manufacturers to ensure they develop aircraft closely replicating the safety and response characteristics inherent in accredited manned aircraft. Furthermore, the FAA has stated that UAVs should equal manned aircraft in terms of ensuring the safety of persons and property, requiring that the probability of '... creating a hazard in a nonexpendable operation should not exceed 1×10^{-9}'.[31]

The requirement for UAVs to operate like manned aircraft will require the incorporation of sophisticated navigation and identification systems. Therefore, increased global access to DGPS is likely to assist in the integration of UAVs within regulated national airspace. At

[27] DRAFT Advisory Circular, 'Unmanned Air Vehicle Design Criteria', US Department of Transport, Federal Aviation Administration, 8 May 1996, para. 7.
[28] 'Unmanned Air Vehicle Design Criteria', para. 7.
[29] *Ibid.*, para. 7.
[30] DRAFT Advisory Circular, 'Unmanned Air Vehicle Operations', US Department of Transport, Federal Aviation Administration, 8 May 1996, para 5.
[31] *Ibid.*, para 5.

minimum, civil SIF or IFF transponders should be incorporated into UAVs destined for flight in controlled airspace. The Global Hawk UAV provides a good example of the sophistication of system components being fitted to provide it with an acceptable level of navigational capability. Global Hawk will be capable of operating in International Civil Aircraft Organisation (ICAO) controlled airspace under instrument flight rules (IFR).[32] Direct VHF/UHF communications will also be possible between Global Hawk's controller and air traffic controllers. For identification and tracking purposes the UAV is being fitted with military IFF transponders with mode 'C'.[33]

Collision Avoidance Measures

With current navigational systems UAVs have similar navigational capabilities to that of manned aircraft. However, the ability to replicate the effectiveness of manned aircraft in avoiding collisions is less easily achieved. Furthermore, the ability to avoid mid-air collisions represents one of the fundamental safety issues for UAVs. In lieu of conventional 'see and avoid' capabilities, UAV operations will therefore be required to employ one or a number of the following measures:[34]

- an on-board traffic alert and collision avoidance system (TCAS)
- ground-based primary or secondary radar
- a chase plane
- ground observers
- other sensor systems

The inclusion of a number of these measures will ensure an adequate level of collision avoidance capability is achieved.

Weather Avoidance and System Robustness

The effect of weather and temperature change on UAV reliability is one that has prompted a number of modifications to current UAV systems. The problem with wing-icing during Predator operations in the Balkans led to the proposed development of anti-icing equipment for its wings.[35] In fact, the Predator UAV was found to be significantly constrained by adverse weather conditions including moderate to heavy precipitation. For operation on runways, Predator is limited to a maximum crosswind of 14 knots and a maximum ground operation wind of 30 knots.[36]

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[32] *Air Command Concept of Operations for Endurance Unmanned Aerial Vehicles*, Air Combat Command, United States Air Force, Version 2, 3 December 1996, para. 3.10.
[33] *Ibid.*, para. 2.5.8.
[34] 'Unmanned Air Vehicle Operations', para 12.
[35] 'Extra Training Delays US Predator Programme', *Jane's Defence Weekly*, 14 August 1996, p 9.
[36] *Air Command Concept of Operations for Endurance Unmanned Aerial Vehicles*, para. 2.4.10.

New systems such as Global Hawk are being developed with superior weather tolerance capabilities and will be capable of operations in moderately adverse weather conditions. In contrast to Predator, Global Hawk is expected to be capable of operations in crosswinds up to 20 knots due to the speed and roll control provided through its wing spoilers.[37] Capable of operating in zero zero surface weather conditions, Global Hawk will also have the capability to take-off and land in lowered runway condition readings (RCR), as it is fitted with anti-skid braking systems.[38] Similarly, the effects of high altitude clear air turbulence will be overcome through Global Hawk's large control surfaces and fly by wire operations.[39] While weather avoidance radar is not currently being considered, the USAF propose to avoid thunderstorm activity through updates from on-board sensors and frequent updates from local weather radars.

Prompted by the operational difficulties experienced by the Predator UAV in Bosnia, UAV manufacturers are giving greater consideration to the incorporation of features to overcome and to avoid the effects of weather. This is evident in the design of TRA's Global Hawk UAV. The relationship between adverse weather conditions, and the reliability and safety of UAV operations should be considered as an important issue, both in the design and accreditation of UAV systems.

Datalink Requirements for Control and Communications

The reliability of datalinks will also be an important feature if UAVs are to be accepted for operations over populated areas. Datalink reliability will need to be demonstrated for UAV systems which rely on datalinks for command and control. In most cases, UAVs will achieve redundancy of their datalinks through the employment of two discrete communication systems. For situations where communications are lost from both systems, many UAVs have the capability to revert to a pre-programmed sequence which will guide them back to base. In any case, manufacturers and operators will need to demonstrate that their systems comply with requirements for public safety.

System Redundancy

As with manned aircraft, redundancies across a number of system components will be required to meet civil aviation standards. Engines, avionics and other components which are critical to flight safety will require a level of redundancy. UAVs will also require recovery and flight termination mechanisms where the aircraft will automatically return to base if a critical failure is inevitable.[40] For catastrophic failures, a non-explosive termination mechanism is required.

[37] *Ibid.*, para. 2.5.6.
[38] *Ibid.*, para. 2.5.6.
[39] *Ibid.*, para. 2.5.6.
[40] *Air Command Concept of Operations for Endurance Unmanned Aerial Vehicles*, para. 3.11.

Maintenance Procedures

Generally speaking, maintenance procedures for UAV systems should be in line with those for manned aircraft. Maintenance procedures, including scheduled maintenance servicings and inspection procedures should be set out by the manufacturer. As with other aircraft, normal record keeping and log books should be maintained. The recommended variation to normal procedures is the periodic reporting to the national airspace authority of failures associated with UAV operations.[41] This would enable the airspace authority to remain abreast of UAV developments and difficulties, and amend/develop airspace regulations accordingly.

