Military Experimentation

Hallmark of Professionalism

Alex Post

2004 CHIEF OF AIR FORCE FELLOW

AIR POWER DEVELOPMENT CENTRE
CANBERRA

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Alex returned to Canberra in 2002 as the Staff Officer for Air Vice-Marshal Norm Gray, Head Airborne Surveillance and Control Division in the Defence Materiel Organisation. While in this position, Alex completed a Master of Arts (War Studies) at the Australian Defence Force Academy.

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ABBREVIATIONS AND ACRONYMS

AAR	Air-to-Air Refuelling
ACES	Air Force Command Exercise System
ADDER	NATO designation for the Russian R-77 air-to-air missile
ADF	Australian Defence Force
ADFWC	ADF Warfare Centre
ADHQ	Australian Defence Headquarters
ADO	Australian Defence Organisation
ADSO	Australian Defence Simulation Office
AEF	Army Experimental Framework
AESA	Active Electronically Scanned Array
AEW	Airborne Early Warning
AEW&C	Airborne Early Warning and Control
AFCC	Air Force Capability Committee
AFEB	Air Force Experimentation Board
AFEC	Air Force Experimentation Capability
AFEO	Air Force Experimentation Office
AFSAA	Air Force Studies and Analysis Agency
AG	Action Group
AIPS	Australian Illustrative Planning Scenarios
AMCDG	Australian Maritime Concept Development Group
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AO	Area of Operations
APDC	Air Power Development Centre
ASE	Aerospace Synthetic Environment
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASTOPR	Australian Theatre Operational Preparedness Requirement
AWAC	Airborne Warning and Command
AWD	Air Warfare Destroyer
BCSS	Battlefield Command Support System
BMS	Battlefield Management System
CAOC	Combined Air Operations Centre
CAP	Combat Air Patrol
CD&E	Concept Development and Experimentation
CDEF	Concept Development and Experimentation Framework
CDF	Chief of the Defence Force
CEC	Cooperative Engagement Capability
CEPMAN	Capital Equipment Procurement Manual
CESAW	Centre for Evaluation, Simulation and Analysis of Weapons
COA	Course of Action
COC	Combined Operations Centre

COD	Capability Options Document
CONOPS	Concept of Operations
COSC	Chiefs of Service Committee
CPD	CDF Preparedness Directive
CSA	Customer Service Agreements
CSC	Command and Staff College
CSD	Capability Systems Division
CSLCMM	Capability Systems Life Cycle Management Manual
CTD	Concept Technology Demonstrator
DARNOS	Dynamic Agents Representation of Networks of System
DCAF	Deputy Chief of Air Force
DCC	Defence Capability Committee
DCEE	Distributed Continuous Experimentation Environment
DCP	Defence Capability Plan
DCPG	Defence Capability Planning Guidance
DEB	Defence Experimentation Board
DEF	Defence Experimentation Framework
DEPSEC CS	Deputy Secretary Corporate Services
DEPSEC SP	Deputy Secretary Strategic Policy
DFEF	Defence Futures and Experimentation Forum
DFF	Defence Futures Forum
DFW	Directorate of Future Warfighting
DFWC	Directorate of Future Warfare Concepts
DIE	Defence Information Environment
DLOC	Directed Level of Capability
DMO	Defence Materiel Organisation
DOF	Degrees of Freedom
DNSF	Directorate of Navy Strategy and Futures
DSAD	Defence Systems Analysis Division
DSN	Defence Secret Network
DSTO	Defence Science and Technology Organisation
DWP	Defence Working Plan
EADSIM	Extended Air Defence Simulation
ESM	Electronic Support Measures
ESSM	Evolved Seasparrow Missile
FASCIR	First Assistant Secretary Capability Investment and Resources
FDG	Force Development Group
FEG	Force Element Group
FIC	Fundamental Inputs to Capability

FMOC	Future Maritime Operational Concepts
FOB	Forward Operating Base
FORTRAN	IBM Mathematical FORmula TRANslation System
FPB	Fast Patrol Boats
FPS	Function and Performance Specification
FWC	Future Warfare Concepts
GBAD	Ground Based Air Defence
GEMM	Generic Missile Model
GTEM	Generic Template Model
GTS	Generic Threat Simulator
GTS CD	GTS Concept Demonstrator
GTV	Generic Telemetry Viewer
GUI	Graphical User Interface
HARM	High Speed Anti-Radiation Missile
HIL	Hardware-in-Loop
HLA	High Level Architecture
HQAC	Headquarters Air Command
HQADF	Headquarters Australian Defence Force
HQAST	Headquarters Australian Theatre
ICBM	Intercontinental Ballistic Missile
ILS	Integrated Logistic Support
INTSIM	International Simulations
ISD	In-Service Date
ISR	Intelligence, Surveillance and Reconnaissance
JFACC	Joint Force Air Component Commander
JMAP	Joint Military Appreciation Process
JOIC	Junior Officer Initial Course
JORN	Jindalee Operational Radar Network
JSA	Joint Systems Analysis
JSAF	Joint Semi-Automated Forces
JSC	Joint Simulation Capability
JSF	Joint Strike Fighter
JTF	Joint Task Force
JTLS	Joint Theatre Level Simulation
LCC	Life Cycle Costs
LCU	Utility Landing Craft
LOA	Limited Objective Activity

LOE	Limited Objective Experiment
LOTE	Life of Type Extensions
LWDC	Land Warfare Development Centre
MAAP	Master Air Attack Plan
MCLM	Missile-Closed-Loop-Model
MECA	Missile Engagement and Coverage Analysis
MEXF	Maritime Experimental Framework
MNE	Multinational Experimentation
MSB	Military Strategy Branch
MSP	Military Strategic Priority
MSTARS	Munition Simulation Tools and Resources
NACC	New Aerospace Combat Capability
NATO	North Atlantic Treaty Organisation
NCC	Navy Capability Committee
NCW	Network Centric Warfare
NIS	Navy Innovation Strategy
NISWG	NIS Working Group
NSPF	Navy Strategic Policy and Futures
OA	Operations Analysis
OCD	Operational Concept Document
OCIO	Office of the Chief Information Officer
OPA	Operational Performance Agreements
OT&E	Operational Test and Evaluation
PCOD	Preliminary Concept Options Document
PF	Private Finance
PGA	Policy Guidance and Analysis Division
PGM	Precision Guided Munitions
PMP	Project Management Plan
R&D	Research and Development
RAAF	Royal Australian Air Force
RAF	Royal Air Force
RMA	Revolution in Military Affairs
RP&D	Rapid Prototyping and Development
SADM	Ship Air Defence Model
SCD	Senior Concept Developer
SLC	Squadron Leader Course

SOD	Strategic Operations Division
SOF	Special Operation Force
StEW	Strategic Early Warning Tracking
T&E	Test and Evaluation
T&EC	Test and Evaluation Concept
TACPROCS	Tactical Procedures
TCD	Test Concept Document
TEMP	Test and Evaluation Master Plan
TEMS	Terminal Effects Modelling System
TLS	Through Life Support
TTCP	The Technical Cooperation Program
TUAV	Tactical Uninhabited Aerial Vehicle
UAV	Uninhabited Aerial Vehicle
UCAV	Uninhabited Combat Aerial Vehicle
UK	United Kingdom
US	United States
USAAF	United States Army Air Force
USDM	Under Secretary Defence Materiel
USJFCOM	United States Joint Forces Command
USN	United States Navy
USSR	Union of Soviet Socialist Republic
VAE	Virtual Air Environment
VCDF	Vice Chief of the Defence Force
VIEWLAB	Virtual Integrated Experimental Warfighting Laboratory
VLAN	Virtual Local Area Network
WCC	Wing Commander Course
WSD	Weapons System Division
WSP	Weapon System Plan

INTRODUCTION

The terms ‘revolutionary planning’, ‘force transformation’ and ‘revolution in military affairs’ are common phrases that have been used in the past few decades in association with the process of evaluating a current force and then planning for its modification into a force better equipped and organised for an anticipated future environment. The words ‘revolutionary’ and ‘transformation’ generate the impression that major changes are involved that will transport the force’s capabilities from its current level to a much higher level, and that with the completion of the change the process will have finished. However, an examination of the 40 prominent aerospace events contained in the list on page 3 will indicate that there has been a continual development and growth in the capabilities fielded by aerospace forces and in the concepts that guide their application over the past hundred years.

