**AIR POWER STUDIES CENTRE**

**PAPER 57**

**August 1997**

# EMPLOYMENT OF CRUISE MISSILES BY THE ADF

**By**

**Wing Commander Paul Hislop**

## About the Author

Wing Commander Paul Hislop joined the RAAF on No. 31 Academy Course in 1978, graduating with a degree in Physics in 1981. On completing Academy diploma studies he was posted on course to the School if Air Navigation, from which he subsequently graduated as a navigator in 1983. His three flying postings have all been in Maritime Patrol with Nos. 10 and 11 Squadrons. His duties in those postings included navigation of P-3B and P-3C aircraft, operating sensors, instructing, aircraft tactical coordinator, detachment commander and squadron flight commander. His joint ground tour was as an intelligence analyst to the Australian Joint Acoustics Analysis Centre at HMAS Albatross, where he also instructed in acoustics, and in 1988 he completed the RAAF Weapons Systems Course at RAAF East Sale.

In 1991, on promotion to Squadron Leader, he was posted to Plans and Policy Branch within Air Force Office, working on RAAF Infrastructure policy, then as secretary to the Air Force Development Committee. In 1995 he was posted to the RAF Advanced Staff Course in the UK, and was promoted to Wing Commander on his return to Australia. Wing Commander Hislop was posted to the Air Power Studies Centre in January 1996 for 12 months before taking up his current position as Secretary to the Defence Sub-committee of the Joint Foreign Affairs, Defence and Trade Committee.

# INTRODUCTION

At the beginning of the 20th Century, nations accepted the Clausewitzian concept that war necessarily inflicted large numbers of casualties. The two world wars fought in the first half of the century demonstrated the common wisdom of that view, with vast battles fought by individual warriors, or by machines manned by those warriors. However, more recent conflicts have demonstrated a changing attitude to war, at least by Western nations, and a resultant sea change in the manner in which wars are fought. The emphasis on exchanges of violence between warriors, or the machines bearing them, is diminishing, and the appeal of military options which offer the greatest promise of rapidly terminating hostilities with minimal losses has increased. No longer is war the ‘great adventure’ of past generations. It is now seen, where it cannot be avoided by other means, as a matter to be pursued as expeditiously as possible.

But even more important than changes in attitude, modern technologies have enabled wars to be fought in this manner more than in past conflicts. First mechanisation, then the evolution of air power, then nuclear weaponry, and most recently, the combined influences of stealth technologies, precision navigation and guidance, the use of space, automation through computerisation, and advances in sensors and propulsion have jointly contributed to change the nature of war. These technologies have allowed production of weapons and military systems which have loosened the reliance of warring nations on the need for force-on-force engagements. As witnessed in the short, sharp, Arab-Israeli Wars since 1967, Operation *Eldorado Canyon* against Libya in 1986, the 1991 Persian Gulf War, and in Operation *Deliberate Force* against the Bosnian Serbs in 1995, conflicts between nations are being resolved increasingly through immediate resort to strikes against targets designed to achieve strategic aims.
This paper is an examination of only one aspect of the weaponry which has allowed this change in war to take place: the class of weapons generically grouped under the heading of cruise missiles. The purpose behind the foregoing discourse on the changing nature of war, however, has been more than just a digressive introduction of a single weapon type. It has also been intended to set the scene for a later discussion on the further impact of these weapons *on warfare*. For, just as the changing nature of war has resulted in the evolution of the cruise missile, the capabilities offered by the cruise missile are continuing to shape the way in which conflicts are fought. Increasingly, the cruise missile continues to live up to the 1915 description of its ancestor - the aerial torpedo - as ‘A device ... likely to revolutionise modern warfare’.[1]

This paper will examine some doctrinal, political, legal and operational aspects of the acquisition and employment of cruise missiles, with particular reference to the potential use of these weapons by the ADF. This examination of the subject should not be taken to infer that the concept of cruise missiles in the ADF inventory is a new one. The ADF has possessed a cruise missile, in the form of the AGM-84 Harpoon, for over a decade. Because of this previous experience, the implications and tactics of employing cruise missiles in an anti-shipping role are already known. Accordingly,

[1] ‘Aerial Torpedo is Guided 100 miles by Gyroscope’, *New York Tribune*, 21 October 1915, p. 1, as quoted in Werrell, K.P., *The Evolution of the Cruise Missile*, Air University Press, Maxwell Air Force Base, Alabama, September 1985, p 2.

the scope of this paper will be limited to discussion of the implications of cruise missiles in a land strike role only.

Further, as will be covered in the following discussion on the definition of cruise missiles, some medium-range weapons may technically be considered as cruise missiles. While the existence of tactical-type stand-off weapons with cruise missile characteristics is acknowledged, the generic sense used in this paper (unless otherwise specified) is that a cruise missile is largely regarded as a longer-range strike weapon, capable of launch from outside the effective range of conventional defences.

**What Is A Cruise Missile?**

The majority of readers having some familiarity with military weaponry will generally understand the concept of a cruise missile, but rigid definition of the class is a complicated process. Several authoritative writers on the subject (notably Carus[2]) have proffered earlier, useful definitions of a cruise missile, which generally view the cruise missile as an autonomous system. However, these definitions have now been dated by quite recent developments in hybrid guidance types, which necessitate establishment of refined definitional criteria. (Examples include the man-in-the-loop systems used by the Tomahawk Block IV and one version of AGM-142). Other recent developments have also produced weapons which, although meeting the earlier criteria, arguably do not cruise, and so should not be considered as cruise missiles. In an attempt to distinguish cruise missiles from armed unmanned aerial vehicles (UAVs), guided glide bombs, and extended-range powered PGMs, the following defining characteristics are offered. Cruise missiles:

a. are unmanned;

b. are anti-surface weapons, intended to impact on, or detonate over a selected surface target;

c. have an integral means of sustained self-propulsion (most commonly air-breathing, but some examples use rockets);

d. possess some form of precision guidance, (which may be wholly autonomous, or may require limited external input from a human operator);

e. make use of aerodynamic surfaces to generate lift to sustain their flight; and

f. are intended to autonomously achieve a sustained 'cruise' phase of flight at a predetermined level relative to overflown terrain or sea level (as differentiated from ballistic missiles, which follow a ballistic path, and are generally unpowered after launch).

Using these distinguishing criteria, cruise missiles are a sub-set of UAVs, and they are also a subset of stand-off weapons, where stand-off weapons can be defined as those which enable the launching platform to release the weapon at some physical

[2] Carus, W.S., *Cruise Missile Proliferation in the 1990s*, Center for Strategic and International Studies, Washington DC, 1992.

separation from the intended target, providing a degree of protection from the target's defensive systems.[3] However, while cruise missiles are commonly regarded as encompassing the high-capability end of the range of stand-off weapons, distinction between cruise missiles and stand-off weapons cannot be made solely on the basis of range capability. Cruise missiles can be optimised for use across a broad spectrum of ranges, depending on their intended use against tactical or intercontinental targets. As a result, some possess relatively short range capabilities. At the same time, some stand-off weapons are capable of relatively long ranges, but do not fit the aforementioned criteria for classification as cruise missiles. For example, the agile gliding weapon (AGW) currently under development by British Aerospace Australia has a range capability (from high level release) of up to 75 nautical miles,[4] but cannot be regarded as a cruise missile, while the French AM 39 Exocet *does* meet the criteria for classification as a cruise missile, yet has a range of less than 30 nautical miles.[5]

In its conventional form, a cruise missile is commonly regarded as a precision guided munition (PGM), although the level of precision needed for delivery will depend upon the characteristics of the warhead. For example, an area-effect warhead, such as a fuel-air explosive or cluster bomblet dispenser, will require less precision than would be required by a penetrating warhead intended for use against a hardened target. Obviously, a high-yield nuclear warhead will require even less precision.

As a final comment on definitions, it is also worth noting the scope of weapon configurations which fit the listed criteria and can be regarded as cruise missiles. While the Exocet and Tomahawk missiles have acquired high public profiles as a result of television coverage from the Falkland Islands and Persian Gulf Wars respectively, a cruise missile need not be a relatively high-speed missile powered by a rocket or jet engine. A lower-technology platform may be powered by a small propeller, and cruise at speeds as low as 40 knots, while still fitting the criteria for classification as a cruise missile. As advanced guidance and navigation technology becomes cheaper and more widely available, the potential for proliferation of such lower-capability weapons amongst even Third World nations will increase and potentially alter current strategic balances.[6]

[3] This definition is largely a construct by the author, but is based upon a concept contained in 'Dossier', *International Defense Review* 4/1995, p. 70.
[4] Kopp, Carlo, 'Australia's Kerkanya Based Agile Gliding Weapon', *Australian Aviation*, June 1996, p 29.
[5] *Jane's Air Launched Weapons*, Issue 22, October 1995, lists the range of the air launched Exocet as 50 kilometres (27 nautical miles).
[6] For detailed discussion of this point, see Carus, *Cruise Missile Proliferation in the 1990s*,

## Examples

Examples of common current cruise missiles are:

a. ***Tomahawk Land Attack Missile - Conventional (TLAM-C),*** which uses Terrain Contour Matching (TERCOM) and Digital Scene Matching Area Correlator (DSMAC) to achieve a terminal accuracy of around five metres CEP[7] and a range of 500 nautical miles (subsurface launched) to 800 nautical miles (surface launched).

b. ***Tomahawk Block IV***, which uses Global Positioning System (GPS)/ Inertial Navigation System (INS) or TERCOM and Imaging Infra-Red (IIR) terminal guidance with a datalink for operator updates to achieve an accuracy reported to be around three metres CEP.

c. ***AGM-86C*** conventionally-armed air-launched cruise missile (CALCM), which uses GPS/INS cruise guidance and DSMAC terminal homing. Range is quoted as around 1,000 nautical miles, but accuracy is less than that for Tomahawk, possibly 10 to 30 metres CEP.

The full range of contenders submitted to meet the UK's Staff Requirement (Air) 1236, for a conventionally-armed stand-off missile (CASOM). Contenders such as the Matra Apache, the Bofors KEPD350, and the McDonnell Douglas Grand SLAM (Stand-off Land Attack Missile) generally use GPS/INS cruise guidance and IIR terminal homing, with ranges of over 160 nautical miles and with sufficient accuracy to allow use of penetration warheads (generally less than 8 metres CEP). Although these weapons are termed stand-off missiles, the range capabilities for most are well beyond the UK's stated 250 kilometre (135 nautical mile) requirement, and most fit the definition of a cruise missile.

## A Brief ADF History of Cruise Missiles

The potential use of cruise missiles to meet at least some of Australia's strategic strike requirements against land targets is a topic with over a decade of history. Much of this work has been conducted by the RAN in seeking such a capability at first for the *Oxley* Class and, more recently, for the *Collins* Class submarines.

Acquisition of a land strike cruise missile capability was seriously considered as early as 1980 with the drafting of the RAN's Navy Staff Objective 1285, which sought procurement of cruise missiles for the *Oxley* Class submarines. Although Navy Staff Objective 1285 was not subsequently progressed, the Hawke Government's 1987 White Paper, *The Defence of Australia, 1987,* acknowledged that the issue of cruise missiles had not been permanently laid to rest, noting that 'a submarine launched missile is another strike option for the longer term'.[8]

---

[7] Circular Error Probable - a measure of the size of the circle into which 50 per cent of weapons should impact.

[8] *The Defence of Australia 1987*, Australian Government Publishing Service, Canberra, 1987, p 41, para 4.39.

The most recent Defence White Paper, *Defending Australia*, makes only passing reference of the topic, stating that Defence will 'continue to monitor the need for more capable submarine-launched missiles'.[9] However, with the change of government in 1996, there arose potential for a revision of the White Paper to contain expanded reference to cruise missiles, in accordance with the Liberal Party pre-election defence policy statement of March 1996. This document stated that 'acquisition of a stand-off weapons system for the *Collins* Class submarines may prove a cost-effective means of maintaining an effective strike capability in the longer term' and the party undertook to 'fund technical definition studies in [its] first term to assess the most appropriate stand-off weapons system'.[10]

It is likely that the ADF's previous inquiries on acquisition of the TLAM-C would have met with a degree of reluctance from the US to supply technical information. This would have been an understandable outcome of the US's intention to maintain its clear lead in the technologies involved and prevent their proliferation, especially during the Cold War. However, with the recent US agreement to supply Tomahawk to the UK for fitment on Royal Navy attack submarines (and the active marketing of related technologies in shorter range weapons such as AGM-142 and Air Hawk), there is clear evidence of a change in the US position on distribution of this technology to its allies. With this improvement in the potential opportunity for acquisition, the RAN continues to press for a long-range cruise missile capability as an enhancement for the *Collins* Class submarine fleet. The increasingly longer range of weapons procured for use by the RAAF also demonstrates a trend toward eventual acquisition of a cruise missile-like capability.

## COST

### Cost and Effectiveness

Modern military conflict is at least in part a test of national economic capacity. Therefore, to maximise military potential, forces must be structured, and war must be waged, by cost-effective means (unless one side possesses an overwhelming superiority in economic capacity and can afford disproportionate expenditure of resources). For most nations, this factor places practical restrictions on the employment of expensive single-use weapons. While some targets may emerge which have a military value disproportionate to their economic value, continued expenditure of multi-million-dollar ordnance against targets of comparable cost but little military value will achieve, at most, a war of attrition, and could lead to loss of a conflict on economic grounds. This principle was referred to in the introduction: that modern warfare has advanced to the level of efficiency (and weapon systems have increased in price to a level) which dictates that war must be fought by means intended to quickly achieve a nation's strategic aims. Economic rationale thus dictates that weapons should be used only against targets of much higher value (and thus liable to

[9] *Defending Australia - Defence White Paper 1994*, Australian Government Publishing Service , Canberra, 1994, p 44, para 5.31.

[10] Coalition Defence Policy Statement of March 1996. Section 5 'Structuring the Australian Defence Force', p 16, para 5.8.

have a disproportionate effect on the adversary's capability), or those whose destruction offers the potential to quickly end a conflict.