Accountability

Crew Training and Certification

The diversity of UAVs makes the development of standards for crew training and certification somewhat complicated. Unsophisticated UAVs which operate within visual range are unlikely, for example, to employ complex navigation aids. At the far end of the spectrum, UAVs will demonstrate all the features of sophisticated manned aircraft with obvious implications for crew training. The US FAA suggests that, at minimum, all UAV pilots should be certified airmen. Where more than one UAV is being operated simultaneously, a single 'pilot-in-command' could oversee less qualified operators. While the complexity of the system will determine the level of qualifications required, the FAA foresee that a 'pilot-in-command' should be in possession of a commercial pilot certificate with instrument ratings applicable to the aircraft type as a minimum qualification.[42] Those operators acting under the supervision of a 'pilot-in-command' should have instruction in the following subjects:[43]

- Aerodynamics and principles of flight
- Structures, flight controls, electrical systems, navigation systems, etc
- Flight instruments, displays and interpretation
- UAV performance
- Weather limitations
- Navigation skills
- Use of flight information publications

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[41] DRAFT Advisory Circular, 'Unmanned Air Vehicle Maintenance', US Department of Transport, Federal Aviation Administration, 8 May 1996, p 2, para 5c.
[42] DRAFT Advisory Circular, 'Unmanned Air Vehicle Pilot Qualification and Training', US Department of Transport, Federal Aviation Administration, 8 May 1996, pp 5-6, para 8d.
[43] *Ibid.*, pp 5-6, para 8d.

Responsibility for Operations

Finally, acceptance of UAV operations by the wider community is likely to be dependent on the establishment of clear lines of responsibility for such operations. Military and civil operators alike will need to address the issue of who retains ultimate responsibility for the UAV in flight and at what stage responsibility is transferred from one operator to another. These legal aspects will be as important as many of the technical requirements of UAV operations in civil airspace.

Summary

One of the biggest challenges to the effective utilisation of UAVs will be the development of flexible airspace regulations. This will require some foresight on behalf of both defence and civilian authorities, as the development of regulations will have a significant influence on the design of UAV systems. Therefore, in developing regulations designed to provide flexible air operations whilst ensuring adequate levels of public safety, consideration of the implications for design and operation is required. Given the inclusion of UAVs as platform options for projects within the ADF, early involvement in the development of national regulations is warranted.

Chapter 18

System Vulnerabilities and Limitations

The removal of aircrew from aircraft creates a number of unique vulnerabilities and limitations for unmanned systems. These differences represent both actual and perceived limitations to the introduction and effective operation of UAVs. For example, their level of acceptance at the force development level is likely to be adversely influenced by 'perceived', or overestimations of, operational limitations and vulnerabilities. Alternatively, a realistic appreciation of their actual limitations is required so that planners do not acquire systems with unexpected operational and resource costs. Thus, examination of the issues will provide an understanding of the real vulnerabilities to UAV operations and the progress being made to address them. Furthermore, this process should highlight areas for the prioritisation of research and development, as well as providing a starting point for the development of doctrine and capabilities to counter the effectiveness of UAVs employed by an enemy.

Arguably, the most significant vulnerability lies in the UAV system's reliance on datalinks to effect the control of the aircraft. While this vulnerability can be addressed through greater automation of UAV systems, the political requirements to minimise casualties and collateral damage through improved accuracy have seen the re-emergence of datalinks usage for control and verification purposes. The relationship between accuracy and cost-effectiveness has placed further emphasis on incorporating a 'responsive' navigation system through the establishment of a datalink between the UAV and operator. This issue will therefore continue to represent one of the more significant challenges to UAV operations. The other major technical challenge will be to overcome current limitations to replicating the 'situational awareness' of manned aircraft. However, difficulties in matching the tactical advantage provided by 'situational awareness' is only likely to impede the development and acceptance of reuseable combat UAVs. In order to operate these advanced combat UAVs, or indeed the majority of reconnaissance UAVs in development, a sound communications infrastructure is required. For Australia, the absence of an organic military communications satellite represents a significant operational limitation to the employment of UAVs. These issues pose significant, though not insurmountable, challenges to the effective utilisation of UAVs and are therefore worthy of further examination.

Reliance on Datalinks for Control

The reliance on datalinks for both the control of UAVs and transmission of sensor data is seen as the greatest vulnerability to operating UAVs in a high-threat scenario.[1] Continuing developments in Electronic Warfare (EW) technologies are resulting in the creation of capabilities to intercept and jam datalinks between the UAV and the operator almost as fast as technologies are developed to secure the datalinks. While these threats are probably no more serious than those posed by other air defence systems such as surface-to-air missiles and intercept aircraft, the vulnerability of datalinks will continue to be cited as the main challenge to the widespread acceptance of UAVs. Accordingly, nations contemplating the employment of UAVs should take efforts to address the potential vulnerabilities of these datalinks. This will be particularly important for those who use the datalinks for the transmission of sensor data or who are likely to meet an enemy with sophisticated EW capabilities. Obviously, where an enemy's EW capability is primitive or limited, the vulnerability of datalinks is not an issue. However, where the potential threat to datalinks is considered substantial, several actions can be taken.

Datalinks are used for two purposes: as a method for positive control over the UAV and its sensors, and as a means for obtaining its sensor data or 'product' in real time. Where datalinks are used primarily for control purposes, greater automation of UAV operations represents one method of reducing their reliance on ground-to-air datalinks. The majority of cruise missiles, for example, use fully automated guidance systems. However, the current trend is to re-establish the man-in-the-loop for greater accuracy, flexibility and for political reasons. This has occurred for the Block IV Tomahawk cruise missiles, where a datalink between a ground control station and the missile was established to address the limitations of the TERCOM and DSMAC guidance systems incorporated in the fully automated Block III missiles.[2]

Other UAV systems have continued to pursue automation as it not only reduces the reliance on datalinks but also means fewer personnel are required to operate the platform and its sensors. Nevertheless the possibility of corrupting GPS and other navigation and guidance systems remains. This represents a significant concern to the US; however, it is unlikely that the capability to jam GPS will be widespread. Furthermore, this level of capability will have significant implications for manned aircraft as well as UAVs. The incorporation of a number of redundant navigation systems, such as 'ground-mapping' (as employed by cruise missiles), will further reduce the reliance on datalinks, although, each redundancy measure increases the cost and weight of the platform.

For UAVs and manned aircraft which use datalinks to transmit sensor imagery, their vulnerability is less easily reduced through automation. For those systems which have a heavy reliance on datalinks for their operation, a number of EW techniques can be employed

[1] Teleconference discussion with Dr A. Chaput, C. Link & A. Hill, UCAV IPT, Lockheed Martin Tactical Aircraft Systems, Fort Worth, Texas, 3 September 1997.

[2] Wing Commander P.A. Hislop, *Employment of Cruise Missiles by the ADF*, Paper No 57, Air Power Studies Centre, Royal Australian Air Force, Canberra, August 1997, pp 13-17.

to increase the security of the link. In addition, the use of software to process data on-board the UAV and transmit only data considered relevant, will reduce the reliance on a continuous link. This also addresses in part the limitation of available bandwidth.

