ROYAL AUSTRALIAN AIR FORCE
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Horses for Courses:
A Framework for Evaluating Capability Options Across Multiple Contexts

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FOREWORD

The global strategic environment is extremely dynamic, and accurately predicting future threats to national security remains a demanding task. The uncertainty associated with ensuring adequate preparedness to deal with divergent contexts makes it almost impossible to identify an ideal capability development option for all potential contexts. This paper looks at this complexity and suggests a framework for evaluating defence capability options.

The proposed framework can be used to evaluate low level, project specific issues on the one hand and, alternately, to assess the overall priorities for the entire ADF on the other. While the framework does not provide an answer to resolve issues regarding competing capability options, it provides the means to identify the key elements that contribute to the capability facilitating accurate and focused analysis and assessment. The use of such a framework provides the possibility that decisions surrounding national security issues can be optimised.

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Wing Commander Peter McLennan joined the RAAF in 1980. He was commissioned as an Aeronautical Engineer, and has filled a number of deeper maintenance positions predominantly related to C-130 and P-3 maintenance. In addition, he has undertaken responsibilities for non-destructive inspection, F-111 systems engineering, maintenance engineering analysis, engineering policy, air force preparedness and strategic planning. He is currently on staff at the Air Power Development Centre.

Wing Commander McLennan completed a CAF Fellowship at the Aerospace Centre in 1994, and was the RAAF Visiting Fellow at the ANU's Strategic and Defence Studies Centre in 1999–2000. In addition to a Bachelors Degree in Aeronautical Engineering, Wing Commander McLennan holds a Masters Degree in Information Science and a PhD on the topic of dealing with uncertain futures in defence strategic planning.

INTRODUCTION

Threats to Australia's security may take many forms. The uncertainty associated with not being able to predict future threats is usually dealt with by considering multiple possible situations, or contexts, in which military action may be required. The further we try to peer into the future, the more divergent the descriptions of possible contexts become.[1] As a result, it is unlikely that an ideal capability development option can be identified; rather, each competing option will have strengths in some contexts but may be weak in others. Resource constraints prevent the acquisition of all possible capability options, necessitating difficult trade-off decisions.

This paper proposes a relatively simple framework for guiding the evaluation of competing defence capability options given multiple possible contexts. Having described the core framework, a number of extensions are described for dealing with variations to the basic planning problem.

Although topical real-world examples are used to demonstrate the application of the framework, the focus of the paper is on the framework itself, rather than on the assessments used to populate it or the conclusions that may be drawn from it. All of the assessments used in this paper are hypothetical and have no justification or authority (except where noted). To assist with focusing on the framework as opposed to the assessments, it is suggested that readers not question the assessments in the first instance, but simply observe the process by which they are used. Once the process is understood, questioning and adjusting assessments, and working through the implications of any changes, would be a useful exercise to reinforce understanding of the framework.

BASIC FRAMEWORK

Derivation of the Basic Framework

The performance of every capability option needs to be evaluated in each possible context.[2] Accordingly, a matrix is required. Possible contexts are listed down the left-hand column, and capability options across the top. Table 1 shows the simplest possible non-trivial case, involving two competing capability options and two possible contexts in which they may be required (shaded areas).[3]

	Capability Option	
Context (x)	**Capability Option 1 (c_1)**	**Capability Option 2 (c_2)**
Context 1 (x_1)		
Context 2 (x_2)		

Table 1: Capability Options versus Contexts

A risk management approach will be used to guide the prioritisation of capability options. The untreated (ie. unmitigated) level of risk associated with each context is listed beside each context. Each such assessment must be a combination of the likelihood and consequences associated with the context assuming that nothing were done to avoid it or respond to it (eg. assuming that the Australian Defence Force (ADF) possessed no relevant military capabilities).[4]

Following standard risk management principles, a qualitative, quantitative or semi-quantitative approach could be taken. In this paper, qualitative risk assessments will be used, due to the difficulty in quantifying context risk and capability option performance, and the potentially controversial nature of such assessments. Nevertheless, there are advantages in attempting a quantitative approach, such as exposing the relative significance of assessments in a more absolute and unbiased manner.

Regardless of whether a qualitative or quantitative approach is taken, it is important to bear in mind that the ADF contributes to the security of different kinds of Australian interests. Different kinds of interests will usually have differing significance. For example, the loss of a life is more significant than a loss of a dollar. The relative worth of such interests needs to be taken into account when assessing context risk. The ability to reduce potential loss of life should probably be the dominant factor for those contexts that are most likely to define the overall shape of the ADF.

The relevance of each capability option to each context is assessed in terms of the extent to which the capability option would be expected to reduce context risk. The effect of the capability option on both likelihood and consequences should be considered (an explicit example of this is included later in this paper). A capability option that can virtually eliminate all risk posed by a context could be rated as having a 'dramatic' effect; a capability option that makes no change to context risk could be rated as having a 'negligible' effect. These assessments should not consider the *magnitude* of the untreated level of risk posed by the context; rather, they are expressed in terms of the *proportion* by which that risk would be reduced. Specifying capability option performance in dimensionless form allows separation of assessments of context risk and capability option effectiveness. This simplifies subsequent sensitivity analysis; eg. we can explore the implications of different context risk assessments without having to reassess capability option performance.

Table 2 extends Table 1 to accommodate the assessments described above (shaded areas).[5]

		Capability Option	
		Capability Option 1 (c_1)	Capability Option 2 (c_2)
Context (x)	**Context Risk (r)**	**Effectiveness (e)**	**Effectiveness (e)**
Context 1 (x_1)	r_{x_1}	$e_{c_1\|x_1}$	$e_{c_2\|x_1}$
Context 2 (x_2)	r_{x_2}	$e_{c_1\|x_2}$	$e_{c_2\|x_2}$

Table 2: Context Risk and Capability Option Effectiveness

The performance of a capability option in absolute terms is found by combining the assessments for capability option effectiveness with context risk. In a quantitative approach, this is simply the product of the two assessments. The required changes to the framework are shown in Table 3 (shaded).

		Capability Option			
		Capability Option 1 (c_1)		Capability Option 2 (c_2)	
Context (x)	**Context Risk (r)**	**Effectiveness (e)**	**Risk Reduction (Δr)**	**Effectiveness (e)**	**Risk Reduction (Δr)**
Context 1 (x_1)	r_{x_1}	$e_{c_1\|x_1}$	$\Delta r_{x_1\|c_1} = r_{x_1} \times e_{c_1\|x_1}$	$e_{c_2\|x_1}$	$\Delta r_{x_1\|c_2} = r_{x_1} \times e_{c_2\|x_1}$
Context 2 (x_2)	r_{x_2}	$e_{c_1\|x_2}$	$\Delta r_{x_2\|c_1} = r_{x_2} \times e_{c_1\|x_2}$	$e_{c_2\|x_2}$	$\Delta r_{x_2\|c_2} = r_{x_2} \times e_{c_2\|x_2}$

Table 3: Risk Reduction Assessments

The overall performance of each capability option is simply the sum of the risk reduction assessments that it can achieve in each context, as shown in Table 4 (shaded).