The cruise missile is inherently an expensive weapon. With its requirement for sustained flight, mid-course navigation, terrain and obstacle avoidance and target discrimination with high reliability and survivability, it has more in common with a UAV or manned aircraft than with a short-range PGM. The various systems needed to provide its advanced capabilities, while countering improving defensive measures, will ensure that the long-range autonomous cruise missile remains a high-cost strike option. As a fairly recent example, the FY94 price for a continuation order of Block III Tomahawk for the US Navy was US$1.4m per missile.[11] Although the price per missile quoted to the Royal Navy in its impending purchase of 65 Block III Tomahawks for its attack submarines was US$0.9m, the total cost for the project is estimated at US$288m,[12] indicating an average price of US$4.4m (AUD$5.5m) per missile when integration costs are included. Estimates of the cost to Australia of the same missile range from US$1.0m to $5.0m per missile, depending on the size of the order, and whether integration, infrastructure and support costs are considered.

By comparison, a number of weapons currently in the ADF inventory have the capacity to inflict at least the same amount of damage as a cruise missile, but at a significantly lower cost per weapon. Examples are the Mk84 bomb (AUD$5,000), the laser-guided GBU-10 (approximately AUD$50,000) and the soon-to-be-acquired AGM-142 Raptor stand-off weapon (over AUD$500,000). These weapons can provide similar single shot probabilities of damage (SSPD) as a cruise missile for a variety of potential targets.[13]

However, as argued by proponents of the cruise missile, the cost of attrition to the launching aircraft (or other platform) must also be considered in attacks using lower-capability weapons, raising the total cost per weapon launched. The advantage provided by cruise missiles is that they promise a PGM's high probability of success without risking the loss of human aircrew and an expensive aircraft when attacking a heavily defended target. The counter argument is that, for many potential targets, either through poor planning by an adversary or through pure good fortune, the defences will not necessitate use of an expensive long-range missile to minimise attrition. In such cases, the use of a $1.0m-plus missile, where a weapon costing $5,000 would have achieved the same SSPD, would be a waste of limited military resources. These two arguments form the crux of the rationale for the development and employment of the cruise missile: the decision to employ a cruise missile in preference to another form of strike must be made on balance between the cost of this expensive, single-shot weapon, and the cost of the (usually aircraft-launched) alternative, considering the potential costs of attrition on the launch platform. The

[11] 'US Briefing', *Navy International*, July/August 1994, p. 216. As this was a continuation buy, the price would exclude infrastructure and support systems.

[12] 'Tomahawks to UK for SSNs', *Jane's Defence Weekly*, 22 July 1995, p. 3, *and Jane's Defence Contracts*, March 1996, p 11. Jane's Defence Contracts lists the cost of supplying the missiles alone as US$58.4m ($.9m per missile) while the $288m obviously includes support systems and integration costs.

[13] Even the unguided Mk 84 bomb may achieve a CEP of around 20 metres, when dropped by a modern strike aircraft at low altitude in an environment with no significant air defence threat.

determinant of which option will be the most cost effective, then, becomes the attrition which the defender is able to inflict on the launching platform at the weapon's effective launch range. A simple attrition/cost model for comparison purposes is discussed below.

**A Cost Comparison Model**

It is cost that currently restricts the practical use of cruise missiles. Where strike aircraft can deliver cheaper ordnance with equal or greater effect, cost considerations dictate that aircraft be used wherever possible, particularly for high-tempo operations. The graphs shown at Figure 1 below, however, model the total costs for this ordnance when the impact of attrition to the launch platforms is included.[14] The mathematical basis of this model is explained in the appendix to this paper.

Obviously, in a zero-attrition environment, the cost of an attack is equal to the cost of the weapon,[15] increasing to the opposite extreme where an attack suffering 100 per cent attrition equates to the cost of the weapon plus the cost of the launch platform. These graphs illustrate the relationship that, as attrition increases as a result of increasingly effective target defences, the effective cost of each weapon launched increases.[16]

Figure 1 is based on the use of a generic $100m strike aircraft.[17] The two lower-cost reference lines have been plotted to represent loads of four 2,000-pound class GBU-10 Paveway II and GBU-24 Paveway III laser-guided bombs (LGB) ($50,000 and $100,000 per unit respectively as order-of-magnitude costs). Two other curves have been calculated. The first represents higher-capability, medium-range stand-off weapons such as two AGM-142, with $800,000 selected as an order-of-magnitude

---

[14] The graphs are based on the premise that the cost of an aircraft or ship, with crew, fuel and maintenance costs, can be reduced to monetary terms. This is acknowledged to be somewhat simplistic, as there always remains other costs, such as that of infrastructure, and a number of intangibles, such as the political cost of the loss of an aircraft or ship and its crew, which cannot be easily incorporated into such calculations.

[15] This disregards fuel, but any launching platform (ship, submarine, or aircraft) will require fuel to position for weapon launch, so this will be disregarded for comparison purposes.

[16] Figures 1 and 2 were generated using the following assumptions:

a. Cost of aircraft in Fig 1 includes cost of crew and fuel. Cost of UAV includes fuel.
b. Attrition is suffered equally by aircraft/UAV before and after weapon release.
c. Maintenance is not considered, as this will also be required for the platform launching the cruise missile (such as a surface vessel or submarine), and will tend to have a cancelling effect.
d. Destructive potential of the cruise missile equals that of each of the other weapons under consideration (in fact, the warhead of a Tomahawk contains significantly less explosive power than a 2,000lb bomb, but this will be discussed later).
e. No attrition cost is inflicted on the platform launching the cruise missile.
f. Effective cost per weapon launched = $(aC + wc)/[w(1-a/2)]$, where:
   a = attrition rate (overall)
   w = number of weapons per aircraft
   C = cost per aircraft/UAV
   c = cost per weapon

[17] This cost represents a high estimate of the overall cost of a future generation strike aircraft. While a cheaper aircraft is likely to become available, use of a low figure (say, $60 million) to generate this graph would skew the outcome further away from the use of cruise missiles, and might provide latitude for allegations of biased argument. In terms of the point made, the $100 million figure is considered conservatively high.

costing for this class of weapon. The final line, selected arbitrarily at $1.0m per weapon, is intended to represent weapons of even higher capability, (greater stand-off range) possibly including even medium-sized air-launched cruise missiles. Some weapons in this class were proposed as contenders for the UK's CASOM requirement. In this case, this conceptual $1.0m cruise missile may be differentiated from very long range weapons such as Tomahawk in that it relies on launch from an aircraft, and its lesser range capability (and consequently its significantly lower cost per round) places it into an intermediate class of weapon below systems such as Tomahawk and AGM-86C.

If the human costs of attrition are (albeit callously) reduced to monetary terms, this graph can be used as a tool to indicate the situations when more expensive strike weapon options (enabling low risk of attrition) become more cost-efficient than the use of lower-cost (but shorter range, higher attrition) weapon options. For example, by drawing a line across the graph at $800,000, Figure 1 shows that a no-attrition strike using an $800,000 medium-range stand-off weapon is more cost-efficient than the use of $100,000 Paveway III LGB when the aircraft attrition rate for the LGB strike rises above 2.8 per cent.

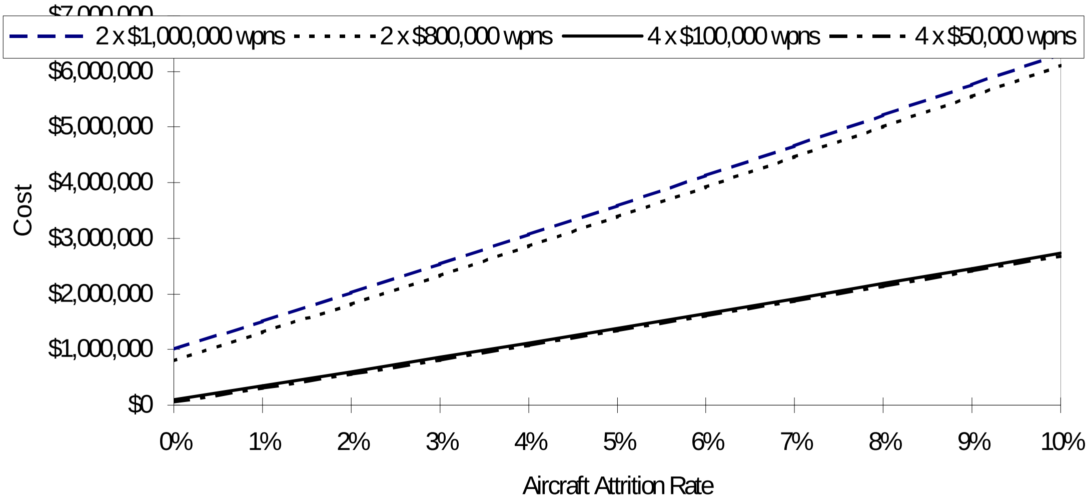


**Figure 1 - Effective Cost per Weapon Launched - $100m Strike Aircraft**

For comparison, Figure 2 was generated based on a generic $500m naval vessel, capable of carrying 20 long-range cruise missiles (a cost of $2.5m per missile was used, for order-of-magnitude purposes). The costs may be directly compared between Figure 1 and Figure 2, again enabling comparison of expensive, lower attrition strike options (say, employing a ship- or submarine-launched cruise missile strike) with less expensive, possibly higher attrition strikes (say, by an aircraft using LGBs). For example, a mission by a ship which faces a 1 per cent chance of being intercepted and sunk, in launching its 20 missiles, equates to a cost per missile of slightly over $3.0m. To rise to this average cost per weapon (from Figure 1), the aircraft conducting the LGB strike would need to suffer greater than 11 per cent attrition per sortie. As a further comparison, the aircraft launching medium-range stand-off missiles would have to suffer greater than 4.3 per cent attrition before the cruise missile option became more cost-efficient.

So in purely economic terms, target air defences can potentially be increased to a level where strike by ship- or submarine-launched cruise missiles may become a cost efficient option. However, Figures 1 and 2 demonstrate that this will only occur in a very high risk (and hence high probability of attrition) air defence environment.

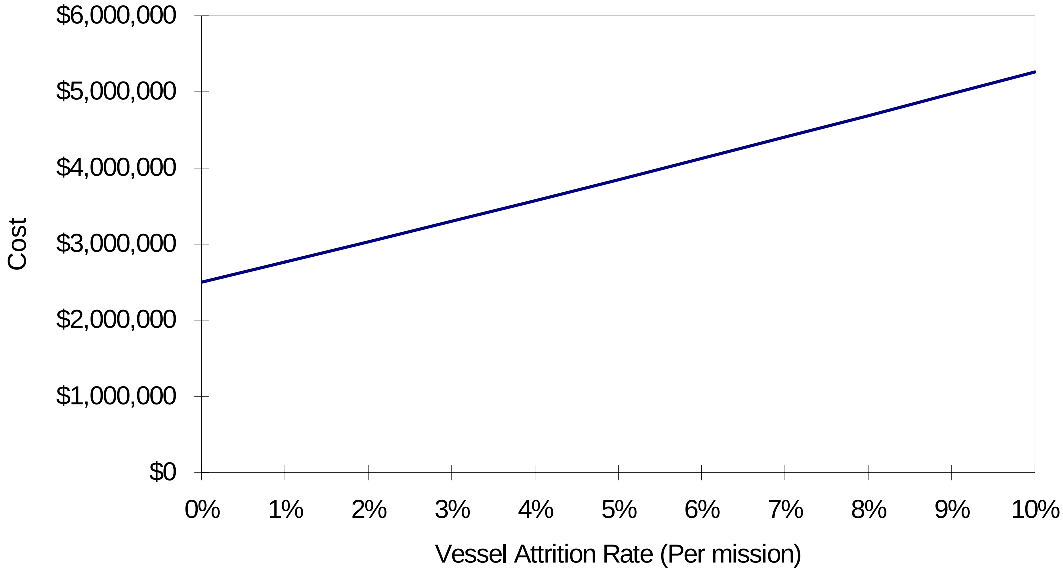


**Figure 2 - Effective Cost per Weapon Launched - $500m Vessel Carrying 20 Cruise Missiles**

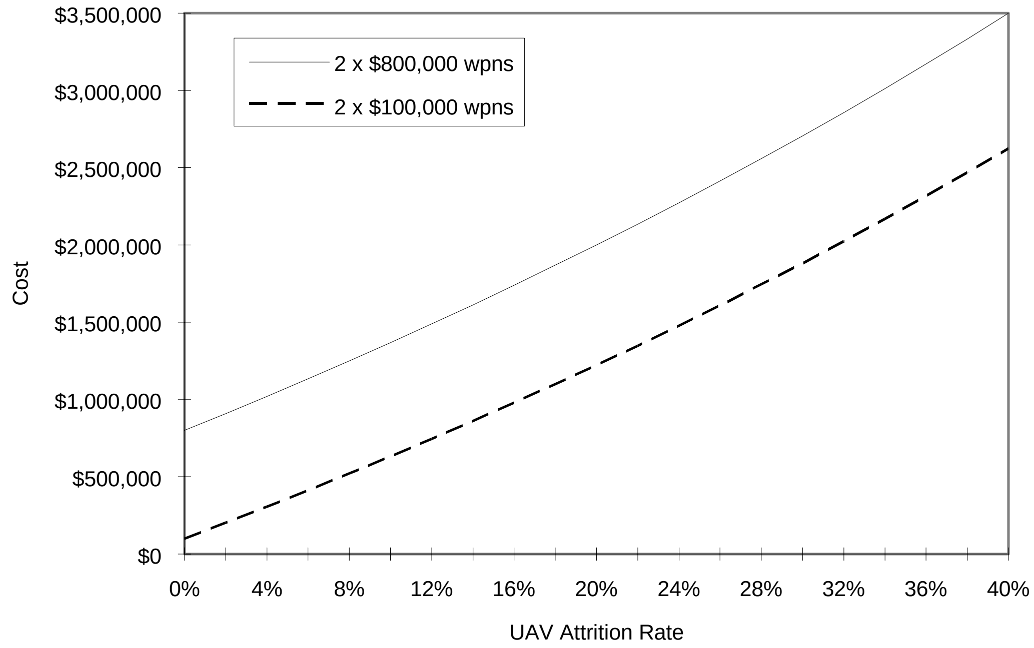


**Figure 3 - Effective Cost per Weapon Launched - $10m Armed UAV**

The implications of this type of cost comparison graph become more revealing when the cost of the strike aircraft can be reduced, for example, by employing a less capable platform. Figure 3 illustrates an example of the cost comparisons for airborne launch platforms at this end of the spectrum, in this example using an offensive UAV costing $10m and capable of carrying two weapons. Again, compared with the cost of employing a $2.5m cruise missile (even, in this example, considering no attrition to the cruise missile launch platform), the armed UAV remains more efficient until the target's air defences can inflict 27 per cent attrition against the UAV armed with medium-range stand-off missiles, or 38 per cent attrition for the UAV armed with two LGBs. The economic rationale behind development of armed UAVs is thus evident.