An issue of growing concern to defence communities is the finite bandwidth available for use. In the global communications market with its growing requirement for bandwidth, military access to bandwidth will be in competition with international communications companies. The cost of access to bandwidth will rise as the requirement for high resolution video data in real-time increases. As this limitation applies to all platforms using bandwidth for the transmission of real-time data, it applies to manned aircraft as much as it does to UAVs. The management of finite bandwidth through coordinated communications protocols and architecture, particularly at the national level, will be essential for the exploitation of UAVs and other platforms in providing information dominance of the battlespace.

Replicating 'Situational Awareness'

The most commonly accepted limitation to UAV operations is their inability to replicate the 'situational awareness' of manned aircraft. This is seen as the greatest impediment to their development as combat platforms and represents the major reason why manned fighter aircraft are likely to be the last aircraft type[3] to be replaced by unmanned systems. The ability for UAVs or their ground-based operators to avoid threats to the platform's survivability is limited by the placement of its sensors and radar systems. For manned aircraft, aircrew provide an additional redundancy, through the flexibility to 'see' threats to their aircraft from almost any angle. The ability for aircrew to make instantaneous decisions based on an unfolding scenario cannot be matched by current decision-making algorithms, thus providing the manned aircraft with another advantage over UAVs.

The issue of providing UAVs with 'situational awareness' is not one without a solution. Two options may be employed to reduce the 'situational awareness' gap between manned aircraft and UAVs. The prerequisite to both of these options is the placement of more sensors to provide the same inputs as those received by aircrew in their cockpits. This concept is indeed already being developed for windowless cockpits, designed to remove the danger of aircrew being blinded by laser weapons.[4] Theoretically, a spherical view of the aircraft's environment could be achieved through the use of external sensors, whether they be optical, radar or a combination.

Achieving the 'situational awareness' of aircrew and the consequent decision-making process can either be done through introducing an artificial intelligence capability to the UAV, or through transmitting an image of the 'environment' to controllers in the air or on the ground. Advances in decision support systems are enabling sensor systems to do a significant amount of processing on the platform prior to transmitting 'valuable' information to the ground. This

[3] Other than passenger transport aircraft, which by definition is 'manned'.

[4] B. Sweetman, 'US Air Force ProbesTechnological Frontiers', *Jane's International Defense Review Extra*, Vol 1, No 6, June 1996, p 5.

is demonstrated in the development of automatic target recognition systems that use a series of algorithms to determine whether an object resembles a military or predefined target. The UAV will only then transmit information to the analysts on the ground if the object meets a certain probability of match with a defined target. This type of decision support system reduces the amount of bandwidth and transmission time required to send sensor data to analysts by filtering out only those items of interest. Advances in this type of support system can be further developed to identify threats to the UAV itself and prompt pre-programmed avoidance or retaliation sequences. The TRA Global Hawk, for example, is being fitted with the AN/ALR-89 Threat Warning Receiver (TWR), the ALE-50 Towed Decoy System and a Threat Deception System (TDS) which includes on-board jammers, expendable decoys and appliques.[5] Further, through full integration of the TWR with the flight computer, Global Hawk will be capable of manoeuvring for greater survivability against detected threats.

While artificial intelligence has not advanced to the state where the aircraft can replicate the responses provided by aircrew, such development is foreseeable within the next twenty years. The contemporary intelligence of current air-to-air missiles provides a striking example of the sophistication of decision support systems already in existence. Those missiles at the forefront of technology are able to distinguish between the aircraft and its use of chaff and decoys through complex decision algorithms. This level of intelligence present in fourth generation missiles has already, in part, replaced the requirement for aircrew to provide continuous tracking of the aircraft for the missile. The extension of this concept to re-useable UAVs is, therefore, achievable.

The second method of providing UAVs with the 'situational awareness' of manned aircraft is by maintaining the man-in-the-loop. Controllers employ helmet-mounted-displays which can re-create a virtual environment using datalinked imagery and data. This system enables the controller to provide the human computing-power to instruct the UAV on its course of action. In essence, the maintenance of the man-in-the-loop for the Block IV Tomahawk missiles has redressed the limitations of pre-programming by enabling the missiles to be retasked mid-course by the operator. The limitation to this mode of operation is the vulnerability of the datalink and amount of bandwidth required to replicate the UAV's operating environment to standards necessary for fighter-operators. The adoption of a combined system based on the use of on-board artificial intelligence and using a modified form of transmission to the ground-based operator, could see UAVs with similar capabilities to manned aircraft in terms of 'situational awareness'. The specialised training of ground-operators might even see them demonstrate a better fighting capability than those with the limited horizon of contemporary cockpits.

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[5] *Air Command Concept of Operations for Endurance Unmanned Aerial Vehicles*, Air Combat Command, United States Air Force, Version 2, 3 December 1996, para. 2.5.5.

Limitations for the ADF

Discussing the potential employment of UAVs must be tempered by the understanding that UAVs are limited to an operational radius of between 200-300 kilometres for line-of-sight transfer of real-time data. For beyond line-of-sight transfer, a relay is required using either a satellite or another air platform, capable of processing the necessary bandwidth. As the ADF does not currently possess an organic communications satellite asset, bandwidth requirements would either have to be purchased from civilian communication companies or from military allies. The civilian option would prove costly, whilst the allied option has the obvious constraints in terms of priority and the potential for restrictions of accessibility.

The requirement for satellite bandwidth, however, rests on the premise that real-time data is required. Advanced UAVs such as Global Hawk are capable of performing pre-programmed missions with no requirement for satellite communications other than the use of a Global Positioning System (GPS) to verify their position and track. Global Hawk has the capability to undertake surveillance missions and to store data until it is within range of a ground station where it can down-load its mission data. Alternatively, the data could be stored until the platform returns to base. In undertaking peacetime surveillance tasks, there is perhaps an arguable case that visual data need not necessarily be provided in real-time. As discussed in Section Three, the purpose of peacetime surveillance by military assets is to paint the picture of what constitutes 'normal' activity in the sea-air gap. Notwithstanding, a capability to transfer real-time data in beyond line-of-sight operations would be preferred.