This continual growth and development indicates that major changes in aerospace capabilities are no short-term phenomena, as suggested by the words ‘revolutionary’ and ‘transformational’. Rather, they are continuing, long-term characteristics of aerospace technology and these change processes should, alternatively, be seen as ‘evolutionary’ and ‘maturational’. The processes used to manage this continuing growth and development must therefore also be of an enduring and lasting nature and not just a temporary measure put in place to solve a short-term problem.

The method that has been implemented within the Australian Defence Force (ADF) and throughout the wider Australian Defence Organisation (ADO) to guide and influence the development of capability is the process of concept development and experimentation (CD&E).

Concept development is concerned with the gathering of new ideas about how the ADF could be trained, structured, organised, equipped or employed and developing the original thought or idea into a robust military concept. The concept will undergo rigorous examination through experiments that are soundly based upon the principles of experimental science. In these experiments the future capabilities anticipated by the concept can be fielded in a futuristic environment to determine their characteristics, utility and limits. The validated concepts produced by CD&E will then be used to guide the development of the required capabilities through the ADF’s capability development processes that govern the entire life cycle of a capability.

From the CD&E process a number of benefits will flow to the ADF. The decisions taken on the replacement of old capability and the development of new capabilities will be more informed in respect of all the capabilities attributes. CD&E will allow unsound concepts to be identified and discarded early in the capability development process, with a consequent reduction in the chance of resources being wasted. In addition, the risks associated with acquiring developmental capability systems will also be mitigated to a greater degree by this increased early awareness of the systems' attributes. Finally, the professional mastery of the ADF's people will be enhanced by their greater understanding of future capabilities and future environments, and will allow them to use more effectively a new capability when it is actually introduced into service.

Secondary benefits will also accrue to the ADO through the acquisition of the tools required to conduct experimentation. The tools required for the testing and analysis of concepts and capabilities may also be used in the training of ADF personnel and will also support the analysis of mission plans developed by Royal Australian Air Force (RAAF) units and formations. Campaign plans created by the headquarters elements of the ADF and the RAAF can also benefit from these same tools as they provide the ability to analyse this level of planning as well.

As the CD&E process becomes embedded in the organisations and activities of the ADO it will involve a growing number of members in the development of concepts, in the conduct of experiments and in the implementation of CD&E results in the development, management and operation of the ADF's capabilities. For members of the RAAF to obtain maximum benefit from CD&E it is necessary for them to understand more fully the CD&E process. In this essay an attempt is made to provide an understanding of that process. To begin, an examination of the basic factors influencing experimentation will be undertaken. Following on from this some considerations that continue to affect CD&E will then be drawn from actual historical examples. The organisation that has been established by Defence for CD&E will then be outlined to describe the overall Defence CD&E effort and the common infrastructure that the RAAF can draw on. The focus of Defence's CD&E efforts is specifically centred on the capability development of the ADF and Chapter 4 will explain how the results of CD&E are translated into actual capability. Finally, an example of a RAAF experimental activity will be described in order to illustrate some of the practicalities of how the RAAF currently plans and runs such activities and, additionally, to give some idea of the type of results that can be generated from experimentation. The benefit to the RAAF and its members of this treatment is that they will better understand the CD&E resources of the RAAF and Defence, be more prepared to participate in the CD&E processes established with the RAAF, and be able to draw upon them to enhance the capabilities of the RAAF at all levels.

FORTY PROMINENT EVENTS IN AEROSPACE HISTORY

1902/3 - First powered flight by Richard Pearce (of New Zealand) or Wright brothers
1912 - First bomb carried and dropped by an aircraft
1914 - Interrupter gear introduced on the Fokker Eindecker
1914 - First anti-aircraft artillery weapons developed
1915 - First operational dropping of a torpedo from an aircraft
1915 - First strategic air attack on London
1917 - First Integrated Air Defence System established in Britain
1937 - First operational radar network established in Britain (Chain Home)
1940 - First operational use of paratroops
1940 - Battle of Britain – Air offensive defeated by defensive use of air power
1940 - RAF learn that the unescorted daylight bomber doctrine is unsound
1940 - First use of Electronic Warfare to degrade enemy operations
1941 - Sinking of HMS *Repulse* and *Prince of Wales* demonstrates the aircraft's ability to destroy warships even when fully manned, manoeuvring and fighting back.
1941 - First operational use of an airborne air intercept radar
1943 - USAAF learn that the unescorted daylight bomber doctrine is unsound
1943 - First air-to-surface guided missile used to destroy UK ship (HS293)
1944 - First cruise missile (V-I)
1944 - First ballistic missile (V-2)
1944 - First operational jet fighter (Me. 262)
1944 - First surface-to-air guided missile (Wasserfall)
1945 - Atomic bombs dropped on Hiroshima and Nagasaki
1947 - Mach 1 flight achieved
1950 - First operational helicopter
1953 - First infra-red guided air-to-air missile (AIM 9 Sidewinder)
1956 - Berlin Airlift – Air power supplies entire city in spite of ground blockade
1957 - First ICBM tested by the USSR
1957 - First satellite in space launched by USSR (Sputnik)
1960 - First spy satellite launched by the US (Corona)
1960 - First semi-active radar-homing air-to-air missile (AIM 7 Sparrow)
1961 - First man in space (Yuri Gagarin)
1968 - First anti-satellite weapon developed by the USSR
1969 - First man on the moon (Neil Armstrong)
1972 - First PGM used in Vietnam to destroy the Than Hoah bridge
1982 - First operational use of UAV by Israel in Bekaa Valley
1991 - First operational use of Stealth (F117)
1995 - First use of an active homing air-to-air missile (AIM 120 AMRAAM)
1999 - First conflict decided by air power alone (Operation *Allied Force*)
2001 - Terrorist attack uses civilian airliner as a 'poor mans' guided missile
2001 - First use of UAV in combat (Predator in Afghanistan)
2002 - First purpose designed UCAV flies for the first time (X45)

CHAPTER 1 - EXPERIMENTAL BASICS

WHAT IS MILITARY EXPERIMENTATION?

A broad understanding of the term can be gained from the dictionary meaning of the words used. The word 'military' contains as part of its definition the term '- n. Soldiers generally, the armed forces'.[1] The word 'experiment' is defined as '1. A test or trial; a tentative procedure; an act or operation for the purpose of discovering something unknown or testing a principle, supposition, etc. ... 2. To try or test in order to find something out'.[2] Combining these two interpretations we can produce a definition of military experimentation that is 'the practice of discovering something unknown (but useful) about the armed forces'.[3] In addition, a second meaning is that experimentation can be used to test a principle or hypothesis, while a third use suggested by some dictionaries is to 'illustrate a known law'.[4] With these definitions in mind it is important to understand what an experiment requires to meet in order to constitute a valid experiment.

THE FOUR REQUIREMENTS OF A VALID EXPERIMENT

An international scientific organisation to which Defence belongs is The Technical Cooperation Program (TTCP). A number of TTCP sub-groups have been established to consider technical issues relating to military affairs. In 2002 the Joint Systems Analysis (JSA) sub-group of the TTCP created an Action Group (AG-12) to investigate a number of matters in connection with military experimentation. As part of their work AG-12 identified four fundamental requirements that an experiment must meet in order to be considered a valid experiment. The first requirement was that the experiment must contain the ability to use the new capability being experimented. Secondly, the experiment must have the ability to detect any change in performance that occurs during the experiment and which may, or may not, be associated with the new capability. Thirdly, the experiment must

1 The Macquarie Library, *The Macquarie Concise Dictionary*, The Macquarie Library, Macquarie University, 1997.

2 ibid.

3 Dean Bowley, Michael Brennan and Stephen Cook, *Military Experimentation: A Systems Engineering Approach to Force Development*, Defence Science and Technology Organisation (DSTO) Salisbury, 2001.