**Some Conclusions on Cost**

The principle governing the economic use of offensive weapons can be broadly stated as follows:

> The cheapest offensive weapon(s) that can achieve the required probability of damage should be used in offence, until an adversary's defensive systems have sufficient capability to inflict uneconomical (or otherwise unacceptable) rates of attrition on the launch platform. When this stage is reached, the next cheapest weapon that can minimise the effects of the defensive systems (through stand-off, stealth, jamming, self-defence, decoys or other survivability measures) should be used.[18]

In considering the defensive systems against which the ADF may have to operate in the foreseeable future, the AGM-142, with its range of approximately 50 nautical miles, provides sufficient stand-off to reduce the risk to the delivery platform to tolerable levels. Use of a longer range system (if significantly more expensive) could not be justified until a potential adversary acquires a defensive system capable of defeating the AGM-142 or its launch platform. If this were to occur, then the logical step for Australia would be the acquisition of the next most economical system capable of providing sufficient stand-off or other survivability measures. Australia's military capabilities are based on the level of capability available within the region. To justify acquisition of a weapon as expensive as, say, Tomahawk or the AGM-86C would require the introduction into the region of defensive systems much more capable than is currently foreseeable. The aim in strategic strike planning must be to match the appropriate weapon to the target, taking account of the risk (and hence potential cost) of attrition. This logic suggests that the ADF needs to retain a range of capabilities and a range of strike options to achieve maximum cost benefit from its weapons expenditure.

Based on the cost comparisons in the above model, some other interim conclusions can be made on the efficient use of reusable platforms and cruise missiles. These are that:

> Where the human cost of attrition is politically tolerable (this would exclude attacks against heavily defended targets), reusable strike platforms will provide a more cost-efficient means of attack than more expensive high-end capability cruise missiles.

[18] Construct by author.

Considering the level of air defence capabilities of a likely aggressor, shorter-range air-launched cruise missiles offer a more cost-effective strike option than longer-range, significantly more expensive surface- or air-launched cruise missiles, such as the BGM-109 Tomahawk or AGM-86 ALCM.

**The Human Cost**

In all conflicts short of a fight for national survival, the human costs of attrition will continue to be a major factor in determining how conflict is fought by Western nations,[19] and will be influential in selection of the means of strike used in future conflict. Accordingly, in strikes against targets where defences could be expected to inflict even moderate levels of attrition on the attacking platform, cruise missiles will be examined for their ability to reduce attrition to a level which is politically tolerable. This should not be taken as an overriding argument for replacement of strike aircraft with cruise missiles, as Figures 1 and 3 have demonstrated alternative, and more cost-efficient options. These are:

a. the use of medium-range stand-off missiles (or relatively lower-cost, medium-range, air-launched cruise missiles) to reduce attrition through enabling a degree of stand-off. This intermediate option will provide an acceptable compromise between minimising attrition, and providing a cost-efficient means of attack, in all but the heaviest air defence environments.

b. the use of reusable unmanned strike options, such as that offered by an armed UAV. In comparing this option against cruise missiles, the human cost factor is eliminated, and the argument may be calculated in purely economic terms.

**The 'Cheap' Cruise Missile**

One potential development which may invalidate the above argument is the emergence of a comparatively lower-cost, high capability cruise missile. As previously discussed, this development has not been in prospect. However, a recent report[20] of a 'low-cost Tomahawk', estimated to cost around $250,000 per weapon, may signal the end of cost considerations as an argument against employment of the cruise missile. Current information on the proposal remains incomplete, as the price may not include any warhead, guidance or datalink system, and, like other examples, does not consider integration costs, or support infrastructure.

## EFFECTIVENESS

The cruise missile possesses a number of unique features, each of which either contribute to, or detract from, the utility of the weapon. These will be discussed in turn, with special consideration given to the implication that these attributes have for employment by the ADF in a regional scenario. As in previous discussion, the paper

[19] For discussion of this point, see Hislop, P.A., ‘The Bodybag Factor: A Study into the Decreasing Public Tolerance Toward Attrition in War’, *The Hawk Journal,* 1996, Royal Air Force Staff College, Bracknell, pp 47-57.
[20] Holzer, Robert, ‘U.S. Navy Eyes Low-Cost Tomahawk Plan’ in *Defense News,* April 28 - May 4, 1997, p. 3, 26.

will consider the generic case of a cruise missile as a long-range weapon, using the TLAM-C and AGM-86C as typical examples.

**TERCOM and DSMAC Guidance Systems**

Earlier-generation cruise missiles, such as the Tomahawk (pre-Block IV) and the AGM-86 were designed to be independent of external navigation aids, instead relying on the autonomous TERCOM system. This form of guidance uses a radar altimeter to measure the profile of the terrain over which it is flying, and compares the profile detected with a number of pre-programmed, digitally-stored, unique terrain matrices to calculate its position and provide periodic updates for its INS. The positional information available through this method is sufficiently accurate for use with nuclear warheads and, in conventional versions of the missile, serves to keep the missile on course until its DSMAC terminal guidance can assume guidance of the missile for terminal homing to its target. The DSMAC system works by comparing a stored digital image of a distinctive ground feature on the lead-in to a target with the image of the same feature as viewed by the missile in flight. Comparison of the two images allows the missile to calculate its course error and correct its flight path to the target. While more recent missiles tend to use different forms of guidance, an examination of these systems is necessary to understand some constraints associated with many earlier-generation cruise missiles.

***TERCOM Implications*.** The principle of TERCOM relies on measurement of terrain profiles to enable comparison with unique terrain matrices programmed in the missile's memory. While the geography of northern Europe or Western Russia enables ready selection of unique geographical profiles for use in TERCOM updates, the unavailability of distinctive, accurately mapped terrain in some other areas prevents reliable use of the system, forcing the system to fall back to reliance on its inertial system. Prolonged reliance on the inertial system without external update decreases the weapon's tracking accuracy. Given sufficient length of time without update, the weapon may deviate sufficiently from its planned course to prevent identification of the subsequent TERCOM grid, resulting in the failure of the weapon to reach its target. In the case of the TERCOM system used in Tomahawk, this limits the maximum firing range from land to approximately 50 nautical miles. For this reason, the system cannot be employed over large ocean approaches to coastal targets,[21] over flat or featureless terrain, over areas of heavy vegetation, or where the necessary terrain data is not available. The area must also be very accurately mapped, requiring access to an extensive database of information, usually from satellite sources. Short-warning requirements for strikes using this technology can be hampered by a lack of geographic data on the approaches to the target. Where information is available to enable guidance to a particular target, the data available may limit missile approaches to a single ingress route, making repeated strikes predictable and easier to counter. An example of the problems possible from TERCOM was the failure of many Tomahawks launched from the Red Sea to reach their targets in Iraq during the Gulf War,[22] presumably due to either inherent limitations of their TERCOM or DSMAC systems over that terrain, or due to a lack of

---

[21] Kopp, Carlo, 'Cruise Missiles, Pt 1 - The Strategic Cruise Missile', *Australian Aviation*, September 1985, p 72 (paraphrased - Kopp's words are 'TERCOM system ... is useless over ocean').
[22] Information provided by Mr Mike Price, from Report to US Congress on the Conduct of the Gulf War.

sufficiently accurate geographic data over that route. Similarly, unclassified statistics regarding use of 35 AGM-86C CALCMs during the Gulf War indicate the failure of an unspecified number of weapons to reach their targets. This potential for guidance reliability problems has Law of Armed Conflict (LOAC) implications which will be discussed later.

***DSMAC Implications.*** The functioning of the DSMAC system also causes some reliability concerns. In early versions of the Tomahawk, the DSMAC guidance was strongly affected by diurnal cycles and seasonal changes.[23] Recent improvements have resulted in greater reliability, but because the system requires optical discrimination of pre-programmed images, it remains susceptible to simple camouflage and deception measures, where the feature used for the final update can be surmised by the defender. These DSMAC limitations may have in part contributed to the guidance failures of several missiles launched during the Gulf War. The DSMAC system also suffers from some accuracy limitations in cases where a precise strike may be required. DSMAC's reliance on identifying update features before arriving at the target results in a degree of error between the final update and target impact. Hughes, the makers of the Tomahawk variants, concede that DSMAC is not as accurate as a man-in-the-loop system[24] (which looks at the target, rather than a pre-target update feature), and this is a reason why pre-Block IV Tomahawks were limited to non-penetration warheads.

Not all cruise missiles, however, are restricted to use of a DSMAC system with its related limitations. One Israeli system currently on offer uses an imaging sensor to scan and compare both the intended target and its surrounding geography, making it much less susceptible to camouflage, deception or obscuration measures. Other systems make use of data-linked imagery from the weapon to allow a human operator to assess the weapon's tracking and adjust its homing to the target.

***Intelligence Requirements.*** Another limitation of the TERCOM/ DSMAC system identified in previous studies is the requirement for mapping and imagery information to support these forms of guidance. To date, this data has only been available through US sources, creating a reliance on the USA for supply of targeting intelligence. In turn, this has implied a third-party (US) veto capability,[25] or at least a requirement for US consent, on any use of the weapons by the ADF. The procurement of this information has also been viewed previously as a significant additional cost associated with these systems. While a DSMAC system still relies on the use of recent detailed imagery, the previous dependence on US sources for that data is decreasing as commercially available satellite imagery improves in resolution. The dependence on the US for TERCOM data currently remains, although commercial digital mapping techniques may offer a future alternative in selected geographic areas. In the ADF case, another option would be the development of an indigenous Australian system to provide this data, although this would require access to high-quality satellite imagery.

---

[23] Kandebo, S.W. 'Cruise Missile Updates Pending', *Aviation Week and Space Technology*, 17 January 1994, p 56.
[24] *International Defense Review*, 4/1995, p 77.
[25] Kopp, Carlo, from discussions with author, 19 February 1996.

**Use of GPS Guidance**

To overcome many of the perceived limitations of the earlier mid-course guidance systems, many current-generation cruise missiles and shorter range stand-off weapons rely on an inertial navigation system updated by GPS. This provides a reasonably cheap, and, given access to GPS precision (P-code) data, relatively accurate source of data for mid-course guidance. The military-standard P-code data (encrypted, and hence available only to the US and its allies) gives positional information accurate to approximately 16 metres SEP,[26] which is more accurate than that currently available from the commercial-standard Course Acquisition (C/A code) GPS (which currently provides accuracy to around 100 metres SEP[27]). This allows adequate positioning of the weapon to enable a scene-matching terminal guidance to home the weapon to the desired impact point. However, GPS still introduces the problem of third country (US) veto on strike operations. The US has the option of choosing to withhold the P-code if a suspected strike by the ADF were not within the US national interests. Another US option, as the GPS controlling nation, would be the artificial injection of errors to corrupt the midcourse guidance. However, should Australia be acting in legitimate self defence, and/or as part of a US-led coalition, and have consulted with the US in compliance with the provisions of ANZUS, the potential for problems to emerge from US intervention would appear small.

Of greater concern is the susceptibility of GPS to jamming. Even a one-watt jammer can render commercial GPS-dependent systems ineffective from a range of 22 kilometres.[28] Most current military systems are similarly susceptible, because they rely on prior acquisition of the C/A code before jumping to P-code. As a result, a recent report by the RAND corporation concluded that even military GPS systems remain extremely vulnerable to jamming, unless several anti-jam measures were incorporated. One such measure is direct P-code acquisition by military systems, which reduces susceptibility to jamming.[29] Other GPS anti-jam measures are currently being developed, and will be incorporated into the replacement constellation of GPS satellites, which will probably become operational within 15 years. However, the effectiveness of these features is not known. The further variable in this situation is the work being done into GPS jamming, even while anti-jam measure are under development. While also recommending review of anti-jam measures, the RAND report also recommended investigation into GPS jamming techniques as a US self-defensive measure.

Yet another implication of GPS for the guidance of missiles, particularly for Australia, stems from the potential environment in which it would be likely to be used. The wide geographic areas involved and the possible lack of friendly territory

---

[26] Spherical Error Probable - a three-dimensional measure of accuracy - the sphere within which 50 per cent of measurements will fall.

[27] The accuracy of C/A data will be improved in future US developments, but the US will retain the capability to artificially degrade this accuracy available to non-US-military users when judged to be in US interests.

[28] Grier, Peter, 'GPS in Peace and War', *Air Force Magazine*, April 1996, p 79.

[29] Although the P-code signal currently remains susceptible to jamming, the signal has a higher signal-to-noise ratio than the C/A code signal, reducing the range of effectiveness of a jammer.

surrounding a potential adversary mean that differential GPS[30] and similar error-reduction techniques would be much more difficult to apply in a situation of conflict. Hence, even with US support and P-code data, accuracy is unlikely to be further improved above the current 16 metres. This level of accuracy implies either a need to use an additional, more accurate guidance system for terminal homing, or a need to use an area-effect warhead, with its related implications of lack of discrimination and reduced effect against hardened targets.

Reliance on GPS can be overcome by providing a dual-source update for the weapon's INS. The latest updates of the Tomahawk use terrain-referenced navigation with GPS as a back-up. This would offer the greatest reliability in guidance, but would also increase the cost of the weapon, and impose the same requirements for geographic data as are imposed by a TERCOM system. Based on the current activity in offensive and defensive GPS measures, heavy reliance on current GPS technology for weapon guidance may produce vulnerabilities within the foreseeable future. However, should Australia be permitted full access to planned GPS upgrades, GPS guidance for future weapons may provide a practical and reliable alternative to other guidance methods.