Another solution to the absence of an indigenous ADF satellite capability is the use of other air or ground-based communication relay platforms. For land-based surveillance, small communication stations could be built to extend the reach of UAVs around high-value targets. Alternatively, mobile communication stations, whether ground or air-based could prove cost effective in extending the legs of reconnaissance UAVs. For Battle Damage Assessment (BDA) and other high-risk missions, the control of the UAV and receipt of its imagery from another aircraft platform, represents a concept of operations with some merit. While the lack of an organic military communications satellite poses a significant operational limitation to the employment of UAVs in Australia, other less costly solutions will partially address the need for communication relays for beyond-visual-range operations. If and when the ADF acquires a satellite, some consideration should be given to the potential requirement for manned and unmanned systems to transmit real-time imagery using the satellite. Any requirement may affect decisions on the most appropriate placement of the satellite footprint and therefore warrants early analysis.

Summary

UAVs have some significant operational limitations and system vulnerabilities. For Australia, the most significant limitation relates to the absence of a comprehensive satellite communications infrastructure which severely limits the employment of UAVs for beyond-visual-range tasking. Any analysis of the ability of UAVs to undertake specific mission profiles must account for this operational limitation. Fully costed solutions to providing the UAV with communications relays are required where a beyond-visual-range capability is necessary.

For nations like the US who see the cost-effectiveness in developing combat UAVs, other limitations, such as the inability to replicate the 'situational awareness' of aircrew, have greater implications for the acceptance of UAVs. This lack of situational awareness makes the UAV more vulnerable to conventional air defence threats. However, it is the reliance on its datalinks that is considered by many as the greatest vulnerability of the UAV system. Accordingly, the security of datalinks and the further development of automated systems will remain the focus of UAV manufacturers.

Chapter 19

Culture

Introduction

> The operational promise of UAVs and their uninhabited combat aircraft successors offers one example of the growing need for a more open-minded view among airmen understandably wedded to the conviction that airplanes without pilots are like days without sunshine[1]

A unique consideration for the employment of UAVs in roles traditionally performed by manned aircraft is the influence of culture on their acceptance. Cultures can have a profound, though sometimes innocuous, influence on decision-making processes. Choices considered incongruent to a society or institution's health will be rejected. For this reason, UAVs are likely to encounter cultural resistance based on a combination of both technical and social issues. On a technical level, system reliability and operational effectiveness will influence the acceptability of UAVs in performing a number of tasks. For example, the technical reliability of UAVs to operate in national airspace, with the guarantee of equivalent levels of public safety to that achieved by manned aircraft, will play a large part in the acceptance of UAVs by society in general. Similarly, comparative operational effectiveness must be demonstrated in order to convince those organisations involved in aerospace operations that UAVs represent a competitive alternative to manned aircraft and satellites. Discussed in earlier chapters, resolution of these technical issues will go some way to addressing cultural resistance to UAVs. There will remain, however, a level of resistance, which is based on more emotive and instinctive foundations. For example, there appears to be an inherent level of scepticism associated with fully automated 'computer' systems; public safety may be seen to be compromised by virtue of removing the redundancy provided through aircrew. Cultural resistance is also likely to be encountered by those threatened by the widespread introduction of unmanned aircraft - namely, aircrew. The removal of aircrew from aircraft directly threatens the employment opportunities for aircrew. Therefore, cultural aversion to UAVs in performing some manned roles will be experienced from two areas: pro-aircrew lobbies in particular and, to a lesser extent, society in general.

This chapter examines the cultural barriers which may impede the widespread acceptance of UAVs for both military and non-military tasks. The cultural aversion to UAVs by the general public is subject to limited examination given the moderate influence they will have on the

[1] Benjamin S. Lambeth, 'Technology Trends in Air Warfare', A. Stephens (Ed), *New Era Security: The RAAF in the Next Twenty-Five Years*, Air Power Studies Centre, Canberra, June 1996, p 157.

employment of UAVs in military operations. Comparatively, the acceptance or otherwise of UAVs by the military and other aerospace organisations will have a significant influence on the mindset of the general public. The cultural barriers to UAVs, therefore, are mainly examined in the context of the armed forces in general, and air forces in particular.

Cultural Resistance to UAVs

Reliability and Public Safety

A key legal and cultural barrier to the general acceptance of UAVs is the issue of public safety. That UAVs may not be capable of providing sufficient guarantees for public safety by virtue of removing the 'eyes and ears' and extra level of system redundancy provided by on-board operators, is likely to represent the issue of greatest concern to the general public. In addition, the general scepticism surrounding the reliability of machinery, and computers in particular, is likely to temper the widespread acceptance of UAVs.

There are few automated systems that do not have a human operator present for the express purpose of monitoring the system in case of failure. The public's requirement for the redundancy provided by a human operator particularly applies to systems involving the carriage of passengers or having some link with public safety, such as the operation of a dam or nuclear reactor. This on-going scepticism of fully automated systems is evident in the resistance to automatically operated trains, monorails and trams, where a number of countries continue to employ operators as a result of on-going public pressure. Furthermore, the human aversion to placing complete faith in machines is unlikely to disappear overnight; arguably, few people would be willing to travel on a passenger aircraft that relied solely on its 'autopilot' system. With the exception of tasks involving the transport of passengers however, UAVs are likely to gain acceptance by the general public where they demonstrate cost-effectiveness over manned aircraft. This acceptance will be conditional on the ability for UAVs to meet existing aviation standards for safety. UAV operators will be required to prove that their systems are no more prone to mid-air collisions or catastrophic failure over populated areas than manned aircraft. However, as suggested previously, even with equal guarantees of in-built redundancies for safety, an element of cultural bias is likely to remain. The employment of UAVs in other than military-based operations may encounter some resistance, particularly where their operation involves sharing airspace with passenger aircraft or operations over highly populated areas.

Operational Effectiveness

The other technically-based objection to UAVs, which will come from those organisations involved in aerospace operations, is their ability to fulfil operational requirements. As discussed in previous chapters, these objections will provide the underlying guidance on where UAVs can effectively be employed as alternative systems to manned aircraft and satellites. Much of the objections based on operational effectiveness will be resolved through the maturation of technology and due attention to the vulnerabilities of datalinks, development of airspace management regulations and the resolution of other legal issues. For many organisations UAVs will be employed where they demonstrate an operational capability to undertake required tasks in a cost-effective manner. These are likely to include the use of UAVs for environmental research of a continuous or dangerous nature (such as bushfires), or endurance tasks such as election monitoring and the provision of mobile communications capabilities. Many of the organisations involved in these types of activities tend to charter or hire crewed aircraft for the purposes of completing the required tasks. In such instances, where UAVs prove more cost-effective and are operationally capable in completing the task, there is little chance of cultural resistance to their employment.[2] For armed forces, on the other hand, the existence of a large body of permanently employed aircrew significantly changes the cultural acceptance equation.