4 Merriam-Webster Online Dictionary, Entry for 'Experiment', http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=experiment&x=12&y=15, accessed 26 October 2004. The three meanings of experiment are also explained in David S. Alberts and Richard E. Hayes, *Code of Best Practice: Experimentation*, US Department of Defense, Washington DC, 2002, p. 19.

have the ability to isolate the reason for the changes detected in performance, confirming the new capability's relationship to the detected change in performance. The first three requirements may be seen as providing internal validation that the experiment is valid. The fourth and final requirement addresses external validation of the experiment by calling for the experiment to have the ability to relate its results to actual operations.[5]

EXPERIMENTATION CAMPAIGNS

The four requirements outlined above are aimed at ensuring that a single experiment meets the test of providing valid results. However, a single experiment by itself cannot provide sufficient evidence to justify major capability development decisions. The capability needs to be examined and tested in a number of related activities that, taken together, constitute what is called an experimentation campaign. The characteristics of an experiment are compared with those of an experimention campaign in Table 1.1.

	Experiment	**Experimentation Campaign**
Threads of investigation	Involves a single event or axis of investigation	Involves multiple events and multiple axes of investigation
Organising framework	Organised around a set of specific hypotheses	Organised around a broad goal
Analytical goal	Provides focused testing of a specific set of questions	Provides knowledge across a broad set of issues
Number of decision points	Executes a specific experimental design	Has multiple decision points for refining issues and analysis
Number of factors	Measures the impact of a few factors while controlling others	Assesses the relative importance and the impact of many factors
Scenarios	Selected to provide the best test of specific hypotheses	Examines a range of contexts to develop generalised predictions
Methodology	Employs selected methods and metrics	Employs a broad range of methods

Table 1.1 – Comparison of an Experiment to an Experimentation Campaign[6]

5 Dr Rick Kass, *The Logic of Warfighting Experimentation*, Address presented to the Defence Experimentation Symposium, DSTO Salisbury, 29 March 2004.

6 Alberts and Hayes, *Code of Best Practice*, p. 44.

The work conducted by AG-12 identified 15 principles that govern the effective conduct of experimentation campaigns. The likelihood of conducting an effective experimentation campaign is increased when these principles are adhered to. These principles are contained in Table 1.2.

15 PRINCIPLES FOR EFFECTIVE EXPERIMENTATION

1. Warfighting experiments should be embedded in experimentation programs to maximise their utility to capability development.
2. An iterative process of problem formulation and analysis is critical to accumulate knowledge and validity within an experimentation program.
3. Experimentation programs should be designed to integrate all three scientific methods of knowledge generation (studies, observations and experiments).
4. Warfighting experiments are uniquely suitable for supporting capability development decisions.
5. Designing effective experiments requires an understanding of the logic of the experimentation.
6. Warfighting experiments should be designed to meet the four requirements of a valid experiment.
7. Multiple experiment methods are necessary within an experimentation campaign in order to accumulate validity across the four requirements.
8. The model-exercise-model paradigm is critical to maximise the usefulness of war game and field exercises in an experimentation campaign.
9. Human variability in warfighting experimentation requires additional experiment design considerations.
10. Warfighting experimentation that exploits collective training and OT&E opportunities requires additional experiment design considerations.
11. The use of Modelling and Simulation should be considered as an important component of an experimentation campaign.
12. An effective experiment control regime is critical to successful experimentation.
13. The data collection and analysis plan is critical to successful experimentation.
14. All warfighting experiments need to address relevant ethical, environmental, political, multinational and security issues.
15. Effective and frequent communication with the decision-maker is critical to an effective experimentation campaign.

Table 1.2 – 15 Principles for Effective Experimentation[7]

7 TTCP JSA AG-12, Handout, *Workshop One: Methods and Approaches for Warfighting Experimentation*, Workshop presented at the Defence Experimentation Symposium, DSTO Salisbury, 1 April 2004.

While these principles are largely self-explanatory, the principle relating to human variability (Principle 9) is an important matter that requires some further explanation.

In experimenting with armed forces we are faced with the situation of dealing with two types of entities, human and non-human. The human element consists of the soldiers, sailors and airmen that staff our armed forces. The attitude of the ADF's senior leadership to the importance of their personnel has been given explicit pronouncement in the highest level doctrine publications. 'It is not technology, systems or platforms that generate the real capabilities for our Defence Force, it is the strength of our people.'[8] The non-human element of the ADF comprises those technologies, systems and platforms that are operated by, and support our personnel. One of the problems that confronts the practice of military experimentation is how to test, evaluate or discover important information about a field of endeavour that contains elements that can be precisely measured and operate according to verifiable rules (the non-human element), but are operated and manipulated by a human component that does not operate on precise and exact principles or motivations. In this respect military experimentation differs in many respects to any other form of experimentation.

The principles of experimentation developed by the physical sciences are appropriate and useful for discovering important information about our equipment, systems and weapons. What objects can our sensors detect and at what ranges? How far will a missile travel and what effects will the detonation of its warhead have? How quickly and how much data can we communicate from one entity to another? All these are questions that may be readily answered by this branch of the sciences to a quite precise degree. The rules that can govern the different variables that influence these answers can be, and are, deduced and promulgated in a variety of military procedures, manuals and instructions.

When we come to the human element the experimental processes developed by the social and life sciences provide us with less precise answers due the great complexity of human behaviour. Studies of the population of a single country can develop trends and dominant characteristics that are representative of that population. However, the different ethnic, religious and societal values that are found in the culture of another nation can completely change the trends and characteristics that will typify human behaviour in that country. Whichever nation is studied the insights gained are usually expressed in terms provided by the statistician, such as probability and possibility, and do not provide the same degree of certainty as those provided by the purely physical sciences.

The insights provided by the military experimentation process may therefore be based on high quality physical data but less precise human data. As a consequence the military solutions provided by experimentation may be seen as a 'staff solution' to a specific

8 Department of Defence, *Force 2020*, Department of Defence, Canberra, 2002, p. 6.

problem.[9] As a 'staff solution' the insights have been gained by making full use of the available physical data, and involved subject matter experts in determining the best, most appropriate or most likely, manner of employment. However, such a solution does not preclude the use of the capability in a completely different manner.

An historical example demonstrates how an outstanding commander employed his forces in a manner different to the 'staff solution' and with the intention of using his enemy's cultural inclinations against themselves.

In January 1942, General Erwin Rommel launched an offensive against the British and Commonwealth forces in Libya. As part of this operation Rommel planned the destruction of the British 1st Armoured Division near Fort Msus on 25 January. The theory and practice of the day dictated that the German armour tasked to carry out the assault should be concentrated and used to smash through the British defence. Rommel, however, decided to approach the British defence as though he was going to deliver just such an attack, but then turn away in feigned flight when confronted by the defending forces. Rommel anticipated that when the defenders saw his armour fleeing 'the hunting instincts of the cavalry-minded British commanders' would be roused and they would send their last remaining armour to pursue the Germans.[10] In anticipation of this British response Rommel prepared a line of anti-tank weapons based on the overwhelmingly superior German 88mm gun. As the German armour withdrew through the anti-tank line the German anti-tank weapons opened fire on the pursuing British armour and smashed them. The British defence of Msus was defeated and the way to Benghasi was open.

Understanding intimately the capability of his weapons, Rommel employed them in a non-standard manner that was also designed to elicit a cultural response from his British opponents. This approach allowed him to defeat his enemy decisively. Rommel's skills and his ability to know when to set aside established tactics and doctrine and successfully employ innovative methods is not to be found in all commanders. The 'staff solution' for most commanders should form the basis of action in most situations. Innovative methods such as Rommel's plan may also have only a limited usefulness, as the enemy will adapt to continued use of the same approach. Although military experimentation seeks to identify the usefulness, utility and limits of military capabilities, the potential still exists for these capabilities to be employed in unanticipated ways.

Just as the principles governing effective experimentation have been established, so the threats to experimental validity have also been identified and they are contained at Annex A.[11]

9 Air Commodore Mark Lax, interview, Canberra, 18 June 2004.

10 James Lucas, *Battle Group: German Kampfgruppen Action of World War Two*, Arms and Armour Press, London, 1994. pp. 114–15.

11 Kass, *The Logic of Warfighting Experimentation*.

ADF DOCTRINAL DEVELOPMENTS

The importance of military experimentation has been recognised within the ADF and has been captured in a number of its capstone doctrine publications. In 2002 the then Chief of the Defence Force (CDF), Admiral Barrie, released a capstone doctrine publication, *Force 2020*, which outlined a vision of what the future might hold for the ADF and how the ADF intended to change itself for the anticipated future.[12] This document firmly established the concept development and experimentation process as a core method for single and joint Service organisations to employ in their exploration of the future and in deriving guidance for the development of their respective concepts, capabilities and organisations. The description of the experimentation process provided by *Force 2020* was that it 'collects, develops and explores concepts—to identify and recommend changes required—to achieve significant advances in future capabilities'.[13] This process was to be captured by the single Services in their respective experimentation programs: *Headmark* for the Navy, *Headline* for the Army and *Headway* for the Air Force.