**Accuracy**

In his review of the Gulf War, US historian and analyst Richard P. Hallion states that bombing by F-117s in the Gulf War proved 'about ten times more accurate than the TLAM, thanks to the benefits of "man-in-the-loop" weapons control...',[31] and concludes that 'Cruise Missiles should be used ... on targets that do not require the precision strike that manned systems can offer ...'. [32] This assessment refers mainly to the Block III and earlier TLAM-C, which use a DSMAC terminal homing to their target. That is, the DSMAC systems used in cruise missiles in the Gulf War did not provide true precision (sometimes described as 'pick which window') and had to rely on the blast effect of their relatively small warheads. Use of a DSMAC system thus has implications for the effectiveness of the weapon. With a warhead of only 450 kilograms, a near miss against a hardened target may not be sufficient to achieve the required level of damage. Against other targets (for example, a bridge support), a near miss may have no significant effect. This lack of accuracy has also led to reliance on maximum blast effect, thereby reducing penetration capability, and further reducing the weapon's capability against hardened targets.

One solution to these deficiencies has been the reintroduction of the operator into the terminal homing system, through use of a datalink and an imaging infra-red seeker.

---

[30] Differential GPS can provide an accuracy in the order of 2 metres SEP. It works by on providing GPS signal corrections based on the measurements of a GPS receiver at a surveyed location. Its limitation is that its increased accuracy decreases with range from the surveyed location. However, differential GPS may use a network of beacons at surveyed locations to increase accuracy within the area bounded by the beacons.

[31] Hallion, Richard P., *Storm Over Iraq: Air Power and the Gulf War,* Smithsonian Institution Press, Washington DC, 1992, p 250.

[32] *ibid.*, p 251. Hallion's full quote is that 'Cruise missiles should be used where one fears to use a manned airplane, where manned strikes may be politically unacceptable, or on targets that do not require the precision strike that manned systems can offer, or because they have some inherent value - a special weapon or certain capability - that is needed', but has been edited here to deal only with the accuracy aspects of this class of weapon.

These features were incorporated into the Block IV Tomahawk, reputedly enabling a decrease in CEP to 3 metres (a necessary improvement, in view of the shift to a penetration-type warhead). A further alternative presently becoming available is the use of a scene-matching terminal guidance system using a high resolution imaging seeker. Seekers of this type were proposed for most of the CASOM contenders, again providing sufficient accuracy to enable the employment of penetration-type warheads. Accuracy obviously becomes a feature to be considered in potential procurement of a cruise missile for the ADF. With the high cost of this class of weapon, and the limited numbers likely to be procured by the ADF as a result, inaccuracy and lack of a penetrating capability would severely limit the weapon's utility.

**Weapon Survivability**

The relatively small size of a cruise missile produces a small visual, infra-red and radar signature, making the missile harder to detect than a conventional aircraft. Its low altitude approach to its target, often using terrain shielding, also increases the difficulty of detection. The difficulty in detection, in turn, results in a greater probability of success against a defended target when compared to a non-stealthy manned aircraft using short-range weapons. One US commentator makes the point that the problem for the defender can be further complicated through the incorporation of relatively simple stealth technology. He states:

> The regional power's most effective use of stealth technology, ... might be in cruise missiles. Stealth is relatively easy to implement on such vehicles. They are small, have relatively small engines and inlets (because they require only enough power for level-flight cruise) and require no landing gear or cockpit apertures. With some sensible shaping decisions and some use of RAM, they can be made into very small radar targets without advanced stealth technology.[33]

Certainly a covertly launched (either from a covert platform or through launch at long range), stealthy missile would impose a threat which would currently require a disproportionate defensive effort. Yet once detected and tracked, a cruise missile can also be more easily destroyed than a manned aircraft. Its low speed (the majority are high-subsonic, to minimise fuel consumption) and non-evasive course increase its vulnerability to fighters equipped with look-down, shoot-down radars and advanced anti-air missiles. Missile designers continue striving to keep the balance in favour of the offensive: as an example of the measures currently in production to improve the survivability of the missile, the DASA/ Bofors KEPD 350 has stealth features and can be equipped with an integrated self-protection system using chaff, flares and expendable decoys.[34]

However, defences against cruise missiles are also being developed. The US Department of Defense is currently working on a tethered aerostat system for cruise missile detection, to be used in conjunction with Aegis ships, Patriot air defence systems, and fighter aircraft armed with advanced medium range air-to-air missiles

---

[33] Sweetman, Bill, 'Stealth: a How-to Guide for Regional Powers', *International Defense Review,* 3/1994, p 37.

[34] *Jane's International Defence Review,* Volume 1, Number 29, January 1996.

(AMRAAM) missiles, to engage these low-flying targets while over the horizon.[35] A special version of AMRAAM is also being developed, which is specifically designed to track cruise missiles using the emissions from their radar altimeters.

A further factor in the survivability of cruise missiles emerges from the increasing use of space-based surveillance and detection systems. In his analysis of the capabilities of the Nurrungar installation, Desmond Ball claims that this system, designed for detection of ballistic missile launches through their boost-phase IR signatures, is also capable of detecting cruise missile launches.[36] Given the eventual dissemination of this technology to other countries, or the supply of information to clients by more advanced nations, this method of detection may provide the means for a future defensive measure against cruise missiles. Detection within 30 to 90 seconds of launch are likely to be routinely possible,[37] enabling defensive measures to be brought against the missile during its flight time of typically one to three hours. Where the cruise missile is at greatest disadvantage against this form of detection system is where it is surface launched from a ship or submarine. The necessity for a boost phase, to get the missile to cruise height and speed, in combination with its IR contrast against an ocean background, allow greatest opportunity for unambiguous detection (and concomitantly, compromise of a submarine's location). In comparison, the ability of an aircraft to feint, and to mask launch with its own IR signature can reduce the time available for defences to react. Further, an aircraft retains the option of launching an ALCM without a coastal stand-off, reducing flight time of the missile against a land target, compared to an SLCM.[38]

**Platform Survivability**

The main justification for the use of a cruise missile in strike operations is the additional stand-off they provide, in comparison with air-launched precision weapons. This affords greater protection for the launching platform, through avoiding the targets' defences, or allows a similar strike from a more survivable platform, such as a submarine. A longer-range and more capable weapon may also compensate for the lack of capability of the launching platform, such as a surface vessel or a low-performance aircraft. In each case, this increased platform security comes at the cost of an expensive weapon, which must be balanced against the increased likelihood of attrition from using an aircraft and a shorter range weapon. In some cases, the political damage resulting from the loss of an aircraft and possible capture of its crew may far outweigh the cost of the weapon. This was the judgment made by the US after the loss of an F-111 and its crew in the 1986 attack on Libya in Operation *Eldorado Canyon*. The need to strike at a long distance without endangering crews formed a large part of the justification for development of the AGM-86C CALCM. The cost/benefit/attrition balance has already been discussed under 'Cost'.

---

[35] Evers, Stacey, 'US DoD to Develop Anti-Cruise Missile Aerostats', *Jane's Defence Weekly*, 21 February 1996, p 6.

[36] Ball, Desmond, *A Base For Debate - The US Satellite Station at Nurrungar*, Allen and Unwin, Sydney, 1987, p 23, 34.

[37] *ibid.*, p 22.

[38] Mr Mike Price, from discussions with author.

## Element of Surprise

Surprise is one of the ten principles of war accepted by the ADF. The features of a cruise missile which contribute to its survivability also increase its potential to achieve surprise. Mainly through its smaller size and ease of application of stealth principles, the cruise missile has greater potential than a manned aircraft to approach its target undetected. In a strategic strike, this surprise can contribute greatly to the success of the attack. Even a short warning time may be sufficient to permit an adversary to move, camouflage or evacuate the intended target, and bring his defences to a higher state of readiness, potentially decreasing the probability of success of a strike mission.

## Flexibility of Employment

The long range and (usually) subsonic speeds of most cruise missiles dictate that they remain in flight for long periods (depending on the missile, up to three hours). For an autonomous system, this has generally limited the use of cruise missiles to fixed targets, which are unable to be relocated during the missile's time of flight. The availability of near-real-time intelligence now permits a cruise missile strike to be planned and launched against a movable (as opposed to mobile) target, although the possibility remains that the target may be removed while the missile is inbound, thereby decreasing the overall probability of the strike's success. For example, use of a submunition-dispensing cruise missile against an aircraft dispersal area could be rendered ineffective if early warning (or chance) sees those aircraft moved or scrambled before weapon arrival. Considering the cost of such a weapon (and the limited number of weapons likely to be acquired by Australia as a result), this limits its ability against any targets other than fixed infrastructure.

Some flexibility has been added to the Tomahawk Block IV with the incorporation of an imaging infra-red sensor, data-linked back to a man-in-the-loop to permit operator updates during the terminal phase. This allows the operator to determine that an intended target has moved, or has been destroyed in a previous strike, and permits the weapon to be re-assigned, while in-flight, to a secondary target. Although improving the weapon's flexibility, this feature still limits employment to a choice between pre-planned, relatively stationary targets. Future developments in automatic target recognition may further improve the utility of cruise missiles at a tactical level (but also probably at increased cost). The current Tomahawk Mobile Target Attack Capability (TOMTAC) program is one such potential flexibility improvement initiative,[39] although it is unclear whether this includes a target recognition algorithm (to enable it to select its own target, within given criteria), or a relatively simple in-flight retargeting capability. However, at their current stage of development, weapons such as Tomahawk lack sufficient flexibility to permit use against highly mobile targets or targets of opportunity.

---

[39] Holzer, Robert, 'US Navy, Industry Pursue Smart Tomahawks', *Defense News*, February 10-16 1997, p 22.

## Warhead Size

To keep a cruise missile cheap enough for economic employment and small enough for practical launch from a range of platforms, its components and systems must be kept as small and light as possible. One area where this has forced some compromise has been in the warhead. As originally designed, earlier cruise missiles made up for this small size with the destructive capacity of a nuclear warhead. However, with the transition to a conventional weapon, the relatively small high-explosive (HE) warhead limits the destructive power available. Even the current 450 kilogram HE warhead of many cruise missiles has forced a compromise in fuel carriage capacity, reducing their range significantly over nuclear-armed versions of the same missile. As an example, the conventionally-armed AGM-86C ALCM has a range capability 500 kilometres less than the nuclear warhead AGM-86B of the same weight and dimensions.[40]

The average warhead of most cruise missiles, at around 450 kilogram, possesses noticeably less destructive effect than a single Mk 84 bomb. As discussed previously under the subheading of 'Accuracy', this relatively small warhead places great reliance on weapon accuracy to achieve a desired degree of damage. In systems where sufficient accuracy cannot be achieved to allow use of a penetration warhead, the warhead is optimised for blast effect, restricting its capability against targets requiring penetration. An example of this was the case of the 35 CALCMs launched from B-52s during the Gulf War. Their limited accuracy meant that a penetration warhead could not be used. In turn, this restricted their employment to 'soft' targets, such as components of the civilian infrastructure. Typical targets were power stations and telephone exchanges.[41] Conversely, the effect of mismatching this relatively small blast/fragmentation type warhead against a hardened target was seen in the September 1996 US attacks against Iraqi facilities, where the 'missiles' effects appeared negligible'.[42] This accuracy/warhead size trade-off is an important one for the ADF. Procurement of a relatively inaccurate weapon would preclude attacks on hard targets and hence allow an adversary to protect essential infrastructure through application of selective hardening of structures.

Other warhead options for cruise missiles include a cluster-type warhead, capable of dispensing submunitions. The TLAM-D is an example of this type of weapon, and was used operationally in the Gulf War. The ability of such a warhead to target an area, rather than a specific point, implies a reduced need for terminal accuracy. However, the capacity of a typical cruise missile restricts the size and/or number of the individual submunitions to a stage where they may only be employed effectively against soft targets, or a small number of closely-grouped armoured targets, and have limited destructive capability. This suggests that substantial numbers of cluster-armed weapons would still have to be launched against large area targets, particularly area infrastructure targets.

A final limitation imposed by the relatively small warhead of most cruise missiles is the limited total destructive ability of which they are individually capable, or

[40] *Jane's Air-Launched Weapons*, Issue 22, October 1995.
[41] Tirpak, John, 'The Secret Squirrels', *Air Force Magazine*, April 1994, p 58.
[42] Fulghum, David A., 'Hard Lessons in Iraq Lead to New Attack Plan', *Aviation Week and Space Technology*, 16 September 1996, p 25.

conversely, the number of weapons that are required to inflict the required degree of destruction on a large or hardened target. Two examples of this limitation were the use of 42 Tomahawk missiles against Iraq's Zafraniyah Nuclear Fabrication Plant on 17 January 1993, and 23 against the Iraqi Intelligence Service headquarters building on 26 June 1993.[43] Post-mission damage assessment on the latter (a multiple-building complex) showed substantial, but not total, destruction of the facility in spite of the effort matched against it. Previous analyses of the cost effectiveness of ADF reliance on cruise missiles has assumed strikes by cruise-missile armed submarines could, of themselves, achieve Australian strategic objectives. These examples of previous operational use indicate that targets may require much higher weapon usage than commonly estimated. Even accepting the high military value of such targets, the value of the weapons required in each case raises questions regarding Australia's economic ability to rely on cruise missiles as its primary strike means, particularly if a large number of targets needed to be attacked.

**Controllability after Launch**

The reliance of earlier generation US cruise missiles on autonomous guidance and homing has already been discussed. This autonomy of operation following launch was shared by most of the CASOM contenders, which rely on a GPS/ INS (or GPS /TRN/ INS) guidance and usually a form of imaging, scene matching algorithm for terminal homing. This 'fire and forget' capability has implications for compliance with the laws of armed conflict, which will be discussed later. However, autonomy also results in economic and effectiveness drawbacks which may be rectified, to some extent, through reinstatement of the man into the loop. The Block IV Tomahawk, which enables operator input to the weapon, was the US Navy's solution to these deficiencies. The Block IV's capabilities illustrate the rationale for man-in-the-loop homing:

a. It gives greater accuracy, and hence greater weapon effectiveness, through operator refinement of aim point during terminal homing. This also permits use of a penetration-type warhead.

b. It permits in-flight retargeting, if an intended target has already been destroyed, or if targeting priorities change after missile launch.

c. It provides real-time battle damage assessment. This reduces the necessity (and cost) of launching a repeat strike against a target destroyed by a previous weapon.

d. It enables the operator to abort the strike, should updated intelligence, previous mis-identification of the target, or missile malfunction reveal the potential of the attack to incur unacceptable collateral damage.[44]

The in-flight retargeting, in particular, provides economy of effort benefits in missile employment. Whereas previous targeting tactics had required the launch of two

[43] US General Accounting Office - National Security and International Affairs Division 'Cruise Missiles - Proven Capability Should Affect Aircraft and Force Structure Requirements', Report to Congressional Committees, 20 April 1995, p 12.
[44] 'US Briefing'.

missiles against every point target, to ensure a high probability of destruction, the in-flight retargeting of the Block IV Tomahawk reduces the requirement for a second missile in a high proportion of cases. This reduces the number of missiles required to achieve the same probability of destruction.