Aircrew Employment Opportunities

The widespread introduction of UAVs into the military will change both the quantity and nature of employment opportunities for aircrew. This fundamental consideration lies at the heart of what is perceived to be a general aircrew resistance to UAVs. Like the introduction of many other automated systems, UAVs threaten to change the role of aircrew from that of a 'hands-on' operator to one of a system monitor. Furthermore, it is conceivable that one ground-based operator/monitor can control a number of UAVs simultaneously, thereby reducing the quantities of skilled 'aircrew' operators required.

In a sense, these changes have already begun to occur as a result of technological improvements providing better weapon precision and stand-off capabilities. Far fewer aircraft are required in the 1990s to deliver the required firepower to designated targets than previous decades owing to increased weapon precision.[3] Non-expendable UAVs threaten to reduce the requirement for manned aircraft even further. This simple equation forms the basis of what may be described as the resistance of aircrew culture to greater UAV employment within the military sphere. The influence of such a culture in preventing or impeding the acquisition of UAVs into the organisation is, however, difficult to quantify. As stated at the outset of this chapter, a society is unlikely to support a decision which is seen to compromise the health of that society. Arguably then, where an organisation has a significant 'aircrew culture', support for UAVs is unlikely given their potential effect on aircrew employment opportunities.

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[2] The enthusiasm by many research agencies and other civilian organisations in using UAVs for environmental research and other purposes (where proving cost-effective) was evident in a two day seminar on UAVs, held at the CSIRO Headquarters, Canberra, October 1996.

[3] However, while high-precision stand-off weapons have changed the numbers of aircraft involved in strategic strike campaigns, the manned delivery platforms continue to require highly developed flying skills and tactics in order to evade threats from equally well-developed defence systems with capabilities for increasingly greater ranges.

Consequence of Cultural Resistance to UAVs

The particular aversion to UAVs by aircrew is not new. Indeed, lack of support for UAV programs by aircrew in the USAF has arguably hampered their development since the 1970s despite their operational success in the Vietnam conflict.[4] Indeed, UAV development since that period has been largely supported by armies and navies, which had little exposure to the sophisticated UAV operations of the likes of Vietnam. In comparison, air forces, and the USAF in particular, have largely failed to support UAV development other than for specific programs such as air-launched cruise missiles and decoys - both expendable platforms.[5] This has been the case until fairly recently where, arguably, development of sophisticated UAVs by the other Services has forced air forces to come to terms with the platforms.[6] While the political imperative for air forces to maintain their current suite of roles may force them into the UAV arena, a number of other drivers should have an equal role. The imperative to reduce the probability of casualties whilst achieving the mission requirements in the most cost-effective manner should see air forces embrace UAVs on their own merits. The effectiveness of current generation UAV systems in performing tasks previously undertaken by manned aircraft provided the rationale for their acceptance by surface forces. Additionally, because air forces were reluctant to invest in unmanned systems, these surface forces now have an increased number of organic aerospace systems with associated command and control of the assets and air support roles they provide. Furthermore, those Services operating UAV systems are developing a comprehensive understanding of their operational benefits and limitations. This is essential to the development of operational concepts and capabilities to counter the effectiveness UAV systems employed against the armed forces. Moreover, familiarity with the system capabilities is giving rise to unique employment concepts which could provide marked tactical advantage over an adversary.

Services with less powerful aircrew communities more readily recognise and employ the potential of UAVs in appropriate missions. Furthermore, it is in these other Service communities that initiatives on methods of employment and concepts of operations. In 1996, the US Navy used the Predator UAV to provide target surveillance for operations by Navy SEAL special forces teams. The submarine-controlled UAV provided the submarine-based SEAL team with the real-time reconnaissance intelligence required to plan its insertion. The nuclear attack submarine was able to operate the Predator some 100 nautical miles from shore whilst submerged at periscope depth.[7] The implications for the navy are obvious, '...rather

[4] B. Carmichael, T. DeVine, R. Kaufman, P. Pence & R. Wilcox, *Strikestar 2025,* A Research Paper Presented to Air Force 2025, August 1996, p 22.

[5] Arguably, air forces don't have the same requirement for short-range tactical reconnaissance UAVs as the two surface forces. However, despite the significant successes of air force operated UAVs for strategic targeting and EW roles in Vietnam, air forces (with the exception of Israel) have largely neglected the development of UAVs in favour of manned aircraft.

[6] Anecdotal evidence by Wing Commander S.W. Filmer, May 1997, suggested that the USAF had been forced into arguing a case for supporting endurance UAVs as USAF assets in order to maintain a 'line-in-the-sand' demarcating US Army and US Air Force operations.

[7] P.G. Kaminski (US Undersecretary of Defense for Acquisition and Technology) quoted in A. Kimery 'Predator on the prowl', *Military Information Technology*, Summer 1997, p 26.

than having a 15-foot periscope, the submarine effectively [has] a 15,000-foot periscope'.[8] The success of the exercises by Special Operations Forces (SOF) is likely to secure the place of UAVs in future operations and further encourage the development of doctrine to exploit these assets. The Undersecretary of Defense for Acquisition and Technology acknowledged the support the concept received in the Navy, suggesting '... some people in the submarine community have commented that "this is the most exciting thing that has happened in submarine warfare since the nuclear reactor"'.[9]

The pursuit of UAVs by armies is even more prevalent, with UAVs being embraced into Army inventories as systems which are critical to delivering commanders real-time battlespace information. Furthermore, the responsiveness, flexibility and ubiquity of air-based platforms can provide armies with real-time information at significantly lower costs than can ground-based units. In the Australian context, the use of light armoured vehicles to conduct reconnaissance of vast areas is costly in terms of platform and manpower usage. The use of UAVs in support of such ground capabilities could act as a significant force-multiplier. This concept is already being developed by the US Army which is investigating the use of UAVs to extend the eyes and ears of their rotary-wing platforms. Their use in target designation for artillery is also being recognised as an important force-multiplier, as evidenced in the UK requirement for a system to support the self-propelled AS-90 artillery platforms of the British Army.