Force 2020 provided the vision and guidance for the development of the next document in the hierarchy of capstone doctrine publications, the operational level *Future Warfighting Concept*, which was released by CDF, General Cosgrove, in 2003. In the *Future Warfighting Concept* the process of concept development and experimentation was given some further definition.

WHAT IS CONCEPT DEVELOPMENT AND EXPERIMENTATION?

Concept development and experimentation is the application of the structure and methods of experimental science to the challenge of developing future capability. The purpose of this activity is to provide better advice for decision-makers; it also has the additional benefit of helping the Defence organisation to learn about the future. Concept development and experimentation is essential because it helps military innovators to improve and prove their ideas without taking huge risks or outlaying significant resources.

Concept development gives broad and sometimes ill-defined ideas a chance to be examined by groups of experts in a logical process. These ideas can come from many sources: they can be generated by staff processes, operational experience, formal analytical work, or proposals that are published in our journals. There need be no boundaries on the types of ideas that enter the concept development process, although some simpler ones that modify techniques or procedures might be 'fast-tracked' into practice because they are intuitively sound. Typically, promising ideas with a broader scope are explored and refined through workshops and larger seminars to the point where more mature concepts are formed. These

12 Department of Defence, *Force 2020*, p. 1.
13 ibid., p. 26.

concepts are further debated in committees or working groups and, if accepted, are submitted to the experimental process. Once validated and accepted, concepts are incorporated into our organisation—for example, through doctrine and capability development processes.

While not every decision requires it, experimentation is a powerful tool; it provides a better understanding of a range of issues associated with capability and concept development, especially in complex or contested situations that are difficult to address through other approaches. Experimentation aims to assess the feasibility, utility and limits of innovative warfighting concepts in a controlled environment. By using methods that integrate professional judgment, mathematical models, historical experience and field performance, experimentation permits a broader range of participants to be involved in the development of concepts and advice. Experimentation is also an economy measure, since it can provide a means to test ideas without large resource outlays and a way to demonstrate alternatives for decision-makers. It also provides a means of gathering evidence when weapons, situations and organisations to support a concept do not yet exist.

The experimental process is not enough in itself, however: the results of experimentation must be integrated into the capability development process. Such integration requires an ability to capture and cross-test findings gained from experimentation, and use this information to complement the judgment of senior decision-makers. When this integration is achieved, we will have a powerful way to inject new thinking into acquisition, organisation and doctrine development projects.[14]

The explanation of military experimentation contained in these two publications is in accord with the broad definition we have outlined previously. What these documents do provide is a clear statement of purpose for the ADF being involved in the concept development and experimentation process. These purposes may be summarised as providing better advice for decision-makers, helping the Defence organisation to learn about the future, and helping military innovators to improve and verify their ideas without taking large risks or outlaying significant resources.

With this understanding of what experimentation is, and why the ADF is interested in developing expertise in this field, we can now examine what activities can be used to conduct experiments.

14 Department of Defence, *Future Warfighting Concept*, Department of Defence, Canberra, 2003, pp. 41–42.

WAYS OF CONDUCTING EXPERIMENTATION

When the thought of conducting an experiment is first raised, an impression comes to mind of a laboratory environment with its sterilised and controlled conditions. While some military experiments may be conducted in such an environment, a listing of some of the ways in which useful information can be obtained about the country's armed forces helps to dispel this restrictive image.

Some of the activities that can be used to conduct experiments include war games, rehearsals, studies, trials, exercises, models, simulations, and focused research. This list is far from exhaustive but is indicative of the broad spectrum of activities that can be used. An experimental program, and the experimentation campaigns that are conducted within the program, will provide for a number of these different activities to be included in them as the strengths and weaknesses of each method vary from one to another. The maturity of a subject for experimentation will also determine what activities can be employed in its investigation. At the present time the Joint Strike Fighter (JSF) is being developed and its characteristics are anticipated and not yet realised in a production model aircraft. With these characteristics we can construct models and simulations and use them in war games but we, in Australia, obviously cannot employ the actual platform in live exercises or rehearsals. The cost of conducting these activities also varies from one to another with some events, such as field exercises, requiring the commitment of a large amount of resources. The selection of the correct experimental tool is most important, not just in managing capability but in managing resources as well.

The strengths and weaknesses of a variety of experimentation methods can be suggestive of the appropriate mix of methods that should be employed to analyse a capability option. In Table 1.3 the relative abilities of four types of experimental method are compared against the four requirements of a valid experiment in order to identify the strengths and weaknesses of each method for evaluating each of the four requirements.

	Analytical War Game Experiments • Human planners • Simulated forces • Faster than real time • Constructive simulations	**Constructive Experiments** • Simulated forces • Simulated forces • Faster than real time • Constructive simulations	**Human-in-the-Loop Experiments** • Human planners • Simulated forces • Real time • Interactive simulations	**Field Experiments** • Actual forces in the field • Actual forces in the field • Real-time • Interactive simulations
Employ capability	Fair	Good	Good	Fair
Detect change in effect	Fair	Good	Good	Fair
Isolate reason for effect	Poor	Excellent	Good	Poor
Relate results to operations	Fair	Poor	Good	Excellent

Table 1.3 – Experimental Methods and the Four Requirements of Valid Experiments

While the analytical war game would seem to have little to recommend it, this type of experiment is probably the best method of conducting rapid, 'exploratory analysis across a broad range of cases, and, thus, for considering adaptiveness, flexibility and robustness'.[15] This form of experimentation can most quickly highlight areas that are demanding of higher fidelity examination. The constructive experiment excels at isolating the reasons underlying the effects produced in an experiment, while the field experiment cannot be surpassed as the best method of relating experimental results to real operations. The human-in-the-loop experiment is a good all-round performer that can produce useful results while not requiring the commitment of large amounts of resources. It is apparent that a mix of the different methods will provide a more detailed understanding of the factors influencing a capability and the effects that it can produce.

15 Paul K. Davis, James H. Bigelow and Jimmie McEver, *Analytical Methods for Studies and Experiments on 'Transforming the Force'*, RAND, Santa Monica, 1999, p. 22.

RAAF EXPERIMENTAL USAGE IN THE PAST

An examination of the list of experimental methods outlined above will reveal that the RAAF has been using experimentation for a very long time. The Defence Science and Technology Organisation (DSTO) and the Defence Materiel Organistaion (DMO) have long conducted studies and focused research in connection with the acquisition of new capabilities. In the process of acquiring these capabilities trials have been conducted and models and simulations have been developed and carried over into operational service. While in service, all RAAF capabilities have regularly participated in exercises both in Australia and overseas. In short, the RAAF has always utilised experimental activities to develop its force structure and capabilities.

The steps recently taken to establish a RAAF experimental capability do not replace the use of experimentation in any of these roles. Instead the experimental capability being evolved at present has the purpose of looking further into the future than these extant activities and across the whole of the force structure. The horizon for experimentation is being extended further into the future and its breadth is being widened to encompass a wide range of capabilities not only in the RAAF but in the whole ADF also.

The effort to acquire an Airborne Early Warning and Control (AEW&C) capability for the ADF reflects well the RAAF's use of a wide range of experimental activities undertaken over a number of years to gain knowledge, understanding and skills in regard to this important capability. The project began in the early 1980s and began to acquire detailed knowledge of the subject through the establishment of exchange positions with the United States Navy (USN), which operates the Grumman E2 Hawkeye Airborne Early Warning (AEW) aircraft, and the Royal Air Force (RAF), which uses the Boeing E-3 Sentry Airborne Warning and Command (AWAC) platform. These two platforms represent quite different approaches to how battlespace surveillance along with early warning and control functions can be performed. Short-term exchange positions were also obtained in the RAF's AWAC tasking and support cell through the *Longlook* series of exchanges. This breadth of exposure and understanding were of significant benefit to the RAAF personnel charged with the development of an AEW&C concept of operations.