Man-in-the-loop control, however, is not easy to achieve. Real-time operator input requires that the information from the missile be data-linked to the operator. The AWW-13 datalink used by the Block IV is capable of transmitting data to a platform at a range of 100 nautical miles.[45] Another analyst quotes the maximum range of a missile datalink as around 160 nautical miles.[46] In both cases, this range is far shorter than that of the missile, and if launched from a surface vessel or submarine, a second platform or satellite would be required to control the missile or relay the signal back to the launching platform. This would then subject the controlling platform to the same risks which the long stand-off range of the missile is intended to eliminate. One alternative proven by the US Navy is to use a *Pioneer* UAV to relay the data to a surface vessel. The difficulties of launching and controlling a UAV from a submarine while submerged are manifest, and to enable the full covert capabilities of a submarine to be used, the vessel would be ill-advised to remain at the surface (even at periscope depth), controlling the flight of the missile via satellite link for some hours after launch. The full benefits of a man-in-the-loop cruise missile system, if submarine launched, would therefore require a supporting platform. Ideally, rather than using multiple platforms requiring coordination, the controlling platform should also launch the missile. If economic, law of armed conflict (LOAC) or other rationale requires the use of a man-in-the-loop system, then, the best platform for its launch is unlikely to be a submarine.

## LAW OF ARMED CONFLICT ASPECTS

The Australian Government has ratified the Protocols Additional to the Geneva Conventions of 1949, and accepts the LOAC. Australia is therefore legally obliged to ensure that any use of strike weapons also accords with the provisions of the LOAC. This section will discuss that law and how it impacts upon the potential use of cruise missiles by the ADF. This discussion will begin by considering a cruise missile simply as a long-range guided strike weapon and examining the definitions and constraints placed upon the employment of such weapons.

### Legal Position

Two important initial considerations must be stated in discussion of the legal position with regard to cruise missiles. The first is that the use of guided missiles by air, land or sea forces against military objectives is clearly legal under international law, and has been confirmed by the extensive practice of nations in wars during the twentieth century.[47] The second is that the LOAC recognises that incidental injury and collateral damage may be the inevitable result of any aerial attack, and as a result, it is not

---

[45] *ibid.*
[46] Richardson, D., ‘Missiles for the Modern Warplane’, *Asian Defence Journal*, 9/96, p 54.
[47] DI(AF) AAP 1003 - *Operations Law for RAAF Commanders*, First Edition, Commonwealth of Australia, May 1994, para 9.6.

unlawful to cause such injury.[48] From these statements, it may be interpreted that the LOAC would place no legal impediment on acquisition of cruise missiles (used in the sense of a long-range guided weapon) by the ADF. Any LOAC problems arising as a result of acquisition of these weapons would apply mainly to their use, rather than their possession. The above statements also include this factor, restricting their use to attacks against military objectives. Legal obligations place a number of further restrictions and interpretations which may be applied to the employment of cruise missiles:

a. Use of over-the-horizon missiles 'requires careful judgment which must include consideration of the risk to innocent or protected personnel, objects, facilities or units. Normally these systems should have sensors or should be used in conjunction with external sources of targeting data which provide effective target discrimination.'[49]

b. Article 51(5)(b) to Additional Protocol I provides that unlawful indiscriminate attacks include any 'which may be expected to cause incidental loss of civilian life...which would be excessive in relation to the concrete and direct military advantage anticipated'.

c. A precision guided munition (PGM) which can be directed at a military objective, but which may also miss its target because of a failure in its guidance system, is not an indiscriminate weapon because of this failure.[50]

From a legal position, the obligation remains with the defender to provide some protection for his civilian population by ensuring their reasonable separation from valid military targets where possible.[51] However, once reasonable steps have been taken to protect the civilian population, the defender is not legally obliged to take additional measures due to the increased range, decreased reliability, or indiscriminate nature of the warhead of an offensive weapon.[52] Accordingly, in choosing a particular weapons system for the conduct of a strategic strike, it is the duty of the attacker to consider the potential for collateral damage resulting from the characteristics of the weapon.

All of these definitions and restraints may be broadly reduced to a judgment by the user that the cruise missile employed provides *effective* target discrimination, and complies with the principle of proportionality: that is, that there is an acceptable relationship between the legitimate destruction of military targets and the possibility of consequent collateral damage.[53]

An assumption is that Australia would only attack legitimate military targets, would correctly match the warhead type to the target and would adequately train its operators to ensure correct release of the weapon. Assuming also that an enemy takes reasonable steps to protect his population, the possibility of collateral damage

[48] *ibid.*, para 8.13.
[49] *ibid.*, para 9.7.
[50] *ibid.*, para 9-4.
[51] *ibid.*, para 8.14.
[52] From interpretation by WGCDR E.E. Casagrande, LS3-AF, 28 May 96.
[53] DI(AF) AAP 1003, para 6.10.

becomes a product of the *accuracy* and *reliability* of the weapon used. With the stated restrictions, these two factors are the prime determinants of the weapon's ability to be used in compliance with the principle of proportionality.

**Accuracy**

As discussed earlier, the accuracy of cruise missiles varies according to the guidance and homing systems used. Generally, although usually less accurate than an aircraft-dropped PGM, both autonomous and man-in-the-loop cruise missiles permit accuracy to better than 30 metres CEP. This remains adequate to permit sufficiently discriminatory targeting in most cases. However, the accuracy of which the weapon is capable can only be achieved if all related systems function as designed, which is a function of the weapon's reliability.

**Reliability**

Reliability of the weapon thus becomes the final determinant of whether a cruise missile could be used in compliance with the principle of proportionality, and hence may be judged to comply with the LOAC. This reliability is not the same as the total system reliability, which is the product of the reliabilities of all systems involved (launch, propulsion, mid-course guidance, terminal guidance and fusing) and may be relatively low. Clearly, the malfunctioning of, say, the release mechanism, or the weapon fusing on their own will not increase the potential for collateral damage. There is some chance for collateral damage from a missile whose propulsion system fails after launch, but there is no clear indication that this is an area of concern with cruise missiles. The main concern is from those weapons whose guidance or homing system may malfunction, but whose destructive capabilities remain intact.

No authoritative unclassified statistics on the reliability of the guidance systems of most cruise missiles are currently available. However, the failure of at least 40 of the 242 Tomahawk missiles launched in the Gulf War shows that the missile cannot be considered entirely reliable (at least partly due to the effectiveness of TERCOM over the relatively featureless environment on the approaches to Iraq). Similarly in the Gulf War, the failure of some proportion of the 35 AGM-86C CALCMs fired is evident, as even the use of multiple missiles per target achieved only around 90 per cent of expected damage.[54] Of particular concern from a LOAC perspective is the 'general agreement that cruise missile success rates (in the Gulf War) varied anywhere from 55 to 85 per cent'.[55] Further examples of failure rates were provided by the strikes against Iraq in January and June 1993. Of the 45 missiles launched in January and the 23 missiles launched in June, seven apparently failed on each strike, implying failure rates of 15.6 per cent and 30.4 per cent respectively.[56] In 1994, the US Navy quoted

[54] Tirpak,'The Secret Squirrels', p. 60. Tirpak reports that 35 missiles were launched against eight targets (an average of over four per target), but even with this redundancy, achieved only an assessed 85 - 91 per cent of damage expected.

[55] Holzer, Robert, 'Value of Cruise Missile Could Alter Aircraft Plans', *Defense News*, 6-12 Mar 95, p 29. This article quotes unclassified Pentagon assessments of cruise missile performance in the Gulf War, from the perspective of their accuracy. The sense used in this article implies that 'success' is the ability of the missile to hit its target, presumably to within expected accuracy limits.

[56] From data published by CDISS, Lancaster University, on the Internet, at http://www.cdiss.org/cmgulf2.htm, extracted 7 Jan 97.

concerns about the Block III Tomahawks' mission reliability and accuracy as the rationale for development of the Block IV Tomahawk.[57] A Hughes representative confirmed this, stating that, most importantly, the system changes (in moving to the Block IV) were to reduce the risk of collateral damage.[58] This admission infers that lack of reliability is a weakness of those versions of the missile predating the Block IV.

From this it can be inferred that the TERCOM/DSMAC-based systems used to guide some older generation cruise missiles have significant potential for failure and, depending on the environment in which the missiles are used, there is significant potential for collateral damage. As mentioned previously, the potential for failure of a missile's guidance system (or of its propulsion system) does not, of itself, render the missile uncompliant to the provisions of the LOAC. However, this risk of guidance failure may be great enough to outweigh the potential military value to be gained from the attack, and, considering the principle of proportionality, may dictate that a cruise missile should not be used. The most convenient way to avoid potential problems resulting from the missile's guidance system would be to acquire a system which did not rely on TERCOM or DSMAC. Alternative technologies have been mentioned previously. Data transfer via a man-in-the-loop system, with its operator abort capability, would permit closer adherence to LOAC provisions, by reinstating an element of human judgment as a back-up to the missile's target discrimination.[59] A GPS-based mid-course guidance system is less environment-dependent and would provide greater reliability than other autonomous systems.

**Evaluation**

In spite of its refusal to ratify the Additional Protocols of Geneva Convention, the US remains sensitive to international opinion, and strongly compliant in its own interpretation of the LOAC. This applied particularly in the Gulf War, where lawyers were used to review each targeting list for compliance. The willingness of US planners to use a large number of cruise missiles during the Gulf War demonstrates that, from a US perspective, those weapons complied with the LOAC to the best of their knowledge at that time. That they subsequently saw the need to reinstate a man back into the command loop for these missiles (with development of the Block IV Tomahawk) is at least partially attributable to the poor reliability of the autonomous guidance of the earlier versions of the missile, and the potential for criticism regarding US compliance with LOAC principles.

In summary, there is no immediate LOAC case to be made against cruise missiles in general, although the low reliability of the older TERCOM/ DSMAC systems during the Gulf War recommends that they not be considered for Australian acquisition because of the potential for their failure, and the likelihood of that failure to draw international criticism. To ensure *ad litteram* compliance, consideration should be given only to those systems whose technology was demonstrably more reliable than

[57] 'US Briefing'.
[58] *ibid.*
[59] However, balanced *against* the argument for man-in-the-loop are claims that human manual corrections can also degrade the weapon's accuracy; See Richardson, D., 'Missiles for the Modern Warplane', *Asian Defence Journal*, 9/96, p 54.

that of previous generation autonomous missiles. But this would be for the sake of political caution. There is no legal compulsion to use such weapons. In her analysis into PGMs and the Law of War, Danielle Gilmore points out that 'there is no law of war concept requiring that the most discriminatory means be used'.[60]

## REGIONAL PERCEPTIONS

Acquisition of the long-range strike capability provided by a cruise missile could have significant implications for the way Australia is viewed by its regional neighbours. Although the logic for their acquisition has been signalled obliquely in previous Defence White Papers, cruise missiles would herald the introduction of a capability whose purpose was most likely to be interpreted as offensive power-projection. This section will examine regional perspectives and perceptions regarding such a capability, and the political implications for Australia of its prospective use.

### Rationale for Acquisition

With the F-111, Australia already possesses the capability to conduct strategic land and maritime strikes at distances of over 1,000 nautical miles from its coast. From a simplistic perspective, the replacement of this strike capability with one based upon use of cruise missiles appears to offer no greater capacity to inflict damage. As already discussed, most cruise missiles offer a destructive capacity comparable to (and often less than) that of a single Mk 84 bomb, albeit at a far greater cost. This greater cost would dictate that the total number of rounds in Australia's inventory would also be smaller than that of, say, Mk 84 bombs at present. So why should regional neighbours perceive any additional threat from such an acquisition?

Because of the current cost of cruise missiles, the primary economic justification for their acquisition would be restricted to their ability to strike deep with impunity. Unlike the F-111s, whose primary role may be argued to be one of defensive strike against approaching invasion forces throughout Australia's maritime approaches, a land-strike cruise missile is an unambiguously offensive weapon. Also, the cruise missile's lower probability of attrition reduces the potential financial, political or manpower costs associated with loss of a manned aircraft. By implication, an action without the risk of incurring a cost is an action with greater political appeal, and may be seen as an action to which a political leadership might more readily resort. It can be argued that the risk incurred by a manned strike platform on a strategic strike mission, in terms of human life and the value of the platform, is a partial guarantor that the option will be used in only an extreme circumstance. A shift in emphasis to reliance on an option with lower human risk could be perceived within the region as acquisition of a first-strike capability, or at least as a potentially coercive action. To maintain some parity in capability, regional nations may conclude that acquisition of some retaliatory stand-off capability is also warranted, with the potential to result in undesirable proliferation, or an arms race.

---

[60] Gilmore, Danielle L., 'Precision Guided Munitions and the Law of War', Air Power Studies Centre, Paper Number 30, March 1995, p 16.