		Capability Option			
		Capability Option 1 (c_1)		Capability Option 2 (c_2)	
Context (x)	**Context Risk (r)**	**Effectiveness (e)**	**Risk Reduction (Δr)**	**Effectiveness (e)**	**Risk Reduction (Δr)**
Context 1 (x_1)	r_{x_1}	$e_{c_1 \vert x_1}$	$\Delta r_{x_1 \vert c_1} = r_{x_1} \times e_{c_1 \vert x_1}$	$e_{c_2 \vert x_1}$	$\Delta r_{x_1 \vert c_2} = r_{x_1} \times e_{c_2 \vert x_1}$
Context 2 (x_2)	r_{x_2}	$e_{c_1 \vert x_2}$	$\Delta r_{x_2 \vert c_1} = r_{x_2} \times e_{c_1 \vert x_2}$	$e_{c_2 \vert x_2}$	$\Delta r_{x_2 \vert c_2} = r_{x_2} \times e_{c_2 \vert x_2}$
Performance			$\Delta r_{x_1 \vert c_1} + \Delta r_{x_2 \vert c_1}$		$\Delta r_{x_1 \vert c_2} + \Delta r_{x_2 \vert c_2}$

Table 4: Capability Option Performance Assessments

Capability options will have differing resource implications. These must be taken into account when selecting a capability option. Accordingly, an indication of the resource cost of each capability option is included, as shown in Table 5 (shaded).

		Capability Option			
		Capability Option 1 (c_1)		Capability Option 2 (c_2)	
Context (x)	**Context Risk (r)**	**Effectiveness (e)**	**Risk Reduction (Δr)**	**Effectiveness (e)**	**Risk Reduction (Δr)**
Context 1 (x_1)	r_{x_1}	$e_{c_1 \vert x_1}$	$\Delta r_{x_1 \vert c_1} = r_{x_1} \times e_{c_1 \vert x_1}$	$e_{c_2 \vert x_1}$	$\Delta r_{x_1 \vert c_2} = r_{x_1} \times e_{c_2 \vert x_1}$
Context 2 (x_2)	r_{x_2}	$e_{c_1 \vert x_2}$	$\Delta r_{x_2 \vert c_1} = r_{x_2} \times e_{c_1 \vert x_2}$	$e_{c_2 \vert x_2}$	$\Delta r_{x_2 \vert c_2} = r_{x_2} \times e_{c_2 \vert x_2}$
Performance			$\Delta r_{x_1 \vert c_1} + \Delta r_{x_2 \vert c_1}$		$\Delta r_{x_1 \vert c_2} + \Delta r_{x_2 \vert c_2}$
Cost (R)			R_{c_1}		R_{c_2}

Table 5: Resource Cost Assessments

The primary criteria against which the capability options should be evaluated are performance (ie. total risk reduction) and cost. These assessments can be extracted from the table and plotted in the form shown in Figure 1.

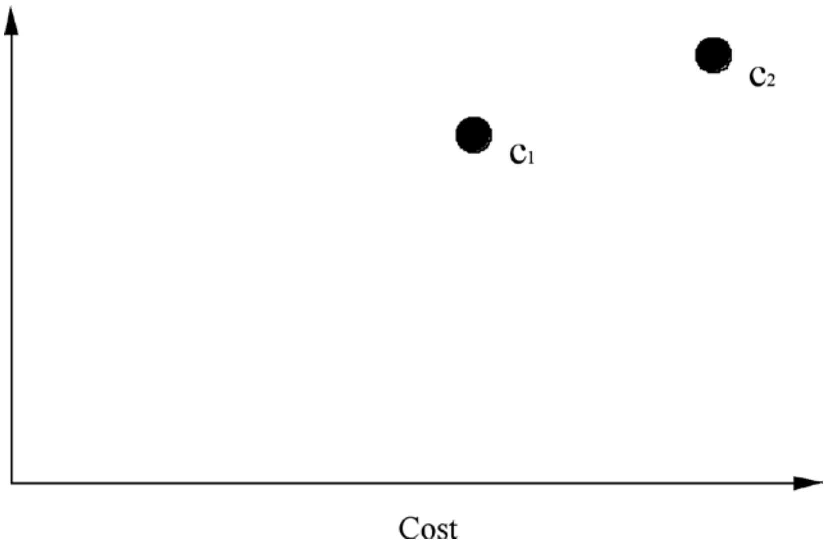

Figure 1: Performance versus Cost

Basic Example 1: Joint Strike Fighter Fleet Mix

The Lockheed Martin F-35 Joint Strike Fighter (JSF) is expected to satisfy the initial requirement for Australia's new air combat capability.[6] Australia is evaluating two versions of the JSF: a conventional take-off and landing (CTOL) variant, and a short take-off and vertical landing (STOVL) variant.[7] The latter has advantages in terms of basing options, and could probably even be operated from the Navy's Landing Helicopter Dock ships that will be entering service over the next decade.[8] However, the STOVL variant has lower performance in terms of range and weapons load, and is also more costly.

The STOVL variant may provide better capability in regional littoral operations due to its shipboard potential. However, the superior performance of the CTOL variant gives it an advantage for the defence of Australia (DA). On what basis can we decide whether to standardise on the CTOL variant or procure a mixed CTOL-STOVL fleet?

Table 6 shows the basic framework (Table 5) populated with hypothetical assessments for this problem. Note that the only assessments that must be made directly are those indicated by shading; the remaining values are derived from other assessments in the table.[9]

		Capability Option			
		CTOL only		Mixed CTOL-STOVL	
Context	**Context Risk**	**Effectiveness**	**Risk Reduction**	**Effectiveness**	**Risk Reduction**
DA	Extreme	Dramatic-	High+	Substantial	High
Regional	Low+	Substantial	Low	Dramatic	Low+
Performance			Extreme-		Extreme-
Cost			$13b		$15b

Table 6: Matrix for JSF Fleet Mix Example

The rating scale used for the assessments of context risk and risk reduction follows the ADF's Enterprise Risk Management approach, in which risk ratings of low, medium, high and extreme are used. To provide maximum ability to discriminate between close assessments, the ratings have been scaled to span the range of risks associated with this problem (eg. with the lowest risk assessment in this example being rated as low, even though in other problems much lower levels of risk may be involved). In addition, gradations within each basic assessment are indicated with + and - ; eg. 'dramatic-' indicates the low end of the 'dramatic' rating band. Annex A summarises all of the rating scales used in this paper.

The scale used to assess capability option effectiveness is a five-band scale with basic ratings of negligible, slight, moderate, substantial and dramatic. As with the risk scale, + and - modifiers have been used to enhance discrimination between close assessments.

The cost estimates fit within the Defence Capability Plan[10] expenditure range for the new air combat capability project. The specific values used in the table are not based on any other analysis, and are only intended to indicate that extra cost would be required for the mixed fleet option.[11]

The overall performance and cost values are plotted at Figure 2. In keeping with the focus of this paper, no attempt to interpret or critique these results will be made. If the results seem counter-intuitive, the interested reader is encouraged to rework the problem using alternative assessments.