The acquisition of knowledge was also supplemented by the involvement of foreign AEW and AWAC aircraft in live exercises held in Australia. The annual *Pitch Black* series of exercises involves the air forces from a range of countries participating in large force employment exercises held in the Northern Territory. Since the 1980s the RAAF has experienced the benefit of operating with, and against, AEW and AWAC platforms from the USN, USAF, RAF and Singapore. This has allowed the RAAF to remain abreast of developments in areas related to AEW&C operations without actually having an existing AEW&C capability.

DSTO was engaged early in the life of the project to advise on the technological performance of the air vehicle itself and a number of the many systems included on

AEW and AWAC aircraft. These systems included radar and electronic support measures (ESM) sensors, and radio, data link and satellite communications. This effort has required a significant amount of study, research and training to acquire the skills required. As the project progressed DSTO was also heavily involved in the project definition study phase, tender evaluation, contract negotiation and contract management.

In the course of providing this support DSTO and the project staff have developed detailed models of the tendered AEW&C platforms. Since contract award, the Boeing AEW&C model has continued in development and has been used by the project to develop operational concepts and tactical procedures that will aid the introduction into service of the AEW&C. The experiments conducted to facilitate this process have been large-scale exercises involving staff from the RAAF, DSTO, Army, Navy, Customs, Coastwatch and Australian Search and Rescue. In a very real way the AEW&C modelling has provided detailed insights into the future operation of this important ADF capability.

Although the AEW&C project provides an excellent example of the way in which the RAAF has utilised experimental activity in the past, it also indicates the time frame usually adopted in the past has only been forward to the point of the introduction into service of a new platform. *Force 2020* and the *Future Warfighting Concept* have rightly concluded that we must look even further into the future and try to determine what it may contain in order that we can effect change now to prepare for that future. Such a responsibility obviously lies outside the responsibility of a single acquisition project and has been devolved upon the RAAF's conceptual and doctrinal centre, the Air Power Development Centre (APDC).

RAAF AIR POWER DEVELOPMENT CENTRE

With the requirement for each of the forces to develop a conceptual and experimental capability being so strongly stated in *Force 2020* and the *Future Warfighting Concept*, the RAAF has taken action to comply with these directives. For the RAAF the responsibility to formally develop concepts, and experiment with them in order to produce validated concepts, now resides with the APDC. Indeed, the concept development and experimentation process has determined the whole organisational structure of the APDC. Seven senior positions have been established in the APDC, in the areas of History, Futures, Concepts, Experimentation, Doctrine and Education, Strategic Planning and Engagement.

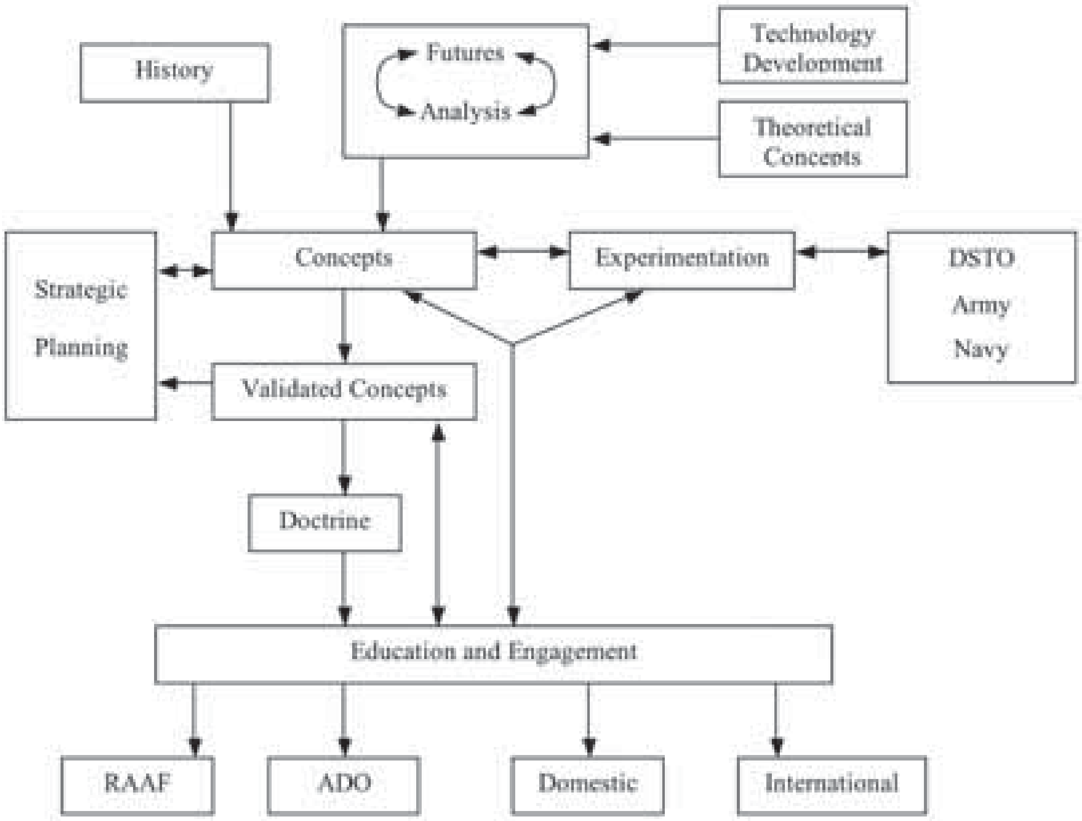

Figure 1.1 – The RAAF Air Power Development Centre[16]

Figure 1.1 outlines the structure of the APDC and the high level relationships that exist between the different functional areas within the organisation. The central core of this organisation is the concept development and experimentation process that draws upon and feeds all other APDC activities.

The only area of speciality not specifically mentioned in this organisational description, is that of Space. The functions of the Space staff at the APDC are located within the concept development area. In addition to the conceptual work they do, these personnel also provide inputs to the experimentation, futures analysis, doctrine, education and engagement functions of the APDC in relation to Space matters.

16 Air Commodore Mark Lax, *The Air Power Development Centre: Positioning the Air Force for the Future*, Keynote Address presented to the Defence Experimentation Symposium, DSTO Salisbury, 1 April 2004; Air Power Development Centre, *Air Power Development Centre: Strategic Overview*, Air Power Development Centre, Canberra, 2004.

RAAF EXPERIMENTION CAPABILITY

Development of the RAAF experimentation capability will be harmonised with that of an Aerospace Synthetic Environment (ASE), which will allow virtual, constructive and live simulations to take place at various levels of aggregation and fidelity, depending on the experiment to be undertaken. The ASE will be grown out of the Virtual Air Environment (VAE) that is currently under development by Air Force as a distributed team training system. The VAE will be readily adaptable to system-level experimentation through appropriate accreditation of the system components and development of data collection, analysis and interpretation methodologies. Many VAE components, including data sets and models, will be assimilated for use as the ASE is developed to support more aggregated simulations that will take place to explore tactical and operational-level concepts and options.

The ASE will be designed from the outset to interface with other synthetic environments so that it can operate as part of a federation in joint, integrated and combined experiments. The adoption of open standards should also facilitate the sharing of data sets and models with other simulations. The joint experimentation capability that will result from the development of this federation is known as the Virtual Integrated Experimental Warfighting Laboratory (VIEWLAB).

The ASE will be the centrepiece of a wider RAAF experimentation capability that will include the use of seminar war games, laboratory experiments and live trials. A management framework exists in the APDC to develop and manage the RAAF experimentation program, design and conduct the experiments, accredit the tools to be used, analyse the results and report on outcomes of experimental activities.

In addition, a commitment will be required from senior leadership for the assets of the Air Force to be available for use as part of an 'aerospace laboratory'. In times of peace, the entire Air Force should be made available for innovation and improvement.

As a general rule, RAAF experimentation will be limited to the tactical and operational levels of war. Experimentation with strategic concepts is best conducted in a joint or integrated environment. That said, formal links between the RAAF and the joint experimentation frameworks have also been established. These links will cover the management, procedural and application perspectives of experimentation.

The first of these links is the RAAF's involvement in the series of experiments conducted by the Army and the Navy. *Headline* is the Army/DSTO Experimental Series that explores Future Land Warfare issues, while *Headmark* is a series of Navy Experimental Workshops that examine and analyse future capability issues involved in transitioning the Navy-in-Being to the Future Navy.