## An Arms Race?

As an element of regional engagement, *Defending Australia - Defence White Paper 1994* states that Australia 'will aim to promote an environment which sustains a stable pattern of strategic relationships and avoids destabilising strategic competition'.[61] Arguably, by seeking to obtain a leap in stand-off range capability for strategic strike, Australia would not be changing the 'current stable pattern of strategic relationships' - it could argue that it was merely maintaining its currently-held technological lead over its regional neighbours. But at the same time, Australia would be setting a problem for those nations to deal with: to meet their own legitimate defence needs, they would seek to obtain some counter to the perceived long-range cruise missile threat. Defence against such a threat is much more difficult, and hence much more costly than the offence. Stuart MacKenzie and Alan Stephens draw a historical parallel illustrating that it is four times more costly,[62] and Carlo Kopp argued (before the end of the Cold War) that:

> ... probably the greatest benefit of the cruise missile [to the US] in time will be the financial drain it has caused the Soviet Union through having to develop a whole new family of expensive countermeasures to combat the threat, thus taking money away from offensive programmes.[63]

A current example of the cost of defending against the cruise missile threat is the previously mentioned aerostat-based cruise missile detection system under development within the US. The Department of Defense has allocated US$540m to the development of one technology (and others are also being developed) for a detection capability alone.[64] The weapon systems needed to provide the associated air defences will be an additional cost. These examples illustrate the escalation argument used by some agencies in support of cruise missile acquisition: that the ability to escalate a conflict beyond the ability of an adversary to defend will rapidly terminate the conflict. (This argument will be examined in more detail later.) However, the obvious option for a nation faced with a formidable escalatory capability is to obtain an ability to counter-escalate the conflict. That is, to acquire some retaliatory strike capability which would then require a large Australian defensive effort. Alternatives open to regional nations include acquisition of relatively cheap cruise missiles or ballistic missile systems such as those available from China or Russia, or potentially the development of weapons of mass destruction, such as biological or chemical weapons. As one example, Russia is currently offering the 115 kilometre-range Raduga Kh-59M Kingbolt cruise missile for export, and the 300 kilometre Kh-65 could be offered shortly.[65]

---

[61] *Defending Australia - Defence White Paper 1994*, p 85, para 8.1.
[62] MacKenzie, Stuart and Stephens, Alan, 'Bolt From the Blue: the Ballistic and Cruise Missile Problem', Air Power Studies Centre, Paper Number 20, February 1994.
[63] Kopp, Carlo, 'Cruise Missiles, Pt 1 - The Strategic Cruise Missile', p 72.
[64] Evers, 'US DoD to Develop Anti-Cruise Missile Aerostats', p 6.
[65] Walters, Stewart, 'Stand-off Weapons: Hitting Hard with Pinpoint Accuracy', *Asian Defence Journal* 8/95, p 47.

The South East Asia and Oceania regions have not yet seen any proliferation of cruise missile technology beyond that of (comparatively short-range) anti-shipping missiles. There are three possible reasons for this:

a. No valid military rationale has yet been established for the acquisition of such a capability. These nations have conducted their own studies into the military capabilities of their neighbours, and have reached a conclusion that more traditional strike weapons offer the most cost-effective and supportable option.

b. Another reason may be the complementarity or 'supplementarity' of this class of weapon. It is a high-end capability with limited flexibility, offering only an incremental improvement in operational capability (compared with a strike by a manned aircraft) for a disproportionately high cost, and regional nations are currently placing greater priority on acquiring the capabilities necessary to meet their current legitimate defence needs.

c. The perceived parities between South-East Asian nations makes this a competitive region, prone to a high degree of posturing and one-upmanship. The fact that strategic strike missiles have not yet been introduced by any nation in the region provides no incentive for other nations to similarly acquire this class of weapon. This also comes back to the argument on escalation discussed earlier: that no need has yet been perceived for a weapon to escalate to this level of stand-off. MacKenzie and Stephens raise, as an example of this proliferation tendency, the Saudi Arabian acquisition of Chinese CSS-2 missiles as a reaction to the Scud missile usage by neighbouring Iran and Iraq.[66]

The ability of a surface force to poise, to project power and to extend national presence are important attributes justifying the need for potent firepower. However, where that surface force is vulnerable to enemy action, its deterrent capability, and hence the military value of its presence, is neutralised. Only where the surface-based launching platforms can be provided with a substantial degree of immunity from attack, can its presence remain militarily useful. The concept used by the US Navy is to achieve relative immunity from attack through remaining part of a carrier battle group with organic air defence cover and substantial ASW assets. An alternative, or additional, means of protection is that embodied in the USS *Iowa* and *Missouri*: these vessels use massive armour to provide a substantial degree of resilience to conventional forms of attack. These measures have been essential in previous employment of cruise missile by the US Navy, due to its reliance on the TLAM-C, which uses TERCOM guidance. Earlier discussion has noted that the TERCOM system cannot be used over water for long distances, placing sole reliance for guidance on the missile's INS. This has forced naval missile carriers to launch their TLAM-Cs within 50 nautical miles of the coast, frequently increasing the vessel's vulnerability to an adversary's land-based defences. This limitation is largely being overcome as ship-launched cruise missiles begin to be updated to rely upon GPS guidance, rather than TERCOM.

[66] MacKenzie and Stephens, 'Bolt From the Blue: the Ballistic and Cruise Missile Problem', p 6.

However, vulnerability to land-based defensive systems, and also to submarines, still complicates the defensive problem for a cruise missile ship, particularly where extensive defensive measures, as used in US fleet deployments, are unavailable. The Falkland War of 1982 confirmed the vulnerability of ships without air cover to high speed, low flying aircraft armed with a reasonable stand-off anti-ship missile.[67] Former USAF Chief of Staff General Michael Dugan considered that the combination of stealthy aircraft and stand-off PGMs may eventually make surface naval combatants obsolete, and predicted that the attacker's advantage in the maritime sphere would continue to grow.[68] There is some irony to this situation. The stealth, low level capability and small target attributes which make the cruise missile a practical and effective weapon against a highly defended target are also the same attributes which render surface vessels impractical platforms for cruise missile carriage, as that surface vessel is likewise vulnerable to anti-shipping cruise missiles.

The alternative, for a surface vessel unable to rely on protection from carrier-borne aircraft, yet still required to project presence off an adversary's coast, is to rely on extensive ship-borne defences to improve its survivability. This implies the need for area and close-in air defence weapons, and extensive resilience or redundancy. In turn this implies the need for an expensive vessel, or, preferably, a fleet containing a number of specialised and expensive vessels. Acquisition of a fleet capable of sustaining its own defence close to an enemy coast in time of conflict, and without air cover, implies a cost likely to remain beyond the ADF's resources for the foreseeable future. Even if affordable, the cost benefit of acquiring these capabilities, to enable launching of a relatively small number of cruise missiles, is unlikely to be justifiable.

As identified previously, the power projection capability of an adequately armed surface vessel, such as the arsenal ship, can be acquired at a considerable cost saving over the price of an aircraft carrier, and it provides the capacity of political signalling by displaying a presence off an adversary's coast in a modern equivalent to the historical concept of gunboat diplomacy. The major advantage of that presence is that it can be sustained for prolonged periods, because of the surface vessel's inherent self-sufficiency. Balanced against this, however, must be the vulnerability of the vessel to air or submarine attack, and the practical and financial difficulties of reducing that vulnerability. The matching of the ranges of the vessel's offensive missiles with that of an adversary's defensive missile platforms means that a surface vessel without adequate air defences is forced to maintain distance between itself and the adversary's coast in order to lessen its vulnerability. This separation is incompatible with the use of earlier-generation TLAM-C missiles, and diminishes the ability of the vessel to then provide its intended presence, except by implication. The concept of presence has always relied on an implied superiority of force, which, since the development of guided anti-shipping missiles, can no longer be assured, except in the case of massive and expensive carrier battle groups. It is time to question whether a 'virtual presence' can now be achieved through the use of sufficiently long range missiles. However, this use of long range missiles does not necessarily imply the need for them to be mounted on a surface vessel.

[67] Stephens, A. 'Combat Air Power in the Asia-Pacific Region', in Lax, M. (Ed), *Regional Air Power Workshop Proceedings*, Air Power Studies Centre, Canberra, 1993, p 126.
[68] Stephens, 'The Implications of Modern Air Power for Defence Strategy', p 16.

The final argument against the use of surface vessels as cruise missile platforms is an outcome of the relatively low transit speeds of these platforms. Once the vessel is in position, its imposed *threat* may be sustained for a long duration. However, once deterrence fails, and the vessel's weapons have been expended through offensive action, the vessel loses its military utility until it can be reloaded. Given that the initial purpose of using a surface vessel is the need to project power *at a distance* from a nation, the vessel is then required to return to that nation, or a forward resupply point, to reload. Alternatively, a resupply vessel is required to perform that transit, then reload the warship in place at sea. Should a replenishment vessel be used, its own vulnerability would be even greater than that of the better equipped warship it was intended to sustain, transferring the vulnerability to a less defendable platform. Although use of a forward-stationed surface vessel enables a very rapid response, once it is in place, the subsequent reloading constraints work to the detriment of operational tempo: any reduction in tempo erodes the advantages acquired through the shock effect available from the cruise missiles.

***Summary.*** In summary, the present inability of the ADF to provide adequate protection for a likely cruise-missile-carrying surface vessel increases its vulnerability to anti-shipping defenses, particularly land-based aircraft. Provision of those defences, while an option, would be too expensive to be justifiable for the relatively small strategic strike capability likely to be possible from any surface vessel currently in the ADF inventory. Finally, although the tempo of operations available from a surface-borne strategic strike capability would be adequate to allow its use for political signalling purposes, it would be insufficient for decisive use in any conflict where large-scale strategic strike would be required.

**Submarines**

The advantage of cruise missiles over manned aircraft is their ability to penetrate an adversary's defences without risk to the manned platform. Use of a submarine for their launch extends this ability to stealthily penetrate an adversary's defences. It also reduces the chance for an adversary to gain warning of the launch of the missiles. The considerable range of a submarine is another major advantage of this platform, and when used to enhance the long range of a cruise missile, the combination offers a threat to a potential adversary, which cannot be matched except by the most capable air platforms, usually supported by air-to-air refuelling. However, the type of missile selected, and particularly the forms of guidance that missile uses, has significant implications for using a submarine as a platform.

***TERCOM Missiles.*** The limitations of TERCOM as a guidance system for missiles have been discussed. The problem associated with submarine launch of the TERCOM-guided missiles currently available is that their need to make landfall, and to update their INS system, within the first 50 nautical miles of their travel, limits the firing options for a submarine, and may prevent the submarine from making full use of the missile's range capabilities. It may compel the submarine to penetrate into shallow coastal waters, through the depth of an adversary's maritime defences. The caution required in this penetration would potentially slow down the reactiveness of the submarine, and would impact upon the tempo of operations of which a submarine would be capable. Operational tempo considerations will be discussed later. Assuming an adversary is similarly aware of the limitations of the missile, his problem of locating the launching platform is reduced to those probably shallow waters within 50 nautical miles of the coast. These limitations have not been crucial in the continental use made of cruise missiles so far by the US Navy, nor would it be in the potential use of the Block III Tomahawk missiles recently acquired for the Royal Navy's submarines. In a continental strike situation, the missiles may be launched from a position off a friendly, neutral or heavily controlled coast, as they were in the Gulf War. In the geostrategic situation likely to apply in any ADF use of cruise missiles, none of these favourable coastal situations for missile launch is likely to apply.

***GPS Guidance.*** By contrast, the adoption of a missile using GPS for cruise guidance would enable a submarine to position itself to make maximum use of the missile's range capabilities, possibly permitting a launch from open ocean. Where there was a relatively low level of ASW capability with which ADF forces conceivably could have to contend, this longer-range launch would give the vessel a good chance of successfully evading reactive ASW defences. Although reliance on GPS entails other limitations, it could increase the potential flexibility and reactiveness of cruise missile employment from a submarine. This was part of the rationale for the US Navy's post-Gulf War upgrade program for the Block III Tomahawk, providing GPS as a back-up to the missile's TERCOM system. As discussed previously, however, GPS should not be relied upon as the sole guidance source, and a further form of terminal homing is likely to be required, imposing its own limitations upon the missile and its employment.

***Man-in-the-Loop Options.*** The realisation by the US of problems with collateral damage emerging from cruise missile use during the Gulf War compelled its development of a man-in-the-loop system with the Tomahawk Block IV. With the similarity of Australian attitudes toward compliance with the LOAC, there may exist political pressure to purchase a system with similar scope for operator input in its terminal guidance. If such a system was to be selected for acquisition by Australia, its launch from a submarine would produce problems resulting from the need to maintain a datalink between the operator and the missile. These problems depend on the method used for relaying information between the missile and its launch platform. Broadly, they may be summarised as follows:

***Satellite Link.*** If the missile were linked to the submarine via a satellite, this would require the submarine to remain at least at periscope depth, to enable operator input through the datalink. The need for the submarine to transmit operator updates would significantly increase the submarine's vulnerability to detection throughout the duration of the missile's time of flight, and partly invalidate the initial logic of using a submarine to decrease launch platform vulnerability.

***UAV Link.*** The US Navy has demonstrated the concept of linking a cruise missile to a naval platform using a UAV, but as previously discussed, the difficulties in launching the UAV, or the extensive coordination difficulties, should the UAV be launched from another platform, would probably preclude this as a practical option for use with a submarine. This option also increases the submarine's vulnerability through its need to remain at periscope depth to control the missile and the UAV.

***Manned Aircraft Link.*** Control of a man-in-the loop SLCM could be passed to, or linked through, a manned aircraft after missile launch. However, as well as potential coordination difficulties, such a method of control would then expose the manned aircraft to the risks which the range of the missile, and the stealth of the submarine, are intended to avoid, negating the rationale of using a submarine as a launch platform.

***Combination Link Options.*** Alternatively, the submarine could be used for launching the missile, with a satellite linking control back to another platform, such as an aircraft or a ship. This would offer a workable option, notwithstanding the potential coordination problems, but the use of a second platform again calls into question the rationale for use of a submarine as the launch platform to begin with.

Similar problems would result from retasking the missile in flight which is another recent development in cruise missile control. Again, the operator-in-the-loop alternative would require a real-time link between the missile and either the submarine or a second platform. Clearly, none of these problems would apply should an autonomous form of terminal homing be selected, but this would require the ADF to forgo the flexibility in employment, and to tolerate potentially lower missile reliability, mainly due to choice of platform. This would produce a case where the platform selected would largely drive the capability of the missile, whereas more conventional force-structuring logic should allow the capability required to ascertain the most suitable platform for the weapon's carriage.

Moving from the problems imposed by the missile's guidance systems, a recent magazine article raises a number of broader deficiencies in the abilities of the *Collins* Class submarines to meet Australia's strategic strike requirements.[69] Among these are:

a. small weapons load;

b. long time to reload;

c. inflexibility, or lack of ability to react quickly to retasking; and

d. problems with transfer of targeting data.