Basic Example 2: A Disruptive Future

The contexts used in the previous example (defence of Australia and regional operations) are both feasible in the medium term. However, in the longer term, a wider range of contexts becomes conceivable. Context descriptions should not be limited to geographic or political considerations, but should take into account a wide range of issues that may have implications for ADF capabilities, such as technology. One possible future includes the existence of advanced technologies such as robotics, genetics, smart materials, nanotechnology, and so on.[12] Some of these technologies have the potential to highly disrupt the use of conventional equipment, such as aircraft. For example, weapons based on nanotechnology, perhaps delivered as an aerosol, have the potential to virtually ensure that aircraft entering contested airspace would not return. While this possibility is perhaps unlikely, the limitation it places on the effectiveness of conventional force structures necessitates consideration. In this example, such a disruptive future will be considered against a more conventional context in which conventional weapon systems remain highly effective.

To further focus the example, it will be couched in terms of the final phase of the new air combat capability project. This requirement may be satisfied though the procurement of an additional tranche of JSF aircraft. However, there are alternative means of achieving some aspects of air combat capability, such as through the use of surface-launched missiles.[13] Since missiles are not expected to be reusable, the impact of a disruptive context would be reduced. Missile losses would be easier to absorb since aircrew lives would not be at stake, and a larger number of systems could be procured due to a lower unit cost.

Table 7 presents a matrix for this problem. The risk associated with the disruptive context is assessed as low+, primarily due to the improbability of the context. This largely nullifies the strong effectiveness advantage of the missile option in that context (but note that this would not be the case if a higher risk assessment were made for the disruptive context). The cost estimates are arbitrary selections from within the Phase 2C expenditure range for the new air combat capability.[14]

		Capability Option			
		Aircraft		Missile	
Context	Context Risk	Effectiveness	Risk Reduction	Effectiveness	Risk Reduction
Conventional	High+	Dramatic-	High-	Substantial	Medium+
Disruptive	Low+	Negligible	Low-	Substantial-	Low
Performance			High-		High-
Cost			$3.5b		$2.5b

Table 7: Matrix for Disruptive Future Example

Figure 3 is a graph of the overall performance and cost of each capability option.

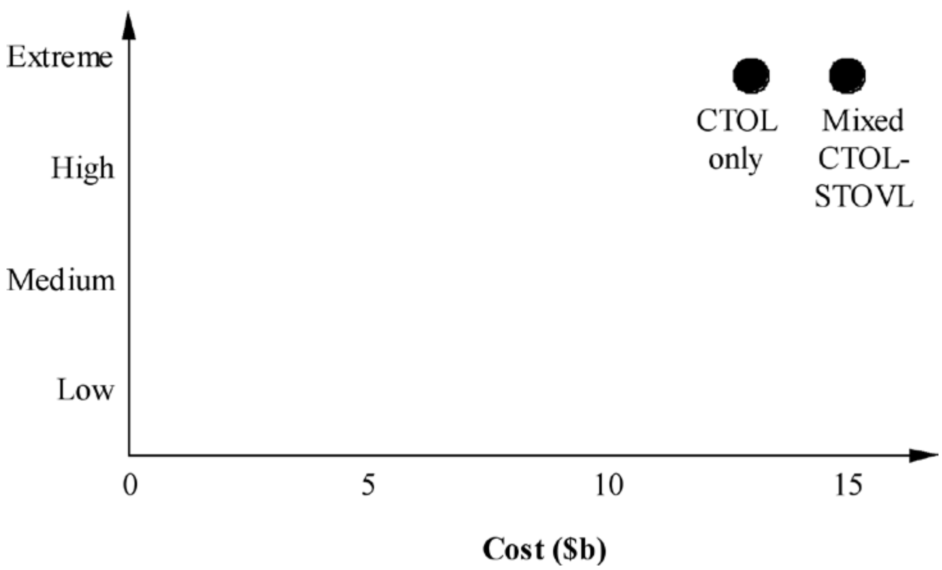

Figure 3: Performance versus Cost Graph for Disruptive Future Example

Notes on the Basic Framework

Before considering extensions to the basic framework, some comments on the basic framework may help to clarify its use.

A minimum number of contexts and capability options has been shown in the examples above. However, the basic framework is perfectly scalable to larger numbers of contexts and capability options, with no change in process required. For example, the conventional and disruptive contexts considered in the second example above are only two examples from a larger number of possible future contexts. Other contexts may feature 'irregular' threats (eg. guerilla, terrorism, etc) and 'limited' threats (ie. constrained but substantial attacks, such as a selective missile strike.[15] A thorough treatment should consider all major types of context that may influence capability decisions.

In addition to including a larger number of capability options, the scope of capability options may be varied to suit the problem at hand. For example, capability options may be limited to a specific issue, such as a single project in isolation, in which case an operational environment that comprises the remainder of the force-in-being is assumed for all options. The examples given above are of this form. Alternatively, for more ambitious problems such as determining the ADF's overall priorities, capability options may embrace multiple capabilities up to the whole of the ADF. An example of this is included later in this paper.

Combination capability options may also be evaluated. The CTOL-STOVL example is an instance of a combination capability option. Broader options are also possible; eg. the appropriate balance between the numbers of JSF and air-to-air refuelling aircraft could be explored. This would be useful since different combinations will perform differently in different contexts. Different balances between fundamental inputs to capability (FICs), such as personnel and major systems (eg. aircraft) could also be tested, again noting that different combinations will perform differently in different contexts.

Operational concepts are another fundamental input to capability (albeit not explicitly listed as such).[16] The effectiveness of a capability option is critically dependent on the concept used for employment of the forces. The proposed framework could be used to evaluate competing concepts by defining separate capability options for each concept, while using an identical force structure in each option. Ultimately, an effects-based approach could be incorporated in this manner, with the utility of different effects being evaluated.

Both of the examples presented above have focused on decisions concerning new ways to deliver capability. However, the framework can also be used to guide decisions regarding the withdrawal of capability delivery systems. An example is at Annex B.

Although the proposed framework relies heavily on risk management principles, it differs from 'standard' risk management in one important regard. Risk management usually involves setting priorities based on the level of risk posed by each threat; however, the framework proposed here bases priorities on achievable risk reduction. This distinction becomes significant when considering high-risk contexts in which all capability options are of relatively low effectiveness.

Clearly, the usefulness of the framework depends on the quality of the assessments used to populate it. In other than trivial cases, some analysis will need to be done prior to populating the framework, to provide assessments of the effectiveness of each capability option in each context, and the resource cost of each option. Experimentation should be especially useful for informing effectiveness assessments.

Although the proposed framework is methodical, and potentially even quantitative, it cannot totally remove the influences of subjectivity and bias (deliberate or otherwise). For example, a predilection for a particular capability option could encourage an emphasis on contexts in which that capability option is likely to excel. This could be done either by inclusion of such contexts at the expense of others, or by over-estimating the risk associated with such contexts.

Context consequence assessments, and hence context risk, need not be assessed as single-point values in the first instance. For example, we might be unwilling to postulate a specific number of lives that may be lost in a DA conflict, recognising that there is a wide range of possibilities. We might prefer to assess the consequences of a context in terms of a probability density function; in this case, a histogram of the likelihood of various levels of consequence (see Figure 4). This can be converted into a single-point assessment of context risk using the 'expected value' principle.[17] The details of this process will not be described in this paper; suffice it to say that representing risk in this more sophisticated manner is no impediment to the use of a single-point risk assessment in the proposed framework.