The RAAF also participates in the Revolution in Military Affairs (RMA) seminars, workshops and working group meetings. Membership of the RMA Working Group includes representatives from across the ADO including Australian Defence Headquarters (ADHQ) and the Service headquarters. The Working Group and ADHQ coordinate RMA seminars and workshops as required.

The Defence Futures Forum (DFF) was organised to coordinate the myriad of futures initiatives being conducted throughout the ADO and to foster the sharing of ideas, methodologies and insights. The futures analysis being undertaken by the APDC dovetails with the DFF efforts and seeks to distil and analyse the implications for RAAF of the DFF's work.

Air Force participates in Headquarters Australian Defence Force's (HQADF) computer-based wargaming evaluation of current and future force options against a range of scenarios.

Air Force is also represented in the KRAIT war games, which are seminar-style war games that explore Future Warfare Concepts (FWC). KRAIT games are held several times each year and involve a mix of technologists, warfighters and strategic planners. Orders of Battle are based on an 'evolved' ADF (an ADF similar to today's force), a 'transformed force' (an ADF that has embraced RMA concepts, technology and doctrine) and a 'Red' force. Scenarios are drawn from plausible future regional contingencies.

Project *Sphinx* aims to develop a shared understanding of future warfare across the ADF and seeks to explore alternative futures for both Australia and the region, and develop a series of FWC.

The final link to joint and multinational experimental activities is the RAAF's involvement in Global 200X. This is a series of war games held at the US Naval War College, which the RAAF has participated in over several years.

In conducting these activities and developing these capabilities the purposes of the experimental capability created by the RAAF remain to provide better advice for decision-makers, help the RAAF to learn about the future, and help military innovators to improve and prove their ideas without taking huge risks or outlaying significant resources. While this support is primarily aimed at informing the senior RAAF leadership, the wider RAAF and ADF community will also benefit from the insights obtained. The advice provided will enhance the professional judgements given by the RAAF senior leadership group as they participate in committees and boards that govern the acquisition and development of new and existing ADF capabilities.

PROFESSIONAL MASTERY AND EXPERIMENTATION

In the capstone doctrine publications of the ADF professional mastery has been recognised as both a core quality that needs to be developed in the ADF's personnel[17] and as being central to the warfighting effectiveness of the ADF.[18] Professional mastery occupies this central role, as it 'is the human element of professional mastery that brings our strategic objectives, doctrine and materiel strength together to form a cohesive and creative force'.[19] In past editions of *The Air Power Manual* the RAAF has also highlighted the important role of professional mastery by making it the paramount principle of air power application.[20] Indeed, 'professional mastery is the master air power principle because it is the means through which the other principles are understood and applied in accordance with particular circumstances'.[21]

The RAAF's capstone doctrine publication, *Fundamentals of Australian Aerospace Power*, accords with these characterisations of professional mastery but also includes an interesting observation in connection with the professional mastery of senior officers. The professional mastery demanded of these officers 'requires a clear understanding of the strengths and limitations of aerospace power and the ability to imbue in others an understanding of those characteristics'.[22] This additional requirement is also important in the field of experimentation as those involved in experimental activities must also be able to imbue in others a similar understanding of their specialised knowledge and experience.

In regard to the operational aspect of professional mastery, the Army has gone one step further in stressing the importance of this quality. In its single Service doctrine publication, *The Fundamentals of Land Warfare*, the Army has stated that professional 'mastery is the single most important prerequisite for operational success'.[23] The obvious importance of this essential quality in all military operations raises the question as to how it can be inculcated in the personnel of the ADF.

The subject of the importance and development of professional mastery was addressed in a Land Warfare Centre Working Paper in 1999. Lieutenant Colonel Greg de Somer

17 Department of Defence, *The Australian Approach to Warfare*, Department of Defence, Canberra, 2002, p. 26.

18 Department of Defence, *Future Warfighting Concept*, p. 30.

19 ibid.

20 Ian MacFarling, *Air Power Terminology*, Aerospace Centre, Canberra, 2000, p. 102.

21 Royal Australian Air Force, AAP1000, *The Air Power Manual*, Third Edition, Air Power Studies Centre, Canberra, 1998, p. 51.

22 Royal Australian Air Force, AAP1000, *Fundamentals of Australian Aerospace Power*, Fourth Edition, Aerospace Centre, Canberra, 2002, pp. 19–21.

23 Australian Army, Land Warfare Doctrine 1, *The Fundamentals of Land Warfare*, Combined Arms Training and Development Centre, Sydney, 1999, p. 5-3.

and Major David John Schmidtchen took as their thesis topic, *Professional Mastery: The Human Dimension of Warfighting Capability in the Army-After-Next*. A number of the comments made by them are of interest in regard to military experimentation.

> Professional mastery is the human dimension of warfighting capability.[24]
>
> It is reasonably apparent to most observers that the military profession requires a high degree of expertise with specialised knowledge and skills. This experience, acquired only by prolonged education and experience, is the basis of measuring objective standards of professional competence. Professional knowledge is essential for the achievement and manifestation of two components: the first, imparting a broad liberal, cultural foundation; and the second, imparting the specialised skills and knowledge of the profession. The test of this professional ability is the application of technical knowledge in a human context. Also, because warfare is not frequently practiced, practitioners must rely on the laboratory of past experiences to gain vicarious experience in war.[25]
>
> Professional mastery … is developed through the challenge of confronting novel problems or contexts, such as the changing nature of conflict.[26]
>
> The aim [of professional mastery] is to sharpen their professional judgement through challenge and to increase the mastery of the military art through experience.[27]
>
> Knowledge generated from experience contributes to increased proficiency and mastery and builds on competence.[28]

From these comments we can see that the development of professional mastery can be obtained through training, education, doctrine, the laboratory of past experience, utilising vicarious experience, actual experience, challenge, and the changing nature of conflict. Military experimentation can play a role in each of these methods of promoting professional mastery.

By experimenting now with future concepts, technology and organisations, we can begin to understand what we need to include in our training, educational and doctrinal processes to prepare the ADF for the future. Experimentation draws upon the past experience of subject matter experts to determine how innovative technology and methods may be employed. This is turn provides insights into the future conflict environment and the RAAF vicariously benefits through the experience obtained by those involved in the

24 Lieutenant Colonel Greg de Somer and Major David John Schmidtchen, *Professional Mastery: The Human Dimension of Warfighting Capability in the Army-After-Next*, Land Warfare Studies Centre, Canberra, 1999, p. 2.
25 ibid., pp. 7–8.
26 ibid., p. 9.
27 ibid., p. 22.
28 ibid., p. 29.

experiment. The participants obtain actual experience of the changing nature of conflict in challenging situations without the attendant cost of actual conflict. In a very real way military experimentation is a way in which the professional mastery of the ADF can be made an enduring and not just a temporary attribute of the Australian profession of military arms.

In the next chapter of this work we will go on to look briefly at some historical considerations in the progress of military experimentation. In doing this two main points become evident. The first is that military experimentation is nothing new and has been around for a very long time. The second point to be made is that there appears to be a correlation between professional mastery, military experimentation and operational success. Alexander the Great, the Romans, the Byzantines, the renaissance Spanish Army, Gustavus Adolphus and Napoleon are all recognised as fielding successful military forces that were the most professional forces of their day and all were also involved in military experimentation in some way. Indeed, as the title of this publication suggests, a study of military history indicates that one of the hallmarks of a professional military force is that it involves itself in some form of military experimentation in an effort to understand the future and how it can prepare for and adapt to it.