***Small Weapons Load.*** The *Collins* Class submarine is equipped with six weapons tubes and the capacity for 17 reloads, giving it a total carrying capacity of 23 weapons.[70] The number of weapons carried would only be reduced from this amount by the number of self-defence weapons, or weapons for other employment, that were required for a mission. Even assuming carriage of a full 23 cruise missiles, the total destructive potential remains comparatively small when considered in the light of the 23 weapons fired against a single large target (Iraqi intelligence headquarters) during the Gulf War by the US, without achieving total destruction. However, this weapon load should only be regarded as inadequate if considered from a perspective of use as the ADF's primary striking capability. Certainly use of even this small number of

[69] Kopp, Carlo, 'Tomahawks, Submarines and the F-111', *Australian Aviation*, January/February 1996, pp 42-45.
[70] From CMDR Chris Donald RAN, project officer for the *Collins* Class Submarine Project, 21 March 1996.

weapons in a single coordinated strike against a strategically significant target would send a powerful political signal to an adversary, and the *capability* to conduct such a strike with relative impunity would provide some degree of deterrence. Thus, while the *Collins* Class submarine would enable insufficient cruise missile carriage for a sustained strategic strike campaign, it would provide an adequate carriage capacity for threatening, or for political signalling.

***Reload Time.*** The tempo argument previously discussed in regard to surface vessels also works to the detriment of using submarines to launch cruise missiles. Like surface vessels, their carrying capacity is limited, and after expenditure of these weapons, the submarine must return to a point where it may reload. However, unlike surface vessels, ADF submarines cannot be resupplied at sea, requiring their transit back to Australia. Further to the detriment of operational tempo, a submarine's transit speed is significantly lower than that of a surface combatant. However, as covered above, tempo requirements are only a consideration when the cruise missiles from surface or subsurface vessels are relied upon as a sole means of strategic strike. Where they are relied upon to fulfil other roles, such as signalling, strike augmentation or tactical support, the required tempo of operations may not be as great, and a submarine (or number of submarines) may have the capability to meet that reduced tempo requirement.

***Flexibility.*** In the article mentioned earlier, Carlo Kopp uses the term 'flexibility' in reference to the ability of a strike platform to be retasked. In this sense, he argues that the need to evade defences and transit or manoeuvre to a missile launch position can take some days for a submarine, and retasking (to another target not within range) similarly can take a long time. This is particularly relevant when the missile must be launched within 50 nautical miles of the coast, as in the case where a missile relies on early-generation TERCOM guidance. Should a GPS-guided missile be used, and in view of the 500 nautical miles range of missiles in the class of Tomahawk, a submarine launch platform gains an increased degree of flexibility. However, the potential area across which the ADF's strike assets may be required to operate against a potential adversary is too large for a single submarine to simultaneously remain within range of all potential strike targets. Accordingly, until a missile becomes available whose range is large enough to cover all potential targets within Australia's northern approaches, the submarine will remain less flexible and potentially less responsive than a long-range strike aircraft in providing a primary means of strategic strike.

***Transfer of Data.*** As an aspect related to flexibility, Kopp also raises an argument regarding the difficulties in transferring targeting information to a submarine used as a strike platform. If SLCMs were to be used as a primary means of strategic strike, the potential number of strike targets would be large, and the volume of data storage required would far exceed the capacity of the submarine, hence requiring that the data be transferred to the vessel as targets were identified. The amount of data required to be transferred would depend upon the guidance method used, with GPS mid-course guidance requiring far less information than a TERCOM system. However, current-generation GPS systems require a second form of guidance for terminal homing, most usually some form of digital scene matching, which requires large quantities of recent intelligence. Kopp suggests that a submarine may have to compromise its stealth to rendezvous with a second platform to receive a physical transfer of data. However, development in communications technology is more likely to see future use of electronic transfer. This, at a minimum, would require the submarine to remain at periscope depth to receive the transfer, resulting in some increase in the risk of revealing its position.

***Communications and Political Control.*** Related to the need to transfer data to a submarine is the need for reliable communications. As strategic strike is a political action, and will therefore be closely controlled at a political level, the need for rapid, reliable communications to a controlling strategic-level command authority is paramount. However, a submarine relies on its stealth for self-protection, and stealth considerations in the tactical environment invariably require the forfeiture of rapid and reliable communications, in favour of preservation of the platform. The draft ADF publication dealing with joint operations acknowledges that submarine response times may be inhibited by communications restrictions,[71] which are inherent in the environment in which a submarine must operate. This factor limits a submarine's military reactiveness in a strategic strike role, but more importantly, it prevents the adequate control at a political level of the political weapons carried aboard a submarine. The clear risk in using a submarine for this role is that a failure to receive timely updates of strike orders or rules of engagement has the potential to increase the risk to the platform or to unintentionally escalate a political situation.

***Technological Advantage.*** Notwithstanding the operational difficulties associated with using submarines as cruise missile carriers, they offer the potential strategic advantage of forcing an adversary to expend disproportionate effort in defending against the threat posed by SLCMs. The addition of the submarine element into the cruise missile equation would throw pressure on an adversary to particularly concentrate on enhanced ASW capabilities, an area in which few developing nations possess any significant capability. The lead time required for a potential adversary to develop the necessary defensive anti-submarine warfare skills as a counter to SLCMs would thus result in a substantial military advantage for Australia for many years. However, acquisition of a defence against SLCMs is only one potential option for an adversary, another being acquisition of a counter-escalatory capability, such as weapons of mass destruction or cruise or ballistic missiles. As covered previously, the outcome of this development would be, on balance, to Australia's disadvantage, and a rationale for continuing to support non-proliferation regimes.

***Summary.*** In summary, the advantages offered by the submarine, if used as a platform for cruise missile carriage, stem mainly from its use as a means of threatening or signalling. If employed in strike operations, it may inflict a small number of punitive strikes as a form of political signalling, and it may be used as a means of influencing the force structuring decisions of a potential adversary, to Australia's advantage. However, if regional nations perceived Australia's acquisition of a SLCM capability as a threat to their own security, they might respond by adding to their own range of offensive weapons. In addition to these considerations, there are

[71] ADFP6 Joint Operations, Supplement 1 (Draft, March 1996), para 235.

also a number of limitations on operational employment of cruise-missile carrying submarines in a primary strategic strike role, in that they:

a. cannot sustain a high tempo of operations,

b. offer low flexibility, and

c. are less subject to immediate political control than other platforms.

Finally, practical difficulties restrict submarines from using cruise missiles with man-in-the-loop guidance, a factor which may have implications for Australia's aspirations to be seen as a strict observer of LOAC protocols.

**Aircraft**

Cruise missiles were originally designed as strategic air weapons, for carriage by long-range strike aircraft such as B-52s. For use in this role, the US Air Force maintained an inventory reported to include around 1,700 AGM-86 and 460 AGM-129 ALCMs,[72] including both conventionally armed and nuclear variants. However, the success of cruise missiles in the Gulf War has produced a shift in that emphasis to a more tactical role, and has seen subsequent fitment of ALCMs to more tactical platforms, such as the F-15, F-16 and F/A-18. As an example of this change in emphasis, the US Air Force's inventory of cruise missiles is planned to be significantly increased, with the addition of the conventionally-armed Joint Air-to-Surface Stand-off Missile (JASSM). With its 350 nautical miles range, this missile is intended to fill the gap between medium-range weapons and the strategic ALCMs. Two thousand-four hundred of these missiles are expected to be produced, with production expected to commence in the year 2000.[73] Another example of the increasing emphasis on ALCMs is the previously-mentioned UK CASOM requirement, with a minimum range specification of 130 nautical miles.

***Attrition.*** The primary reason for the increased interest in ALCMs as tactical weapons is that their use enhances the survival rate of launching aircraft where targets are heavily defended. This consideration is frequently neglected in comparisons between manned-aircraft strategic strike and SLCM strikes. There is clear logic in using SLCMs where manned aircraft (armed with short range weapons) would suffer a high rate of attrition. However, the same manned aircraft armed with ALCMs can achieve a high tempo of operations, with flexibility of employment, while remaining beyond the range of an adversary's air defences. This is the rationale for continued use of the ageing B-52 in this role, in spite of its otherwise relative vulnerability to air defences. One analyst assesses that an ALCM with a stand-off range of 200 nautical miles would be able to defeat any current regional air defence capability,[74] although the balance in this equation would be altered depending on the possession of over-the-horizon surveillance, AEW&C and air defence fighter capabilities. The UK, in inviting CASOM contenders with ranges of as little as 130 nautical miles, indicated its own assessment of an acceptable range to minimise strike aircraft attrition in a

[72] *Janes' Air Launched Weapons Systems*, Issue 22, October 1995.
[73] 'McDonnell Douglas and Lockheed Martin Awarded Competing Development Contracts for New-Generation Missile', *US Defense Web News Briefs*, 18 June 1996, p 1.
[74] Kopp, 'Tomahawks, Submarines and the F-111', p 45.

European environment. However, the successful tenderer for CASOM offered a weapon with a range of around 350 kilometres[75] - close to the 200 nautical miles figure quoted by Kopp. With its intended acquisition of the medium range AGM-142 stand-off weapon, the ADF has made its own judgment on the medium-term capabilities of air defence systems with which it may have to contend. However, should a potential adversary acquire higher levels of AEW&C capabilities, or some form of over-the-horizon radar, Australian acquisition of a mid-range cruise missile such as the British Aerospace Storm Shadow (the successful CASOM contender), or the US JASSM would be one option to retain a low-attrition strategic striking capability.

***Weapon Cost.*** Another factor in the logic for air-launched cruise missiles, and the increased numbers being introduced into service with foreign forces, results from cost considerations in comparison with their SLCM counterparts. The air-launched variant of any cruise missile will generally be cheaper than the surface- or subsurface-launched variant, due to the lack of requirement for a launching container or a boost stage to propel the missile to cruise altitude and speed. As an example, the US's cancelled MRASM air-launched cruise missile project (partially resurrected more recently as the Hughes contender for the CASOM requirement) was based on the Tomahawk, yet was estimated to cost approximately 40 per cent less than the baseline Tomahawk SLCM.[76] Another cost argument for use of airborne platforms for strategic strike is based on the fact that cruise missiles need be only one of a number of strike options employed. As stated in *International Defense Review*, an aircraft's cost per target killed is variable, and once an adversary's defences have been degraded, aircraft have the option of striking at targets with cheaper, shorter-range weapons. By contrast, the cost of a cruise missile strike using surface (or subsurface) platforms remains high, regardless of the defensive situation, because reliance on a cruise missile strike imposes a constant cost equal to at least the base cost of the weapon.[77]

***Flexibility.*** A major advantage of aircraft as cruise missile platforms is that they are not limited to that function, and have the flexibility to be retasked in other roles, or to use another weapon, at short notice. Given Australia's strategic circumstances, the ADF will likely retain the requirement for a high performance strike aircraft well into the next century. The ability of aircraft to be retasked from maritime strike to strategic strike, at short notice, provides essential flexibility and reactivity, without the need for an additional platform. Aircraft may also be switched between targets at short notice, enabling greater political and military control, and the additional range provided by an ALCM would decrease the need for supporting aircraft. The speed of aircraft also enables a greater tempo of operations, and greater sustained firepower than that available from any of the ADF's current surface or subsurface platforms if used as cruise missile carriers. A number of previous papers have concluded that aircraft launch enables greater firepower and tempo, in spite of the considerable variations resulting from the differences in serviceability rates and weapon carriage rates assumed for both submarines and aircraft. A recent example points out that 'three of

---

[75] Morrocco, J.D. 'Missile Makers Vie for CASOM Prize', *Aviation Week and Space Technology,* 1 April 1996, p 52.
[76] Kopp, Carlo, 'Cruise Missiles - Pt II Conventional and Theatre Nuclear Cruise Missiles', p 76.
[77] 'Dossier', *International Defense Review,* 4/1995, p 70.

four F-111s supported by one or two tankers can deliver the same cruise missile load over the same distance as a submarine, in hours instead of days or weeks'.[78]

***Man-in-the-Loop Considerations.*** As discussed under LOAC, should Australia choose to acquire a cruise missile, serious consideration should be given to the option of a man-in-the-loop system, due to the LOAC implications of its decreased probability of collateral damage, and because of its potentially greater accuracy and cost-effectiveness than autonomous systems. However, the system requires a datalink to the controlling platform, either directly, or via a linking platform such as a satellite or UAV. Aircraft may use each type of link, either directly, in the case of shorter range missiles, via satellite, or via an aircraft-launched UAV. By comparison, surface platforms are limited in their ability to maintain a direct line-of-sight link, and submarines must compromise stealth - their principle advantage - to maintain any type of link.

***Proliferation.*** The perception of cruise missiles as a high-capability power projection weapon, and the current difficulty of defending against them, makes them a potentially destabilising class of weapon, and a potential trigger for acquisition by other regional nations. This is particularly so in the case of SLCMs, because the development of an ASW capability requires time and a high level of investment to obtain any measure of defence against a perceived potential threat. In the case of ALCMs, most regional nations possess some level of air defence capability which may be used as a partial counter to a perceived threat from an ALCM launch aircraft. Thus carriage of cruise missiles by aircraft may be marginally less liable to trigger regional acquisition than would carriage by submarine.

***Surprise.*** A significant disadvantage of using an aircraft as a cruise missile launch platform, particularly in ocean approaches to the archipelagic environment to Australia's north, is the likelihood that the launch aircraft may be detected on ingress. This would provide warning of an impending strike, and, although it would be unlikely to prevent the launch of a missile with reasonable stand-off, may increase the effectiveness of the adversary's defences against the missiles themselves. Use of stealthy aircraft, stealthy missiles and indirect routing are options to counter this disadvantage. Prior warning may also enable an adversary to take passive defence measures to counter the attack, such as scrambling of aircraft, protection of key personnel, and deployment of countermeasures.

## Operational Implications for Aircraft Carriage

***Carriage.*** Carriage of current-generation cruise missiles by aircraft currently within the ADF inventory would not appear to offer insurmountable difficulties. Certainly the F-111, F/A-18 and P3C are all capable of carrying the AGM-84 Harpoon, upon which the SLAM, SLAM-ER and Grand SLAM cruise missile family is based. The SLAM has already been cleared within the US for carriage by the F/A-18, and has been fired in combat from that aircraft .[79] The British CASOM requirement may be taken as an indicative situation demanding carriage of cruise missiles by comparable aircraft, and deals with carriage of the successful contender on the Tornado GR4,

[78] Kopp, 'Tomahawks, Submarines and the F-111', p 43.
[79] *Jane's Air Launched Weapons Systems*, Issue 22.

Harrier and Eurofighter.[80] The requirement for carriage of a similar class of weapon aboard the F-111 or the F/A-18, or a future replacement aircraft should be similarly possible. Integration of similar technologies has been shown to be easily achievable with the acquisition program for the AGM-142 Raptor PGM. Accordingly, few problems are foreseen in the operational carriage of a cruise missile relying on similar technologies.