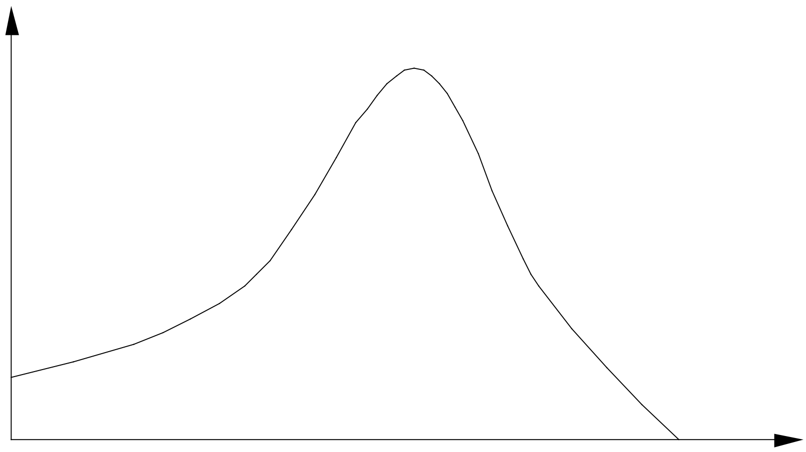

Figure 4: Context Consequence Probability Density Function

A further enhancement to the way in which risk factors are specified is to postulate changes over time. For example, we might assess the consequences of DA as rising over the next decade, perhaps as a result of increasing regional capabilities. It is not difficult to derive a mean value for context risk from such assessments. A more explicit way of considering substantial changes to contexts over time is described in the next section.

Sensitivity analysis should be conducted by exploring the significance of changes to assessments about which considerable uncertainty exists, or which are particularly contentious. For example, changing the performance assessments associated with low-risk contexts will be found to have little overall effect. The results of such a sensitivity analysis could be represented diagrammatically by representing capability option conclusions as regions covering the range of outcomes from the sensitivity analysis, as shown in Figure 5. Often, this will tend to reduce the apparent significance of differences between options. For example, based only on a single-point comparison between the options shown in Figure 5, we might conclude that Option 2 performs significantly better. However, when the full range of uncertainty is considered, we are more likely to conclude that the options perform similarly, in which case the higher cost of Option 2 may not be justified.

MIXING OF CONTEXTS FROM DISPARATE TIMESCALES

The contexts used in the first two examples apply to different timescales. The contexts used in the first example are applicable in the nearer term, whereas the contexts used in the second example (particularly the 'disruptive' context) are applicable in the longer term. However, it is common for capability options to span multiple such timescales. For example, the JSF may need to contend with threats that arise in the next decade, as well as those that are currently impossible but may develop in the middle of this century.

Table 8 includes all four of the contexts used in the previous examples, and evaluates the two capability options from second example against these.

				Capability Option			
				Aircraft		Missile	
Context	Context Risk	Start Time	End Time	Effectiveness	Risk Reduction	Effectiveness	Risk Reduction
DA	Extreme	0	10	Dramatic-	Medium-	Substantial	Low+
Regional	Low+	0	10	Substantial	Low-	Moderate	Low-
Conventional	High+	10	25	Dramatic-	Medium-	Substantial	Medium-
Disruptive	Low+	10	25	Negligible	Low-	Substantial-	Low
Performance					High		High
Cost					$3.5b		$2.5b

Table 8: Matrix for Mixed Context Example

Other than the increased number of rows, the only structural extension to the basic framework is the inclusion of columns to indicate the start and end times bounding the applicability of each context. It is now necessary to consider whether the context risk assessments are the level of risk per year or whether they are aggregated across the whole time period for which the context applies. For example, a context that could only occur in a two-year time window may levy an extreme level of risk in each of those two years, but this may amount to only a medium level of risk overall in an analysis that spans several decades. Regardless of whether context risk assessments are per-year or aggregate, capability option risk reduction values must be based on the duration for which each context applies (in addition to context risk and capability option effectiveness as previously). For example, the risk reduction that can be achieved against a context that exists only briefly would be less than that for a more enduring context (all else being equal).

The overall results from Table 8 are graphed at Figure 6.

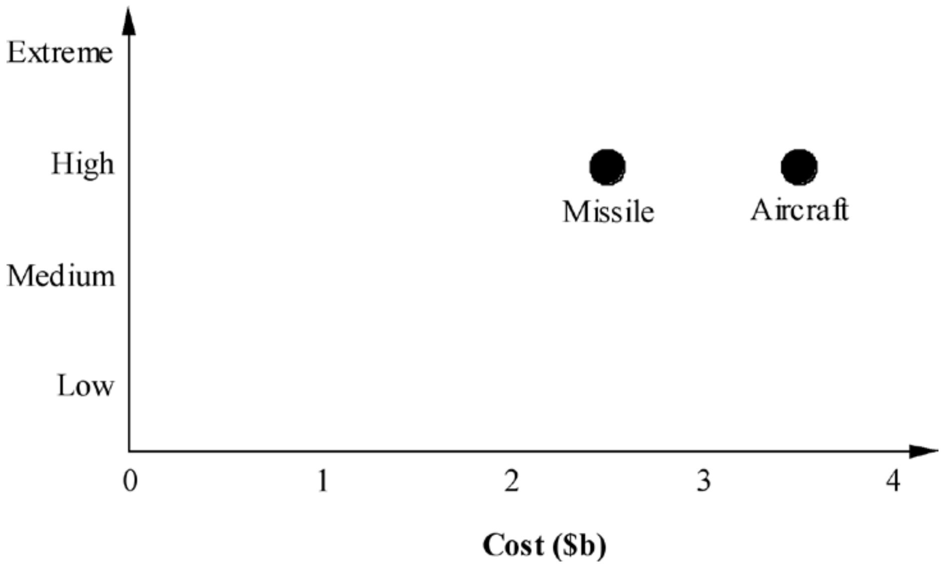

Figure 6: Performance versus Cost Graph for Mixed Content Example

It is desirable to check for sensible continuity between contexts for different time periods. This should be dealt with in the process of context identification. For example, the process of 'back-casting' may be used to verify that a plausible path exists from the present context through to a future context.

Capability options may also vary over time. For example, it may be necessary to evaluate a capability option that includes the introduction of a new aircraft type at a particular point in time (in addition to other elements). This can be done without any changes to the overall framework described above. However, when assessing capability option effectiveness, it is necessary to take into account the state(s) of the capability option over the time window encompassed by the context under consideration. The key is to start by clearly defining capability options. Representing both the capability option and the context on a single time line may assist (see Figure 7).