ANNEX:

A. Threats to an effective warfighting experiment

THREATS TO AN EFFECTIVE WARFIGHTING EXPERIMENT

	Ability to use the capability	Ability to detect changes	Ability to isolate reasons for change		Ability to relate results to operations
			Single Group	Multiple Groups	
Treatment or Capability	**Capability not workable.** Do the hardware and software work?	**Capability variability**. Are the systems and uses in like trials the same?	**Capability changes over time**. Are there system or process changes during the test?	NA	**Non-representative capability**. Is the experimental surrogate functionally representative?
Players	**Player non-use**. Do the players have the tactics, training and procedures to use the capability?	**Player variability**. Do individual operators in like trials have similar characteristics?	**Players change over time**. Will the player unit change over time?	**Player differences**. Are there differences between groups unrelated to the capability?	**Non-representative players**. Is the player unit similar to the operator unit?
Effect	**No potential effect in output** Is the output sensitive to capability use?	**Data collection variability**. Is there a large error variability in the data collection process?	**Data collection changes over time**. Are there changes in instrumentation or manual data collection during the experiment?	**Data collection differences**. Are there potential data collection differences between treatment groups?	**Non-representative measures**. Do the performance measures reflect the desired operational outcome?
Trial or Experiment	**Capability not exercised**. Does the scenario and Master Scenario Event List call for capability use?	**Trial conditions variability** Are there uncontrolled changes in trial conditions for like trials?	**Trial condition changes over time**. Are there changes in the trial conditions during the experiment?	**Trial condition differences**. Are the trial conditions similar for each treatment group?	**Non-representative scenario**. Are the Blue, Green and Red conditions realistic?
Analysis	NA	**Violation of Statistical assumptions.** Are the correct analysis techniques used and error rate avoided? **Low statistical power** Is the analysis efficient sample sufficient?	NA	NA	NA

CHAPTER 2
MILITARY EXPERIMENTATION: SOME HISTORICAL CONSIDERATIONS

ALEXANDER THE GREAT

In 328 BC Alexander the Great completed the conquest of the Persian Empire of King Darius. Not all of his new subjects welcomed such conquest and Alexander faced a rebellion in the province of Samarkand. In all, some seven cities came out in open revolt against Alexander's reign and besieged the occupying Macedonian forces of those cities. The city of Marakanda was the most distant from Alexander's base and he dispatched a force of 60 Companions (elite cavalry), 800 cavalry and 1500 pike-armed infantry to relieve the siege.[1]

The pike, a spear that could be up to 20 feet long, was the main weapon of the Macedonian infantry. It was used in deep infantry formations of 16 ranks, called phalanxes. The spears of the first five ranks extended out in front of the formation and presented a formidable obstacle to an enemy attempting to close with the phalanx and engage it in hand-to-hand combat. In attack against foot-troops and in defence against mounted troops the phalanx was a very dangerous opponent. The phalanx only had two weaknesses. The first was its vulnerability to missile fire from troops, usually on foot, armed with bows, slings and other missile weapons. A rapid and continuous advance by the phalanx usually countered such an enemy. The second weakness was the requirement to maintain the integrity of the phalanx's rigid formation. For example, rough terrain and/or being contacted on two fronts could disorder the formation of the phalanx and thereby create gaps in the wall of spear-points. These gaps could then allow an enemy to penetrate the phalanx's formation and engage the pikemen directly. By deploying the mixed force, mentioned above, to the relief of the besieged city of Marakanda Alexander was relying heavily on the strength of the phalanx to decide the issue, for in the experience of Alexander the phalanx was the decisive weapon system of his day.[2]

Alexander placed one of his generals, Andromachus, in overall charge of the relief expedition. In battle Andromachus, as well as being responsible for the overall conduct of the battle, would also command the Companions while Caranus would command the

1 Arrian, *The Campaigns of Alexander*, Penguin Books, Ringwood, 1982, pp. 208–10.
2 R. Ernest Dupuy and Trevor N. Dupuy, *The Harper Encyclopedia of Military History*, Fourth Edition, Harper Collins, New York, 1993, p. 50.

other cavalry, and at times some of the infantry would be placed under the command of Pharnuches.[3]

With the approach of the relief force the leader of the rebellion around Marakanda, Spitamenes, initially raised the siege and fell back from the advancing Macedonians. The Macedonians were not content with simply raising the siege and continued to pursue Spitamenes to ensure the destruction of the rebellious armed force. Shortly after his initial retreat Spitamenes received an addition to his force of some 600 Scythian horse archers. These troops combined the mobility benefits of mounted troops and the firepower advantage of foot archers. Emboldened by this increase in strength Spitamenes determined to engage the Macedonian relief force in battle on ground of his own choosing.[4]

Spitamenes took up his position on level ground near the Scythian Desert and in the vicinity of the river Polytimetus. The ground ideally suited Spitamenes' mounted archers and he

> dispatched his cavalry to gallop round the Macedonian infantry formation, discharging their arrows as they rode. Pharnuches' men [infantry] attempted to charge, but to no purpose; the enemy, on their swifter horses, were out of range in a moment. Their horses, moreover, were fresh, while those of Andromachus' men [cavalry] were in poor condition from long, forced marches and inadequate feeding. The Macedonians tried to stand their ground, now to withdraw; but all to no effect... The Macedonians were helpless, and all who survived took refuge on a small island in the river; but this did not save them, for Spitamenes' cavalry and the Scythians surrounded the island and shot them down to a man. The few prisoners taken were promptly butchered.[5]

One of the results of this disaster was the genesis in Alexander of a determination to strengthen the phalanx's weakness to missile weapons. The concept he developed was to exchange some of the phalanx's ranks of pikemen for ranks of troops armed with a bow (a lighter, longer-ranged missile) and javelin (a heavier, but shorter-ranged missile). Alexander's determination would find expression in an experimental program that was carried out some years later in more settled times, in 323 BC. After experimenting with different combinations of bowmen, javelin men and pikemen, Alexander arrived at a solution.

> He [Alexander] was also devising a revolutionary tactical reform of his infantry. In each file of the phalanx (16 deep) henceforth only four should be Macedonians, the file-leader, his second and third, and the rear rank man… They alone would

3 Arrian, *The Campaigns of Alexander*, pp. 205, 209–10.
4 ibid., pp. 208–10.
5 ibid.

> carry the sarissa [pike]; after all, three spear-points protruding in front of the front rank should be enough; and the other twelve would be Asiatics armed with bows or javelins and the short sword. Presumably a new battle-drill was to have been worked out whereby the archers would open the battle; then the men with heavy javelins would pass through them; and finally the whole mass would close [with the enemy], with the spearmen in front.[6]

Although Alexander experimented with the phalanx to correct its weakness to missile fire, he never actually employed the new-model phalanx in battle. The reason for this was probably the racial tension that existed between Alexander's Macedonian veterans and the troops supplied by the new Persian dominion. The Macedonians were already displeased with Alexander's adoption of Persian customs, manners and dress, and had publicly demonstrated their dissatisfaction with Alexander for his perceived rejection of Macedonian culture. Should the planned changes have been given effect, the phalanx in quarters, and in the field, would have dispersed Alexander's loyal Macedonians among the subject Persians in the ratio of four Macedonians to twelve Persians. Such circumstances would have provided a prime opportunity for rebellion by the Persians against Alexander's rule.

> The main point to be made here is that in the age of Alexander the Great military experimentation took place. The experiments that Alexander carried out with the phalanx were inspired and guided by a concept that had developed in his mind of incorporating missile weapons in the organisation of the phalanx for use in both offensive and defensive operations. The proposed reorganisation of the phalanx also prefigured some of the changes that the Romans would make in improving their tactical system that was based on the legion.[7]

ROME

In the early years of the Roman Republic the bulk of the fielded army fought in a phalanx-like organisation, armed with long spears and small shields. The infantry were supported by light-infantry and cavalry in similar fashion to Alexander's Macedonians.[8] In about 281 BC, Rome's expansion into southern Italy alarmed some of the Greek City states established in that area. Tarentum, in particular, was so concerned that it declared war on Rome and sought for allies to assist it in the ensuing armed conflict. Pyrrhus, the King of the Greek Kingdom of Epirus, became an ally.[9]

6 A.R. Burn, *Alexander the Great and the Middle East*, Penguin Books, Ringwood, 1973, p. 177; R.D. Milns, *Alexander the Great*, Robert Hale, London, 1968, p. 254.
7 ibid., pp. 177–78.
8 Archer Jones, *The Art of War in the Western World*, Harrap, London, 1988, pp. 26–27.
9 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, p. 66.