Armies and navies are quickly recognising the utility of acquiring organic UAVs for providing responsive air power in support of their respective missions. A consequence of air forces failing to adequately consider the acquisition and development of UAVs in their own right might be the loss of roles to other Services more willing to employ the new technology. For armed forces in general, the failure to consider UAVs in an unbiased manner, could result in the rejection of platforms with greater potential for cost-effectiveness and utility across the spectrum of conflict. It is therefore important to ensure UAVs are assessed objectively. A prerequisite to providing an environment where systems may be assessed with limited subjectivity is in recognising the biases of those involved.

Organisational Culture and Change

Prior to discussing how to address the specific aversion to UAVs within Services with strong aircrew cultures, an understanding of how culture develops within an organisation and what difficulties it can present to organisational change is required.

Geert Hofstede, a leading management theorist, defines culture as follows:

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[8] *Ibid.*, p 26.

[9] *Ibid.*, p 26.

> ... culture is the collective programming of the mind which distinguishes the members of one group or society from those of another. Culture consists of the pattern of thinking ...[10]

Hofstede theorises that culture can form the basis, hence direction, of an institution's thinking:

> Culture, although basically resident in people's minds, becomes crystallised in the institutions and tangible products of a society, which reinforce the mental programs in their turn. Management within a society is very much constrained by its cultural context, because it is impossible to coordinate the actions of people without a deep understanding of their values, beliefs and expressions.[11]

Within tight-knit institutions, change can be particularly difficult to achieve, especially where the change threatens the basic tenets upon which the institution or society is founded. Mukhi et al argue that institutions such as the military forces and visionary companies '... have a kind of unified character or integrity. They know who they are and what they want to be, and that knowledge is brought to bear in making decisions. Incongruent choices are rejected.'[12]

This resistance to change, which is seen to threaten the character of the institution, is easily demonstrated in the military. The 'warrior' ethos of the military in general has seen strong resistance to proposals to accept women in increasing roles, as well as the introduction of policies to allow homosexual personnel to serve. This resistance is also being experienced in the case of the introduction of UAVs within Services with strong aircrew cultures.

Several gauges can be used to determine the extent and influence of a 'cultural bent' within an organisation. The inculcation of culture is achieved through a number of mechanisms including:[13]

- formal statements of organisational philosophy.
- deliberate role modelling by leaders.
- explicit reward and status systems, including promotion and posting criteria.
- stories, legends and myths.
- measure and control mechanisms, leadership priorities.

The overt and covert use of these mechanisms to instil underlying cultural philosophies within an organisation is evident across a number of institutions, including the military. The existence of an aircrew culture within Services, and air forces in particular, will be demonstrated by examining the use of the mechanisms outlined.

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[10] Geert Hofstede, quoted in S. Mukhi, D. Hampton & N. Barnwell, *Australian Management*, McGraw-Hill Book Company, Sydney, 1988, p 76.
[11] *Ibid.*, pp 76-77.
[12] Mukhi, et al, *Australian Management*, p 334.
[13] *Ibid.*, p 335.

Aircrew Culture

Organisational cultures and sub-cultures often represent the essence or fundamental tenets of the institution. In air forces in particular, aircrew represent the 'warrior' of the Service. Essentially, aircrew and their aircraft have come to symbolise air power itself. Not surprisingly then, air forces have particularly strong aircrew cultures. While the aircrew culture may be present in the other services where aircraft are operated, its influence is tempered by the presence of other environmentally-based warrior cultures including ground-based army units, and ocean surface and sub-surface combatants.

The existence of a dominant aircrew culture is both entirely natural and appropriate in Services and other organisations where air power is delivered primarily by means of manned aircraft. Acknowledgment of the existence and influence of an aircrew culture is required, however, in order to be sufficiently cognisant of the potential influence it may have on decisions which potentially change the balance of power or the nature of the organisation.

Arguably, while most air forces have undergone fundamental cultural changes in line with societal and technological influences, there remains expected levels of cultural bias consistent with the make-up of the institution. This bias may impede the acceptance of UAVs, even where they demonstrate equal or better cost-effectiveness in delivering air power.

Establishing a clear link between the employment of formal mechanisms and the existence of aircrew cultures by most modern air forces is surprisingly difficult. While the stories and myths of many air forces revolve around aircrew, particularly of fighter and bomber pilots, the more formal organisational statements and promotion systems are less obviously explicit in promoting a dominant aircrew culture. The Royal Australian Air Force has, for example, adopted a 'One Team' approach as its formal philosophy, which acknowledges the contribution of all air force personnel to the delivery of air power. This approach has extended to the adoption of the General List (GLIST) category for Group Captain rank and above, where positions and promotions are achieved on the basis of individual performance and suitability for specific jobs. Many positions have opened up to contenders across the range of officer categories where they were previously classified by category. The GLIST concept is also a reflection of more subtle cultural changes taking place within the RAAF. For example, cultural changes within the aircrew culture itself has seen transport and maritime pilots fill the Chief of Air Force position, and navigators appointed as commanders of force element groups.

These cultural changes reflect an air force which is adapting to the changing nature of warfare brought about by technology and evolving concepts of operation. Air power in the emerging strategic environment is as much about mobility, information dominance and targeting as it is about bombs on targets. This recognition has slowly seen a change in the aircrew sub-cultures as well as across other categories involved in the delivery of air power. As concepts of air power continue to change with the increased importance of space-based surveillance and information-based capabilities, a further decline in the influence of the aircrew culture appears likely. This may arguably be some way into the future, or may not necessarily eventuate, as has been the case with the USAF's missile command. However, the critical issue is that air forces look past their cultural biases in order to adequately consider new weapons systems and concepts of operations so that they can continue to deliver air power in the most effective and decisive manner available.

Overcoming Cultural Barriers

> Under the many challenges of their rapidly changing environment, the Air Force [US] leadership may have become more focused on the preservation of flying and fliers than on the mission of the institution.[14]

Given the potential threat to aircrew positions, UAVs are likely to be considered an 'incongruent choice' by institutions dominated by pro-pilot cultures. This is likely to continue until their acceptance becomes a matter of organisational survival. Some may argue this theory as simplistic and ignorant of the other drivers within an organisation. Arguably, factors such as limited resources and operational requirements will influence decisions on what type of platform presents the most cost-effective option in delivering specified force capabilities. However, the influence of culture, much like that of politics, on such decisions must also be acknowledged. Measures developed to limit this influence must be incorporated if UAVs are to be impartially compared against other force capability options.