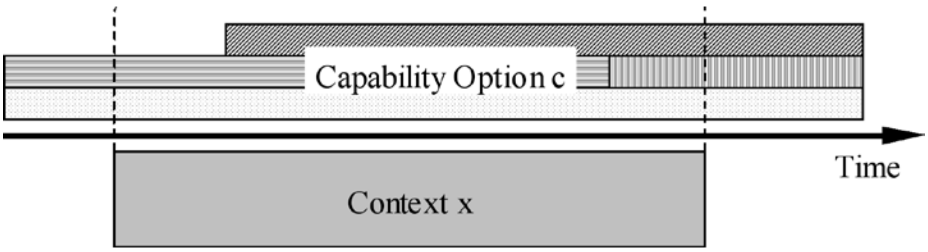

Figure 7: Capability Option and Context Time Line

DYNAMIC CAPABILITY OPTIONS

All of the examples described above assume that capability options must be predetermined. The application of the proposed framework can help to ensure that the chosen capability option is flexible in the face of multiple possible contexts. This is achieved by favouring options that possess reasonable performance across a range of contexts. However, the Air Force also aspires to be adaptable and responsive. These attributes imply a dynamic or reactive approach to dealing with contexts.

The basic framework can be extended to accommodate such an approach. This will be demonstrated using a significantly more ambitious example. From time to time, Australian defence policy has been based on an assumption that substantial forces for high-end warfighting need not be maintained continually, due to the minimal likelihood of a major attack on Australia in the near term. Rather, the assumption has been that sufficient high-end forces could be developed within the warning time associated with the development of such a threat. More recently, the government's willingness to commit Australian forces to potentially high-threat conflicts world-wide has cast this policy into doubt—at the same time that an increasing focus on lower-threat regional operations urges for the strengthening of forces appropriate to such contexts, potentially at the expense of higher-end capabilities. It would be desirable if the proposed framework could accommodate the possible implications of deferring development of a capability option, such as that required for high-end warfighting.

As with most of the previous examples, this problem will be framed using two contexts and two capability options. One context, labelled 'Regional', describes a future characterised by unconventional threats to Australia (such as terrorism) and unconventional or low-level conventional threats in the region (or beyond). This context is essentially consistent with current trends. The other context, labelled 'DA', represents an alternative future in which a more substantial conventional threat to Australia has developed.

The first capability option that we will consider, labelled 'Static', is a balance of light and high-end forces, with somewhat greater emphasis on regional and unconventional threats than today's force-in-being on the basis of recent trends. Combat aircraft such as JSF would be prominent in the high-end component of this option. The whole of the defence budget of about $10b/year would be allocated to the development and maintenance of this capability option.

The second capability option that we will consider, labelled 'Dynamic', largely comprises standing light forces to deal with such unconventional and low-level threats as may arise in the near term, with high-end forces for

DA to be developed dynamically if required. Air power would nominally focus on supporting roles such as mobility and surveillance, with a small number of combat aircraft to undertake limited air defence, strike and offensive air support—as well as providing a kernel from which to grow fully-fledged high-end capabilities should the need arise. In addition to the ongoing cost of $10b/year, supplementation of an average of $2b/year is assumed necessary for the rapid development of high-end forces, should that be necessary.

While it would be possible to roll the required changes to the framework into a single table, it is clearer if the same format as Table 5 is used, with the necessary extensions undertaken as separate preliminary steps prior to populating that table.

The necessary extensions are twofold. Firstly, capability option performance assessments must take into account the possibility that the capability option, if developed dynamically, may be developed too late to have maximal effect on the relevant context(s). If the capability option is late, its effectiveness will be low, whereas if it is ready when required, its effectiveness will be maximum. We need to estimate the overall expected value of effectiveness, which is simply the weighted average of the 'late' and 'ready' effectiveness assessments, using the likelihood of being late or ready as weightings.[18] Note that the likelihood assessments required here are not assessments of context likelihood as previously; rather, they are assessments of the likelihood that a dynamically-developed capability option would be ready on time or not, if required.

The expected value of the effectiveness of dynamically developing high-end capabilities for the defence of Australia might be evaluated as shown in Table 9. As previously, shaded cells indicate direct assessments; the other assessments are derived from these. The same process must be undertaken for every capability option that may be dynamically developed, with each context being considered separately. In the example being considered here, the only dynamic development being contemplated is that of high-end capabilities for the DA context; all other combinations of capability option and context may be assessed directly as in previous examples.

Timing	**Likelihood (p_t)**	**Capability Option Effectiveness ($e_{c\|x}$)**	**Weighted Capability Option Effectiveness ($p_t \times e_{c\|x}$)**
Late	Possible-	Slight-	Negligible-
Ready	Likely+	Dramatic-	Substantial
Total ($\Sigma\, p_t \times e_{c\|x}$)			Substantial

Table 9: Calculation of Expected Value of Capability Option Effectivenes

The second necessary extension to the basic framework is to estimate the expected value of capability option resource costs, taking into account the possibility that a dynamic capability option may never be developed if contexts to which it applies do not occur. Assuming that contexts are mutually exclusive, the expected value of the cost of a capability option is the weighted average of the costs required in each context, weighted by the likelihood of each context.[19] In the example being considered here, the expected value of the cost of the dynamic capability option might be evaluated as shown in Table 10.

Context (x)	Context Likelihood (p_x)	Capability Option Resource Cost ($R_{c\|x}$)	Weighted Capability Option Resource Cost ($p_x \times R_{c\|x}$)
DA	2%	$12b	$0.24b
Regional	98%	$10b	$9.8b
Total ($\Sigma\, p_x \times R_{c\|x}$)			$10.04b

Table 10: Calculation of Expected Value of Capability Option Resource Cost

The overall framework may now be populated, as shown in Table 11. The expected value of the effectiveness of the dynamic option in the DA context is transferred from Table 9 (bottom right cell) into Table 11 (cell marked *), and the expected value of the cost of the dynamic option is transferred from Table 10. All other assessments do not depend on dynamic capability option development, and are assessed directly.

		Capability Option			
		Static		Dynamic	
Context	**Context Risk**	**Effectiveness**	**Risk Reduction**	**Effectiveness**	**Risk Reduction**
DA	Extreme	Moderate	Medium+	Substantial*	High
Regional	Low+	Substantial	Low	Dramatic-	Low+
Performance			High-		Extreme-
Cost			$10b		$10.04b

Table 11: Matrix for Dynamic Capability Option Example

The overall results from Table 11 are graphed at Figure 8.

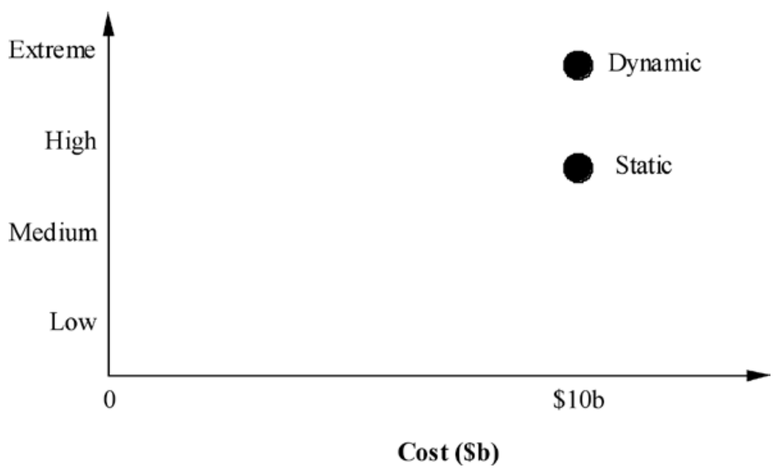

Figure 8: Performance versus Cost Graph for Dynamic Capability Option Example

SHAPING

All of the examples described above have focused exclusively on the ability of capability options to *respond* to contexts. The final extension to the basic framework to be considered in this paper concerns the application of the framework to the *shaping* or *deterrent* effects of capability options.[20] Such a proactive approach to dealing with contexts is usually preferable to reacting once it is too late to prevent a catastrophe, so it is important to include the ability to consider such effects in any overall framework for guiding decisions on defence capability.