***Launch Positioning.*** In a continental European or Middle Eastern environment, the capacity for aircraft launch of a cruise missile has a potential political advantage over the launch of SLCMs. Geographic and tactical constraints imposed on sea-bound platforms in such an environment may require launch of weapons over friendly or neutral territory to reach an inland adversary, or one otherwise inaccessible directly from the sea. Examples are available from the launch of missiles against Iraq during the Gulf War: ingressing missiles were routed over parts of Iran, Turkey and Saudi Arabia, where some potential existed for politically harmful collateral damage to a third country. The flexibility of positioning for an air launch of a long-range weapon largely overcomes this disadvantage of surface launched cruise missiles. However, this argument does not translate directly to maritime environments like those in Australia’s area of direct military interest, where strike by cruise missiles would be unlikely to require overflight of a third country.

***Reach.*** One of the attributes of air power is reach, or the ability to strike at an adversary over large distance. This attribute remains available to the ADF through its employment of the F-111, because of its long range compared to other air platforms within the region. However, upon its retirement from service in the first decades of the next century, options for long-range strike platforms likely to become available may force the acquisition of an aircraft with lower range capability. When considering ALCMs, the other aspect of reach is the range capability of the missile itself. Previous discussion has already covered the restrictions accepted by the US on ALCMs, in compliance with START, and the implied restriction imposed on US export of such systems. Although ALCMs can be given very long ranges, cost and political pressures have restricted most available Western systems to ranges below 600 kilometres (324 nautical miles). Combined with the possibly reduced range of Australia’s future strike aircraft, likely future ADF aircraft/ALCM combinations are likely to have less reach than a *Collins* Class submarine armed with a high-capability SLCM. In low-tempo operations, such as political signalling, this limitation may be offset through the use of air-to-air-refuelling, as used by the RAF in their ‘Black Buck’ raids against the Falkland Islands. A relatively short-range aircraft would have difficulty in sustaining high-tempo strike operations at long range, even with air-to-air refuelling. Acquisition of aircraft with insufficient range for long-range strike would imply an acceptance of this capability gap within ADF force structure planning, as an SLCM option would be similarly unable to meet the requirements of a sustained high-tempo strike operation.

***Summary.*** Use of an aircraft for the carriage of cruise missiles offers several advantages over carriage by surface and subsurface platforms. Some of these attributes are those inherent in air power itself, including flexibility and speed, and the implied utility as a political tool. Use of an aircraft to launch a cruise missile also minimises the chance of attrition to a similar level as use of a submarine, while also

[80] Morrocco, ‘Missile Makers Vie for CASOM Prize’, p 52.

requiring use of a less expensive weapon. It also offers greatest potential for use of man-in-the-loop guidance systems, with their associated implications of lower collateral damage and more efficient expenditure of weapons. Balanced against these advantages must be possible limitations of range (depending on the ADF's choice of future strike aircraft) and lack of surprise. The combination of a medium-range future strike aircraft and a medium-range ALCM would provide less overall reach than an SLCM option, but would offer the capability for more sustained high-tempo cruise missile strike. Given some AEW capability by an adversary, an ALCM is also less liable to achieve surprise than an SLCM, but tactics may be adopted to maintain the weapon's effectiveness.

## Cruise Missiles Vs Manned Aircraft

The majority of analyses conducted previously regarding possible Australian acquisition of cruise missiles have viewed the SLCM as an alternative to the manned strike aircraft. This is also implied in the current Government's stated defence policy.[81] The logic behind this assumption is that Australia would be unlikely to be in a position to afford both strategic strike capabilities. Most opposition to the use of cruise missiles from a submarine are based on the assumption that this would be seen as a replacement for the ADF's current long-range strike capability provided by the F-111. However, in a national strategy based upon a depth in defence, the need to provide interdiction support for other ADF elements against mobile targets, and the need for long-range, reactive maritime strike within the northern sea-air gap, will continue to require inclusion of a long-range strike aircraft within the ADF inventory. As such an aircraft would foreseeably require the capability to launch anti-shipping cruise missiles, conversion to also carry strategic strike ALCMs would not seem a major modification program.

Thus, because some form of strike aircraft will probably remain within the ADF inventory, and because, as previously discussed, cruise missiles are also not cost-effective for use as a means of conducting sustained strike operations, cruise missiles cannot be viewed as a substitute for strike aircraft. They can perform only a small proportion of the roles of a strike aircraft, and can provide only an incremental enhancement in these. Cruise missiles can, however, increase the striking range capabilities of a future strike aircraft whose inherent range may be less than that of the F-111, and can offer the potential to minimise attrition to that strike aircraft, in the face of high levels of adversary air defence capabilities. Regardless of the platform from which they are launched, cruise missiles also offer the capability to degrade an adversary's air defences to a stage where aircraft can conduct a sustained strike campaign using more cost-effective weapons. For these reasons, cruise missiles should only be viewed as an adjunct to, rather than a replacement for, strike aircraft.

[81] Coalition Defence Policy Statement of March 1996. Section 5 'Structuring the Australian Defence Force', p 16, para 5.8.

# CONCLUSION

Previous ADF studies into cruise missiles have largely examined the case of SLCMs versus manned aircraft armed with short range weapons, in some cases producing skewed arguments in favour of SLCMs. However, the questions leading to such a decision should be based on a concise logic hierarchy: Are cruise missiles a cost effective means of waging modern warfare, and are they considered a politically acceptable capability for Australia to acquire? If so, is the capability which they offer militarily necessary to Australia's defence, or politically necessary to Australia's defence strategy? And if so, which platform can allow their use to greatest effect? These questions have been examined in turn, resulting in a number of conclusions.

The general perception of cruise missiles as a high-end capability and a weapon of escalation, and the current difficulty of defending against them, makes cruise missiles an inherently destabilising class of weapon, and a potential trigger for acquisition by other regional nations. Any competitive acquisition of long-range delivery systems into the region would most likely be disadvantageous to Australia, whose strategic infrastructure and major population centres are largely immune to almost all strike systems currently in service within the region.[82] In addition, non-proliferation measures are at best likely to slow, rather than prevent introduction of long-range delivery systems into the South-East Asian region, once competitive acquisition is triggered. As a further consideration, acquisition of such a system would contradict Australia's defence policy aimed at enhancing regional stability, and Australian support of the MTCR, potentially leading to charges of hypocrisy and loss of political standing within the region. From the perspective of compliance with the LOAC, there is no extant rationale to prevent ADF use of cruise missiles, but the weapon selected would need to use a guidance system of demonstrably greater reliability than provided by early generation TERCOM/DSMAC systems. However, unless acquisition could be justified on unequivocal military grounds, say, to reinstate Australia's strike advantage in the face of acquisition of improved defensive systems by a potential competitor, or in response to introduction into the region of long-range delivery systems, the political implications militate against acquisition of a cruise missile capability.

Assuming that these foregoing political impediments can be overcome, the inclusion of cruise missiles into the ADF's force structure would depend on their military utility and cost-effectiveness. While several important roles have emerged for cruise missiles in recent years, numerous previous studies have concluded that cruise missiles are unlikely to be cost-effective as a primary means of conducting sustained strike operations. For a country with a comparatively low military budget, cost effectiveness will remain an important factor, and is likely to limit ADF uses of cruise missiles to roles where they may supplement existing ADF strike weapons, rather than replacing them. These roles are most likely to be:

a. Strategic strike augmentation, as a complement to existing strike assets;

b. Political signalling, probably in low-tempo operations, as a demonstration of capability and resolve.

[82] The obvious exception is lower-level strikes by special forces.

c. Escalation control, to increase the level of cost to an adversary and rapidly terminate a conflict.

d. Tactical support, or degrading an adversary's defences to enable strike by more cost-effective means.

If considered in the context of using a conventional, hard-kill warhead, none of these roles provide sufficient justification for immediate procurement of cruise missiles. The ADF's recent acquisition of a medium-range stand-off missile (in the form of the AGM-142 Raptor), and planned procurement of an anti-radiation missile are expected to maintain ADF strike aircraft survivability in credible threat scenarios into the foreseeable future. Also, by maintaining the most capable strike systems in the region, Australia already possesses the means for political signalling and for escalation beyond the capabilities of most likely potential competitors. Thus the rationale for procurement of a cruise missile again depends on future force development advances among nations which could foreseeably emerge as some threat to Australia. In the absence of these developments in defensive systems, the most promising ADF use for the cruise missile will be as a platform for the delivery of alternative weapons. This may include area weapons, in operations to degrade an adversary's defences; or EMP warheads, as part of a $C^2W$ operation. In future, albeit radically-changed, regional military circumstances, cruise missiles may also be used to carry nuclear weapons, to provide an enhanced level of deterrence. Certainly, cruise missiles currently offer insufficient flexibility and cost-effectiveness to replace a long-range strike aircraft in the ADF inventory, and should be viewed presently only as an adjunct to the capabilities of other current strike assets.

Finally, should the existing military balance change sufficiently to justify ADF acquisition of cruise missiles, the decision on which platform(s) is/are appropriate for their carriage will depend on the envisaged uses of the weapon**.** The vulnerability of surface warships, particularly to air and missile attack, render them unsuitable platforms for strategic strike, unless costly changes are made to RAN force structure to improve the defensibility and/or resilience of the launching platform. Submarines, if armed with SLCMs, offer the capacity for threatening, for political signalling, and, to a degree, for limited strike augmentation in support of air or land operations, while providing high survivability. They also offer excellent potential for diverting an adversary's force structure decisions toward ASW enhancement. However, submarines lack flexibility in retasking, have limited weapon carriage capacity and problems in replenishment, and their need for stealth limits their reactivity to political control. They are also limited in the guidance systems which they can use, imposing operational restrictions on the employment of the weapon.

Aircraft carriage of cruise missiles has disadvantages, including the difficulty in achieving surprise, and the tendency for most ALCMs liable to be made available to Australia to have shorter ranges than available SLCMs. On balance, however, ALCMs tend to be cheaper for a given capability, and the use of an aircraft increases the reactivity, flexibility in tasking, and ability to sustain a high tempo of operations, while maintaining a low probability of attrition, similar to that likely from a submarine in the same task. If regional circumstances develop sufficiently that cruise missiles are deemed a necessary addition in ADF force structure, their carriage by aircraft offers the potential for the greatest military utility from the weapons.

Cruise missiles should not be considered a new capability for the ADF. The use of aircraft with current and planned ADF weapon systems already offers the capability of precision stand-off strike, and cruise missiles simply offer an extension to this capability. However, based on current strategic circumstances, and foreseeable improvements to regional capabilities, only a very small number of potential high-value targets within the region are likely to be sufficiently defended to require use of this capability within the medium term. This paper does not conclude against the addition of a cruise missile to the ADF inventory. However, it does find that the small number of roles or scenarios in which cruise missiles might enhance ADF effectiveness do not currently justify the level of expenditure needed to acquire, develop, support and maintain such a capability.

**Annex:**

A. Discussion of a Cost Comparison Model

## ANNEX A

# DISCUSSION OF A COST COMPARISON MODEL

The cost comparison model presented in the paper is based on the proposition that the real cost of launching a weapon includes a number of factors beyond the basic cost of the weapon. Most significantly, the loss of launch platforms to defenders of the target will greatly increase costs.

This appendix explains the simple mathematic model which was used for cost comparison of platform and weapon options. The various options were presented in graphs in the paper.

**Variables**

The variables used are defined as follows:

n = number of platforms taking part in any attack
a = attrition rate, or total attrition rate suffered by all platforms taking part in an attack - it is the proportion of platforms taking part in an attack which will be lost
w = number of weapons carried per platform
C = cost per platform, and
c = cost per weapon

**Derivation**

If ‘n’ platforms, each carrying ‘w’ weapons, conduct an attack, then (if no weapons are returned on sortie completion)

number of weapons used on attack = nw

If the cost per weapon is ‘c’, then

total cost of weapons used in attack = nwc

If the ‘n’ platforms carrying out that attack suffer an attrition rate of ‘a’, then

total number of platforms lost = na

If the cost of those platforms is ‘C’, then

total cost of platforms lost = naC

As the cost of the attack will equal the cost of the weapons used plus the cost of the platforms lost, then

$$\text{total cost of attack} = nwc + naC = n(wc + aC)$$

Calculating the effectiveness of the attack, it would be overly optimistic to expect that all platforms (in a multiple-platform attack, such as an air raid) would succeed in attacking the target before attrition was inflicted by the target defences. In fact, the proportion of attrition suffered would be highly dependent on the type of defences, the type of attacking platform, the state of alert of the target, and a number of other factors. However, for the sake of simplicity and conservatism, this calculation assumes that equal attrition is suffered on ingress to the target as is suffered on egress. Hence, if half of the attrition is suffered on ingress, then

$$\text{number of platforms failing to attack} = {}^{1}/_{2}\,an$$

So, by subtraction,

$$\text{number of platforms successfully reaching attack} = n - {}^{1}/_{2}\,an = n\,(1 - a/_{2})$$

and as each platform carries ‘w’ weapons, then

$$\text{total number of weapons launched} = wn(1 - a/_{2})$$

The measure of the effectiveness of the sortie which is used in the cost comparison model is the total cost per weapon launched on the sortie, which from the above calculations

$$= \frac{n(wc + aC)}{wn(1 - a/_{2})}$$

$$= \frac{wc + aC}{w(1 - a/_{2})}$$

$$= \frac{\text{total cost of attack}}{\text{no. of weapons reaching target}}$$

From this, it may be noted that the total cost per weapon launched depends on the attrition suffered, but not upon the number of platforms employed on a particular attack.

**Assumptions**

The graphs generated are based on the premise that the cost of a platform (aircraft, UAV, submarine or ship), with crew, fuel and maintenance costs, can be reduced to monetary terms, and these non-platform costs are incorporated into the order-of-magnitude figures used to generate the graphs. This is acknowledged to be somewhat simplistic, but is proposed as a valid approach for general comparison purposes.

There will always remains other costs, such as that of infrastructure, and a number of intangibles, such as the political cost of the loss of an aircraft or ship and its crew, which cannot be easily incorporated into such calculations. However, political costs are of such a magnitude that they will tend to decide the use (or not) of a platform by themselves, and will not be considered in simple cost-comparison modelling.