Education

The first step to overcoming the cultural aversion to UAVs is through the education of their strengths and limitations. Comprehensive knowledge of their potential will encourage innovative development of concepts of operations and operating procedures designed to exploit the strengths inherent in UAVs. Alternatively, an understanding of their limitations should enable defence planners and defence scientists to focus their energies into activities aimed at addressing these limitations. Concerted efforts to develop baseline regulations for UAV standards, and operating procedures for national and international airspace operations provide one example where progress can be made within a relatively short time-span. Other, less easily addressed, limitations such as the vulnerability and limited access to organic space-based datalinks can be used up-front to discount UAVs for near-term acquisition options, thereby reducing the alternatives early in the decision process. Broad-based education of aircrew, force development personnel, defence civilians and politicians on the limitations as well as the potential of UAVs in supporting ADF activities is desirable for these reasons.

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[14] C. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the U.S. Air Force*, Transaction Publishers, New Jersey, 1994, p 200.

Conclusion

The hypothesis taken in this chapter is simple:

> Air forces have a dominant aircrew culture; UAVs threaten the employment opportunities for aircrew; therefore, a degree of cultural resistance to UAVs in air forces is likely to exist.

Ultimately, UAVs should be judged on their own merits. Their competitiveness as options for the ADF should be measured on operational and cost effectiveness. As with all defence purchases the influence of cultural bias should be eliminated from the acquisition process.

Greater awareness of the potential of UAVs in contributing to Australia's national security requirements along with a concrete understanding of their costs and vulnerabilities is needed to break down the cultural aversion to and myths surrounding UAVs. Further, this may provide the impetus to consider their viability in meeting stated force capabilities, and direct energies to address the challenges to their introduction and operation.


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Chapter 20

Conclusion & Recommendations

It is clear that unmanned platforms will feature increasingly in the inventories of many nations as armed forces structure for the range of operations demanded in the emerging security environment of the next millennium. Improvements in technology will see that the ability of unmanned platforms to carry both lethal and non-lethal payloads will ultimately match, if not surpass, the characteristics for accuracy and precision currently achieved by manned operations. Further, removal of the manning requirement in the platform will create a vehicle that will not endanger the lives of on-board operators, a fact that will make the use of such systems appealing in the face of high risk scenarios. In addition to this, the removal of the need to include crew support systems and limit the platform performance to human endurance levels mean that unmanned variants will generally be able to carry out missions with larger payloads and more difficult mission parameters than currently achieved by manned platforms. Factors other than simple performance characteristics including specific geography, political environment and concepts of operations will ultimately influence to what extent unmanned platforms replace or augment existing manned systems.

In the Australian context, the vastness of the continent and the size of the maritime approaches represent a challenge that is almost unique to defence planners. Limited northern infrastructure, relative isolation from neighbours and challenging environmental conditions further exacerbate the difficulties for developing coherent defence response systems. With these factors in mind, any system that can provide extended range and endurance offers definite possibilities for inclusion within the ADF force structure.

The versatility that UAV platforms offer also promotes their consideration for Operations Other Than War. Recent history has showcased the exploits of UAVs for a variety of tasks including peacekeeping and peace-making activities as well as for other scenarios where loss of life would be politically and socially unacceptable. Additionally, the growing requirement for the ADF to support civil operations in security tasks such as coastwatch, cooperative regional surveillance programs and fisheries activities could see the use of UAV platforms which are procured for defence of Australia tasks. The importance of such versatility is referred to specifically in the strategic guidance paper, *Australia's Strategic Policy*, which states:

> In deciding how best to develop forces to defeat attack on Australia, we will take account of the contribution that different options would make to other tasks.[1]

[1] *Australia's Strategic Policy*, Department of Defence, December 1997, p 36.

While UAVs are clearly capable of supplementing current Australian maritime surveillance capabilities, they are likely to prove more competitive for land surveillance and reconnaissance roles. In the short term, the ADF's lack of an organic military communications satellite, coupled with the current payload limitations of current generation UAVs, limit their application in the maritime surveillance role. While these limitations also affect their utility in land surveillance roles, mobile ground control stations and communication relay stations (which may be ground-based) offer practical solutions to extend the reach of the UAVs. Additionally, a smaller range of sensors are required for the land surveillance roles. These sensors have significantly lower power requirements and are substantially smaller than those required for sea and air surveillance.

With the upcoming replacement of the F-111 and F/A-18, the ADF is also likely to give serious consideration to the increased role of UAVs in complementing offensive capabilities. The use of UAVs to enhance the stand-off capability of manned aircraft is already a concept familiar to the RAAF with the AGM-142 and Harpoon missiles (even though these stand-off weapons are more frequently identified as missiles rather than as a branch of the UAV family). The acquisition of longer range stand-off missiles, such as cruise missiles, is likely to be considered to extend the reach of the F-111 replacement aircraft.

Given the increased sophistication of regional air defence capabilities, UAVs may also be considered to supplement Supression of Enemy Air Defence (SEAD) roles. This could involve the acquisition of decoys and UAVs with EW systems. In the nearer term, examination of anti-radiation missiles under Project AIR 5398 will bring the concept to the fore, with Israel Aircraft Industries' (IAI) Harpy and several other anti-radiation missiles being classified as UAVs as a result of their extended loiter capabilities.

The likelihood of a relationship with reuseable combat UAVs, or UCAVs, is less easily forecast. While there is a very real possibility that the ADF may acquire longer-range stand-off weapons in the form of cruise missiles, the leap to reuseable UCAVs within the timeframe set by the study is not considered likely. Though the potential for cost-effectiveness and operational capability is there for UCAVs, the concept is not likely to be sufficiently proven to the extent where an on-line weapons system is available, or indeed accessible, before Australia acquires its F/A-18 and F-111 replacements. Further to this, Australia is unlikely to have the communications infrastructure required to exploit UCAV systems with sufficient flexibility to meet ADF capability requirements. This said, the ADF should keep abreast of developments in the UCAV field and should give appropriate levels of consideration to them as options in the force development process. The open-mindedness demonstrated by the previous Minister for Defence, Ian McLachlan, who stated of the F/A-18 replacement, '... I do not even want to prejudge whether it will be a piloted aircraft',[2] should set an example to those in the capability development area to include all possible options in initial considerations of capability options.

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[2] P. Cole-Adams, 'McLachlan floats pilotless warplane plan to replace F/A-18', *The Canberra Times*, 31 March 1998, p 3.

Establishing such an open-minded approach to UAVs has been one of the primary objectives of the study. Through the examination of the advantages, costs and limitations of UAVs undertaken in this study, it is hoped that they can be analysed objectively as weapons systems options for the ADF. This requires the employment of a comparative analysis methodology which accounts not only for their relative strengths against other options, but includes rigorous analysis of their operational limitations and costs. The foundation for such a methodology was provided in Section Two.