At the strategic level, shaping, and especially deterrence, typically reduces the likelihood that a context will occur. This is accommodated in the proposed framework by requiring assessment of the ability of a capability option to reduce the likelihood of relevant contexts. This is a prerequisite to assessing the overall ability of the capability option to reduce risk, since risk depends on likelihood and consequences. For example, a capability option that has substantial deterrent value must be rated highly in its ability to reduce the likelihood of those contexts that it deters. Even if that capability option's ability to reduce the *consequences* of such contexts is actually negligible, the option still rates well in its overall ability to reduce context *risk*.

Some extensions to the basic framework (Table 5) can help to encourage consideration of the shaping effects of capability options. Rather than directly assessing capability option *risk* reduction effectiveness as has been done in all previous examples, we now directly assess capability option *likelihood* reduction effectiveness and capability option *consequence* reduction effectiveness. Those two assessments are then combined to give an assessment of capability option *risk* reduction effectiveness. This must be done for all combinations of context and capability option. The remainder of the process then proceeds as previously.

Care must be taken when combining the likelihood and consequence reduction effectiveness assessments, since a high assessment for either should result in a high assessment for risk reduction effectiveness. It is not necessary for a capability option to be effective in reducing both likelihood and consequences for it to be effective overall. Figure 9 shows the relationship between likelihood reduction effectiveness, consequence reduction effectiveness, and risk reduction effectiveness (within the chart).[21]

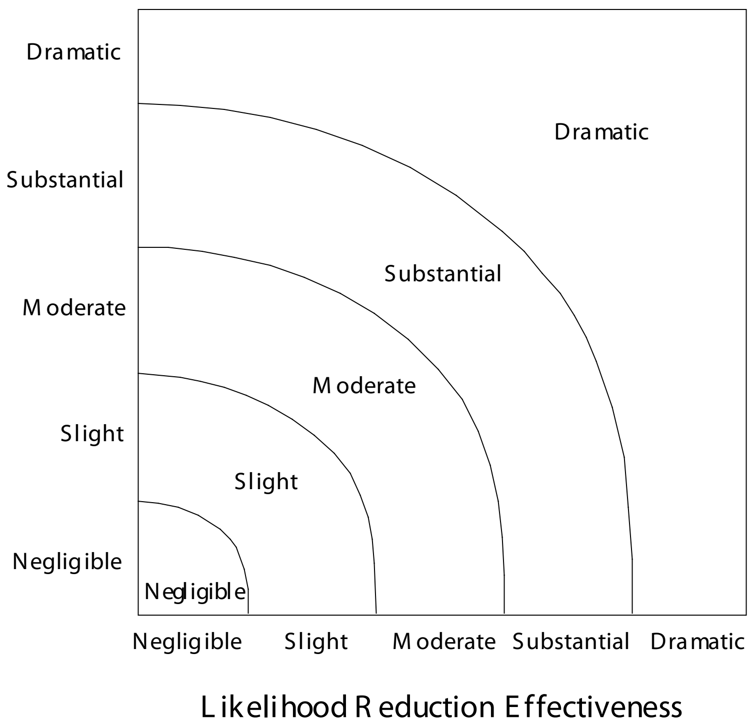

Figure 9: Risk Reduction Effectiveness Assessment

The example framework shown in Table 12 is based on the 'disruptive future' example (Table 7). Extra columns have been added to accommodate the likelihood and consequence reduction effectiveness assessments. To enable the effect of shaping to be seen, we will treat the capability option performance assessments in Table 7 as though they ignored the potential of capability options to shape contexts by reducing their likelihood; ie. the assessments relate only to consequence reduction. Accordingly, those assessments are used for the four consequence reduction effectiveness assessments in Table 12.

		Capability Option							
		Aircraft				Missile			
Context	Context Risk	Likelihood Reduction Effectiveness	Consequence Reduction Effectiveness	Risk Reduction Effectiveness	Risk Reduction	Likelihood Reduction Effectiveness	Consequence Reduction Effectiveness	Risk Reduction Effectiveness	Risk Reduction
Conventional	High+	Dramatic	Dramatic-	Dramatic+	High	Negligible-	Substantial	Substantial	Medium+
Disruptive	Low+	Sight-	Negligible	Sight	Low-	Negligible-	Substantial-	Substantial-	Low
Performance					High+				High-
Cost					$3.5b				$2.5b

Table 12: Matrix for Shaping Example

For reasons that will become clear shortly, we will assume that if a missile-based strike capability were to be adopted, this would be done covertly, such that an adversary could not know of the existence of the capability prior to it being unleashed. In this case, the deterrent value of the capability is zero, which is reflected as 'negligible-' likelihood reduction effectiveness assessments. The risk reduction effectiveness assessments for this capability option are therefore the same as the consequence reduction effectiveness assessments, with the result that the overall performance of this option is unchanged from the Table 7 example.

If the alternative capability option of a tranche of conventional aircraft were to be adopted, this would be overt, and would therefore have a deterrent effect in contexts to which it would be applicable. A 'dramatic' likelihood reduction effectiveness assessment is made for the 'conventional' context. This leads to an increased assessment of risk reduction effectiveness in that context (from 'Dramatic-' to 'Dramatic+'), which flows through to an increased overall performance assessment for this option (from 'High-' to 'High+').

The overall results from Table 12 are graphed at Figure 10.

Although this example has focused on the influence of shaping on context likelihood, shaping may also have an effect on context consequences. For example, an information campaign prior to the 1990 Gulf war dissuaded Iraq from employing its stocks of biological weapons. While such a campaign may not reduce the likelihood of conflict, it can ensure that its consequences would be much reduced. This kind of shaping effect can be accommodated in the proposed framework by making appropriate consequence reduction effectiveness assessments.

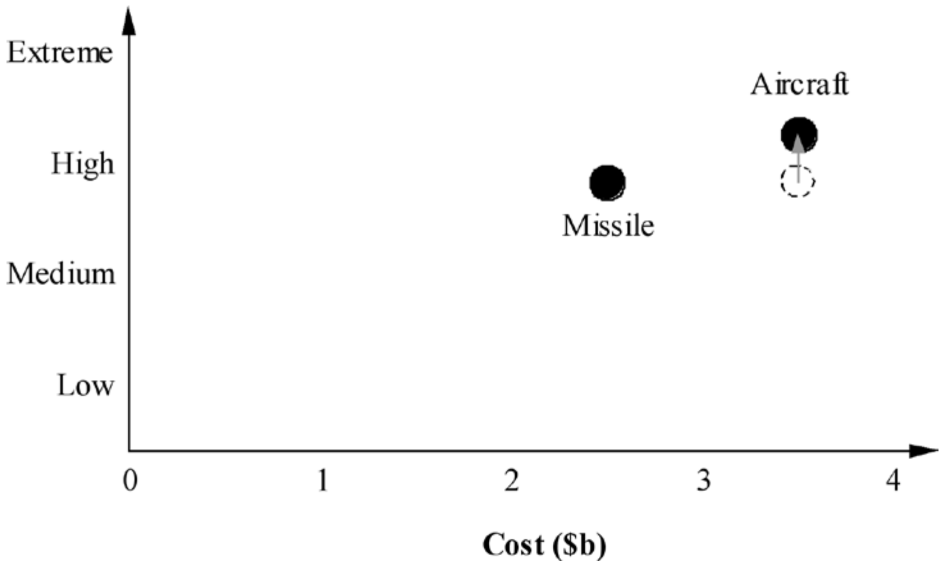

Figure 10: Performance versus Cost Grapgh for Shaping Example

RELATIONSHIP WITH DEFENCE PROCUREMENT REVIEW 2003 ('KINNAIRD REVIEW')