Finally, before UAVs secure a greater place in the ADF force structure, resolution of the challenges discussed in Section Four is required. Development of flexible airspace regulations, concepts of operation and appropriate command and control methodologies will ensure the utility of UAVs is exploited to its fullest. Further research and development of technologies to reduce their limitations, will see UAVs overcome some of the main objections to their acceptance. This will go some way to address the cultural aversion to UAVs by groups both within the military community and society in general.

In summary, the ADF has acknowledged the potential for UAVs to fill a number of roles, as evidenced in their inclusion as an option within Project *Warrendi*. Furthermore, the ADF has taken steps to become involved in the operational test and evaluation phase of Teledyne Ryan's Global Hawk. This level of interest by the ADF suggests that analysts are willing to examine UAVs as platforms with applicability to the Australian environment.

Recommendations

While it has not been the intention of this study to recommend the acquisition of UAVs for their own sake, several recommendations designed to provide the foundation for their introduction and effective operation are made. Many of the challenges to their employment can be overcome provided Defence takes a number of proactive steps to resolve the issues. Accordingly, the following recommendations are made:

1. The ADF should determine possible future requirements for UAV operations and provide input into the Civil Aviation Safety Authority's development of airspace regulations for UAVs.

2. Greater emphasis should be placed on conducting research in the fields of datalink security and methods for breaching datalinks. This will assist the ADF in developing capabilities to counter the employment of UAVs against it, as well as ensuring better security for possible ADF UAV operations. Defence scientists and force development personnel should also be encouraged to remain abreast of UAV developments and advances in associated technologies which will impact on the maturation of UAVs.

3. Field exercises involving the employment of UAVs against ADF units should be considered as a means of providing the ADF an understanding of their effect on the battlefield. This will aid in an assessment of the effectiveness and utility of UAVs in the Australian environment. The exercise will also provide the ADF with the experience from which to develop concepts of operations to counter their effectiveness.

4. The ADF should consider further development of current comparative analysis methodologies to include more substantive measures of utility.

Annexes

Annex A

Surveillance Mission

Scenario: Peacekeeping operations in Bougainville

Global Hawk

Capabilities:

Speed:	300 kts
Endurance:	34 hours
Sensors:	EO/IR, SAR
Swath:	1670 sq nm/hour

Concept of Employment:

Weipa to northern point of Bougainville	1000 nm @ 300 kts	= 3.3 hr
surveillance of area 150 nm x 50 nm	7500 sq nm @ 1670nm/hr	= 4.5 hr
traverse back to start surveillance	200 nm @ 300 kts	= 0.7 hr
surveillance of area 150 nm x 50 nm		= 4.5 hr
traverse back		= 0.7 hr
surveillance of area 150 mi x 50 mi		= 4.5 hr
traverse back		= 0.7 hr
surveillance		= 4.5 hr
traverse		= 0.7 hr
surveillance		= 4.5 hr
Bougainville to Weipa		= 3.3 hr
Total hours		**= 31.9 hr**

A single Global Hawk capability flown from Weipa would provide five surveillance missions in a 26 hour period. The revisit time over any one coordinate would be approximately 5.2 hours. The use of three Global Hawks at staggered intervals could therefore provide a revisit capability of a platform revisiting an area once every 1 hour 40 minutes.

Annex B

Surveillance Mission

Scenario: Peacekeeping operations in Bougainville

King Air 350

Capabilities:

Speed:	240 kts
Endurance:	7 hours
Sensors:	EO/IR, SAR
Swath:	1670 sq nm/hour

Concept of Employment:

Weipa to northern point of Bougainville	1000 nm @ 240 kts	= 4.2 hr
Bougainville to Weipa		= 4.2 hr
Total hours		**= 8.4 hr**

Using the example, a King Air 350 is not capable of being flown from Australia to conduct surveillance missions over Bougainville in the given scenario. Any surveillance from this surveillance platform would require pre-arranged approval to operate from an airstrip on Bougainville or mainland Papua New Guinea. The distance of the base to the start point for surveillance is critical to the viability of certain surveillance platforms.

Annex C

Surveillance Mission

Scenario: Loiter surveillance required over Oil Rig on North-West shelf of Australia

Global Hawk

Capabilities:

Speed:	300 kts
Endurance:	34 hours
Sensors:	EO/IR, SAR
Swath:	1670 sq nm/hour

Concept of Employment:

RAAF Curtin to Oil Rig	430 nm @ 300 kts	= 1.5 hr
surveillance over area		= 31 hr
Oil Rig to RAAF Curtin		= 1.5 hr
Total hours		**= 34 hr**

Global Hawk could be flown to most areas over the North-West shelf from RAAF Base Curtin providing approximately 31 hours continuous surveillance over the area

Annex D

Surveillance Mission

Scenario: Scenario: Loiter surveillance required over Oil Rig on North-West shelf of Australia

King Air 350

Capabilities:

Speed:	240 kts
Endurance:	7 hours
Sensors:	EO/IR, SAR
Swath:	1670 sq nm/hour

Concept of Employment:

RAAF Curtin to Oil Rig	430 nm @ 240 kts	= 1.8 hr
Surveillance of area		= 3.8 hr
Oil Rig to RAAF Curtin		= 1.8 hr
Total hours		**= 7 hr**

The King Air could conduct surveillance over the designated area for 3.8 hours. A single aircraft could not provide 24 hour coverage. Additionally, three to four crews would be required due to aircrew limitations.

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Air Power Studies Centre

Uninhabited Aerial Vehicles (UAVs) are gaining increased popularity for their ability to undertake a number of important defence roles without risking the lives of aircrew. This characteristic, amongst others, promotes them as platforms with utility for employment across the spectrum of conflict. Furthermore, through the removal of aircrew, UAVs promise better cost-effectiveness in tasks of a 'dirty, dull or dangerous' nature.

The potential cost-effectiveness and utility of UAVs promote them for further consideration by defence forces who are seeking adaptable systems for relevance in the emerging strategic environment. However, their applicability is dependent on a nation's strategic and geographic environment, its infrastructure and the method of warfighting employed. The relevance of UAVs to the ADF must therefore be examined in an Australian context.

This book sets out to lay the foundations for the consideration of UAVs as options in support of ADF capabilities. Challenges specific to their introduction and optimum employment are also examined.

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