The Defence Procurement Review 2003, better known as the 'Kinnaird Review', recommended the adoption of clearer documentation to support capability development decisions. This is to include 'an assessment of the types of contingencies Australia might face' and 'advice on the military force required in each contingency'.[22] Subsequent Defence planning to give effect to this recommendation has identified the need for two documents: the Defence Planning Guidance (DPG) and the Defence Capability Strategy (DCS).

The framework described in this paper aligns neatly with the DPG–DCS construct. The framework distinguishes clearly between context-related information that might be presented in the DCP, and capability option information that might be presented in the DCS.

Context-related information required for the proposed framework is contained in the columns at the left-hand side of the framework. This comprises a description of possible contingencies/scenarios/futures, and for each of these:

- the likelihood and consequences (and hence risk) associated with the context,[23] and
- the time window to which the context applies (see Table 8).

Capability-related information required for the proposed framework is contained in the columns at the right-hand side of the framework. This comprises a description of capability options, and for each of these:

- the effectiveness of the option in reducing the likelihood and consequences (and hence risk) associated with each context (note that two of each such assessment may be required for dynamically-developed capability options, indicating 'ready' and 'late' performance assessments as per Table 9);
- if the capability option is to be developed dynamically, the likelihood that this could be done within the available warning time (see Table 9); and
- resource costs (including costs associated with possible dynamic development, as in Table 10).

CONCLUSION

It is possible to use a simple matrix to guide the evaluation of competing capability options, taking into account that there is a range of different contexts in which they may be needed. Basic inputs to this framework include context risk, the effectiveness of each capability option in reducing the risk associated with each context, and capability option cost.

Extensions to the basic framework allow consideration of contexts that are applicable to disparate time periods (such as balancing preparedness objectives against alternative futures), evaluation of dynamic capability options (where capability development is deferred until a need is established), and the effect of shaping (where capability options are used proactively to influence possible contexts, and especially context likelihood). These extensions are not mutually exclusive, but could be combined into a single extended framework.

Is the framework described in this paper dangerously simplistic? Some will say yes. Is the framework too complex to be implemented in practice? Others will say yes. It is necessary to aim for an elusive gap between the simplistic and the 'complexistic'.

The proposed framework could be used to guide decisions ranging from project-specific issues through to the overall priorities for the whole of the ADF. The application of the framework, and its extensions, has been demonstrated using a number of hypothetical examples. Conclusions regarding the issues discussed in the examples cannot be drawn until accepted assessments for the necessary inputs have been established.

Although most of the examples used in this paper pertain to air power, there is nothing in the proposed framework that limits its application to that environment. In fact, it would have great potential for evaluating the competing claims of capabilities from each environment. Ultimately, a national effects-based approach to planning should be adopted, in which competing capability options from all elements of national power are combined and traded off against one another.

The structure of the proposed framework is broadly compatible with the DPG and DCS documents that are intended to satisfy recommendations from the Defence Procurement Review 2003 ('Kinnaird Review'). Depending on the content of the DPG and DCS, use of the framework could flow directly from those documents.

It is highly unlikely that the proposed framework would be able to resolve arguments over competing capability options. However, the framework must be deemed to be useful if it helps with the identification of the key assessments that give rise to differing opinions, perhaps resulting in more focused analysis to better explore the contentious assessments.

By encouraging consideration of the broad range of contexts in which future air power capabilities may be required to operate, the use of a framework such as that proposed in this paper would help to ensure that decisions about Australia's air power maximise its contribution to the security of Australia's interests.

ANNEX A

Rating Scales

Likelihood	Consequences	Risk	Effectiveness
Likely+	Severe+	Extreme+	Dramatic+
Likely	Severe	Extreme	Dramatic
Likely-	Severe-	Extreme-	Dramatic-
Possible+	Major+	High+	Substantial+
Possible	Major	High	Substantial
Possible-	Major-	High-	Substantial-
Occasional+	Medium+	Medium+	Moderate+
Occasional	Medium	Medium	Moderate
Occasional-	Medium-	Medium-	Moderate-
Unlikely+	Minor+	Low+	Slight+
Unlikely	Minor	Low	Slight
Unlikely-	Minor-	Low-	Slight-
Rare+	Insignificant+		Negligible+
Rare	Insignificant		Negligible
Rare-	Insignificant-		Negligible-

ANNEX B

A Capability System Withdrawal Example

The implications of the withdrawal of a major system can be evaluated using the basic framework. To demonstrate this, we will consider the timing of the withdrawal of the F-111 strike aircraft. Assessments of the effectiveness and costs associated with the capability options used in this example have been hotly debated in recent months—including at parliamentary level.[24] While the proposed framework cannot resolve disagreements over assessments, it can help to evaluate the significance of such disagreements.

We will again use two contexts: a relatively low-threat context in which the aircraft would remain largely effective, and a higher-threat context in which the aircraft would be significantly less effective (perhaps due to rapid advances in regional air defence capabilities).

Two capability options will also be considered. Retaining the F-111 out to 2015 has been estimated to cost between $1 billion and $1.5 billion. The alternative option, that of earlier withdrawal of the aircraft, might require around $200 million to be spent on the F-111 fleet.[25] However, in order to retain the required strike capability in the period between the withdrawal of the F-111 and the introduction of the JSF, additional projects would be needed to enhance the strike capability of the F/A-18 Hornet and P-3 Orion fleets. These include the Bomb Improvement Program and the Follow-On Stand-Off Weapon Capability.[26] Adding in the costs of these projects gives a total of around $500 million.

Assessments of context risk and capability option effectiveness and costs, and the values flowing from these assessments, are shown in Table 13. The overall performance and cost values are plotted at Figure 11.

		Capability Option			
		Retain F-111		Withdraw F-111	
Context	Context Risk	Effectiveness	Risk Reduction	Effectiveness	Risk Reduction
Low Threat	Medium-	Dramatic-	Low+	Substantial	Low+
High Threat	Extreme-	Moderate-	Medium-	Substantial-	High-
Performance			High-		High+
Cost			$1.25b		$0.5b

Table 13: Matrix for F-111 Withdrawal Example

One observation that may be drawn from this example is the strength of capability options that provide a good level of performance across a range of contexts. While the F-111 was assessed as providing superior strike effectiveness in the low-threat context, its performance drops off significantly in the high-threat context due to the vulnerability of the ageing platform. In contrast, withdrawing the F-111 and entrusting strike to other platforms provides a level of effectiveness that is not as badly affected by threat levels (due in no small part to the advanced weapons used).

While consistent performance across multiple contexts is often beneficial, it cannot be used as a heuristic for detecting the best option in all cases. When the distribution of risk is highly skewed in favour of a subset of contexts, capability options that are particularly strong in those contexts may be optimal, even though they may perform poorly in lower-risk contexts.

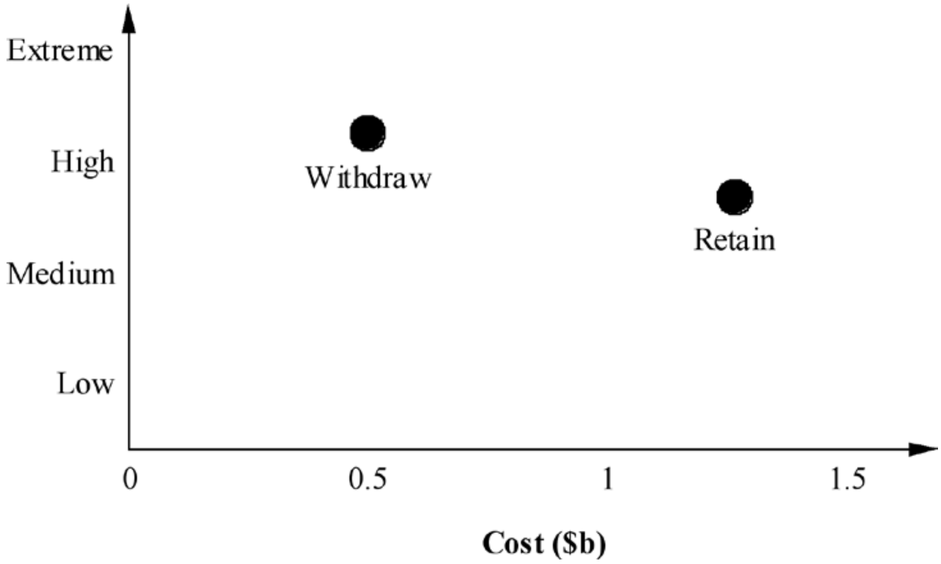

Figure 11: Performance versus Cost Graph for F-111 Withdrawal Example

ENDNOTES

1 For example, see Peter Layton, *Accepting Uncertainty? A Contemporary Methodology for Capability Development*, Paper No. 15, Air Power Development Centre, Department of Defence, Canberra, 2004.

2 In practice, the performance of a capability option that would be largely irrelevant in a given context need not be evaluated in detail. In such cases, an assessment of 'negligible' would suffice.

3 This basic structure may be traced back to Ashby's work on 'requisite variety' as an approach to dealing with uncertainty; see W. Ross Ashby, *An Introduction to Cybernetics*, Chapman and Hall, London, 1961.

4 An alternative approach would be to work from the current level of risk; ie. taking into account extant risk treatments such as current capabilities. Although such assessments might be easier to make, use of the overall framework would be more complicated since capability options usually involve the withdrawal of some elements of current capability, and this would need to be taken into account subsequently.

5 The notation $e_{c_1|x_2}$ indicates a conditional assessment, and simply means the effectiveness of c_1 given that x_2 occurs.

6 Department of Defence, *Defence Capability Plan 2004–2014 Public Version*, Defence Publishing Service, Canberra, 2003, p.44.

7 There is also a Carrier based Variant (CV).

8 Ian Bostock, 'Australia considers STOVL Joint Strike Fighter', *Jane's Defence Weekly*, 7 July 2004.

9 The suspiciously precise assessments in this table probably warrant a confession. All of the examples in this paper were worked through using hypothetical quantitative assessments in the first instance. These were then converted into qualitative assessments using look-up tables for each assessment scale. This approach guarantees consistent and robust treatment of assessments.

10 Department of Defence, *Defence Capability Plan 2004–2014 Public Version*, Defence Publishing Service, Canberra, 2003, p.45.

11 Through-life costs covering the time window of the analysis should be included. Ideally, corrections for inflation, etc, should also be considered; however, the adjustments made by such considerations are likely

to be minor compared to the uncertainty associated with context risk and capability option effectiveness assessments.

12 Sanu Kainikara, 'Future Options for Australian Air Power', in *Proceedings of the 2004 Air Power Conference: Network Centric Warfare and the Future of Air Power*, Air Power Development Centre, Canberra, 2005 (to appear).

13 A discussion of the advantages and disadvantages of surface-launched cruise missiles may be found in Wing Commander P.A. Hislop, *Employment of Cruise Missiles by the ADF*, Paper No. 57, Air Power Studies Centre, Department of Defence, Canberra, 1997.

14 Department of Defence, *Defence Capability Plan 2004–2014 Public Version*, Defence Publishing Service, Canberra, 2003, p. 45.

15 A paper further explaining these contexts, and drawing implications from them, is currently under development within the Air Power Development Centre.

16 Concepts are implicitly included in the 'command and management' FIC.

17 Eric W. Weisstein, 'Expectation Value', from *MathWorld—A Wolfram Web Resource*, http://mathworld.wolfram.com/ExpectationValue.html, accessed 27 September 2004.

18 Intermediate situations (eg. 'a bit late') could also be accommodated, but the difficulty in providing assessments with a high degree of confidence probably overwhelms any advantage gained by increasing the resolution of the process.

19 It may be desirable to also take into account that a dynamic capability option might be developed even if the corresponding context does not eventuate, perhaps as a result of false indications that the context were coming to pass.

20 The basis for Australia's military strategy is summarised as 'shape, deter, respond'. Deterrence may be considered to be a subset of shaping.

21 Mathematically, the relationship is $e_r = 1 - (1-e_p)(1-e_q)$, where e_r is risk reduction effectiveness, e_p is likelihood reduction effectiveness, and e_q is consequence reduction effectiveness, with all effectiveness assessments between 0 and 1. For the derivation of this, see Peter McLennan, *Dealing with Uncertainty in Defence Strategic Planning*, Ph.D. Thesis, Australian National University, Canberra, 2004, pp.82–85.

22 *Defence Procurement Review 2003*, Department of Defence, Canberra, 2003, http://www.defence.gov.au/dmo/DMO/function.cfm?function_id=100, accessed 5 October 2004, p. 8.

23 As described on p. 18, context likelihood and consequence assessments may specify ratings that vary over time, if need be.

24 See Joint Standing Committee on Foreign Affairs, Defence and Trade (Defence Subcommittee), *Review of Defence annual report 2002–03*, Hansard, Commonwealth of Australia, 4 June 2004; and Joint Standing Committee on Foreign Affairs, Defence and Trade (Defence Subcommittee), *Review of Defence annual report 2002–03*, Hansard, Commonwealth of Australia, 2 August 2004.

25 Joint Standing Committee on Foreign Affairs, Defence and Trade (Defence Subcommittee), *Review of Defence annual report 2002–03*, Hansard, Commonwealth of Australia, 4 June 2004, p.30.

26 See Department of Defence, *Defence Capability Plan 2004–2014 Public Version*, Defence Publishing Service, Canberra, 2003, pp. 29, 35.