Pyrrhus landed in Italy with a force that included 20,000 infantry organised into Macedonian-style phalanxes and 3000 cavalry. Pyrrhus also included elephants in his army; these had never before been encountered by the Romans. In the war that was fought between Rome and Pyrrhus there were three major battles. Heraclea in 280 BC and Asculum in 279 BC were victories for Pyrrhus, though after Heraclea Pyrrhus was reputed to have said, 'One more such victory and I am lost'. Asculum was also a hard won victory for Pyrrhus and it is from his experience in these two battles that the term 'Pyrrhic victory' is derived. The third, and final, major battle was that of Beneventum in 275 BC. In this battle the Romans were at last victorious over Pyrrhus, and decisively so. Pyrrhus left Italy that same year, though the war dragged on in his absence until 272 BC when the Romans were finally able to conquer the whole of southern Italy.[10]

In the period surrounding this war with Pyrrhus, the Romans became disenchanted with the phalanx style of infantry organisation. Though we do not know the details it is during this period that the Romans made significant changes to their style of infantry combat, most likely as a direct result of their war with Pyrrhus. The reforms introduced by Camillus replaced the long-spear with the pilum, a short, heavy throwing spear with a wooden body and a metal shaft and point. The pilum was designed so that when it was thrown and embedded in an enemy, or their shield, the shaft would bend due to the weight of its heavy wooden body. When the pilum was bent it could not be easily straightened and so prevented the enemy from withdrawing the weapon and using it against the Romans whom had originally thrown it. The small shield of the early armies was also replaced with a large metal-framed shield called the scutum. This shield was of sturdy enough construction to protect the legionary from missile weapons, such as bows and slings, and hand-to-hand weaponry, such as pikes, spears and swords. The concept that drove such dramatic change in weaponry also involved the reorganisation of the legion itself.[11]

When organised in Macedonian style, the Roman army was subject to the same weakness to disorder and disruption as was the phalanx. The Romans therefore completely changed the way the army would deploy for battle. Instead of creating a continuous wall of spears, the Romans now divided up their army into smaller tactical units, called maniples, each of six ranks and containing a total of 120 men. These smaller units were arranged in three lines with gaps, of maniple width, between each maniple. The gaps in the front line were covered by the maniples of the second line and the maniples of the third line covered the gaps in the second line. The whole arrangement resembled the layout of a chessboard. Such an arrangement provided greater flexibility and maneuverability for the legion as it approached an enemy force, as the rigid requirement to maintain a continuous front among a number of larger units was removed. So organised, the legion was also better able to react to events that would normally disorder a phalanx, such as enemy

10 ibid., pp. 66–67; Jones, *The Art of War*, pp. 28–29.

11 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, pp. 79–81; Jones, *The Art of War*, pp. 26–28.

flank attacks, ambushes, attacks by elephants and rough terrain. In these circumstances part of the legion could be detailed to act independently in a different direction without disordering the rest of the legion. As the legion closed with the enemy line of battle the maniples of the second line could move forward at the last moment so that the front line maniple's flanks were not exposed. In similar fashion the legion standing on the defence could have its maniples of the first line move back into the gaps of the second line as an enemy came close to contact.[12]

Unlike Alexander we have no recorded detail of the testing, trial and experimentation that must have taken place to develop the new weapons and a whole new organisation to employ them. What we do know, however, is that the Romans were renowned for their professional approach to warfighting as attested to by a number of the ancient historians, Josephus being one of them. Josephus had been a commander of the Jewish forces that opposed the advance of the Roman legions into Palestine in 67 AD. He noted:

> Now here one cannot but admire at the precaution of the Romans, … indeed, if any one does but attend to the other parts of their military discipline, he will be forced to confess that their obtaining so large a dominion hath been the acquisition of their valor, and not the bare gift of fortune; for they do not begin to use their weapons first in time of war, nor do they then put their hands first into motion, while they avoided so to do in times of peace; but, as if their weapons did always cling to them, they have never any truce from warlike exercises; nor do they stay till times of war admonish them to use them; for their military exercises differ not at all from the real use of their arms, but every soldier is every day exercised, and that with great diligence, as if it were in time of war, which is the reason why they bear the fatigue of battles so easily; … nor would he be mistaken that should call those their exercises unbloody battles, and their battles bloody exercises.[13]

The 'unbloody battles' of the Romans surely provided a resource for the Romans that allowed them to experiment, develop and refine the new weapons, organisation and battle tactics of the legion before they were used in the 'bloody exercises' of actual combat. This new Roman combat system proved to be superior to all others it encountered in Europe. The superiority of the Roman way of war would continue until it was defeated decisively by the Goths—who by this time had become a predominantly mounted force—at the battle of Adrianople in 378 AD.[14] The professionalism of the Romans, however, continued in the armed forces of the Eastern Empire of the Byzantines.

12 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, pp. 79–81.

13 Flavius Josephus, *The Wars of the Jews*, Book III, Chapter 5, Paragraph 1, http://www.ccel.org/j/josephus/works/war-3.htm, accessed 4 May 2004.

14 Charles Oman, *A History of the Art of War in the Middle Ages – Volume One: 378–1278 AD*, Greenhill Books, London, 1991, pp. 12–15.

The case of the Romans is one of the first situations where a force was completely changed through the process of CD&E. The change was from a rigid wall of shields relying on the spear as the main weapon, to a highly mobile, flexible force that used a variety of weapon effects to engage its enemies. The professional mastery of its troops was developed through regular training and exercises, and exhibited in the complex manoeuvres and tactics of the legion.

BYZANTIUM

Following the loss at Adrianople the Eastern Emperors acknowledged that cavalry had become the dominant military force of the age. Without means to replace rapidly the forces lost at Adrianople, the Byzantines first incorporated cavalry into their own army by hiring such troops from the nations that surrounded them, including the Gothic victors of Adrianople. Foreign forces continued to dominate the Byzantine army for a century after the great battle. After this period the Byzantines developed their own cavalry arm in a distinct fashion that would serve them well, with little change, for the next 500 years.

This dominance, like that of the Roman legion that preceded it, was due to the fact 'that in courage they were equal to their enemies; in discipline, organisation, and armament far superior'.[15]

> The Byzantines were able to achieve and maintain these superiorities by their emphasis on analysis: analysis of themselves, of their enemies, and of the geophysical factors of combat.[16]

In contrast to the other nations of the time, the Byzantines studied the practice of warfighting as an art and wrote comprehensively on the matter. Three manuals in particular—Maurice's *Strategikon* (580), Leo the Wise's *Tactica* (900) and an untitled manual by Nicephorus Phiocas (980)—demonstrate the theoretical effort expended by the Byzantines over the period of their dominance. The individual strengths and weaknesses of a range of enemies are analysed in these manuals and specific strategies and tactics that had been evaluated and tested are recommended.[17]

Such manuals were of great use in the instruction of officers who commenced training while still in youth.

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15 ibid., pp. 171–72.
16 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, p. 233.
17 ibid.; Oman, *A History of the Art of War in the Middle Ages*, p. 172.

> The peace time training of these youths was probably not much different in concept from a modern officer training program: emphasis on the basic tasks of a soldier, mastery of weapons and horses, study of the writings of military experts of the past and present, exercises in which theoretical knowledge was put to practice.[18]

With these attributes of theoretical inquiry, professional training and analysis representative of their army the Byzantines developed a unique military force.

The army was based on the heavy cavalry who were armoured from head to foot, and armed with lance, shield, sword, dagger, sometimes an axe and, distinctively, a bow. In this way the heavy cavalry combined the strengths of mobility, firepower and protection in the one troop type. Great flexibility was also provided as the

> Men and horses were superbly trained and capable of complex evolutions on drillfield and battlefield. There was great emphasis on archery marksmanship and on constant practice in the use of other weapons.[19]

Cavalry training also included dismounted operations in the appropriate circumstances. The only weaknesses the cavalry had were the rough terrain and that, being mounted, their bows had a shorter range compared with foot archers.

The Byzantine infantry who were divided almost equally into heavy and light infantry compensated for this weakness. The light infantry were armed with bow and other missiles and could therefore compete on even terms with enemy archers as well as operate without disruption in difficult terrain. The heavy infantry were armed much the same as the cavalry and could be used to assault enemy infantry formations or stand on the defence providing a secure base of operations for the Byzantine light infantry or heavy cavalry.

Byzantine military thought provides one of the first instances of strategic planning that clearly employed the use of effects-based operations. Each enemy was well understood and appropriate effects were selected for use against them. This did not always entail the clash of military forces but could include a wide range of alternative approaches. The second thing that the Byzantines did that we need to note is that they recorded their concepts and methods and used them for training, discussion and debate, which, in turn, led to the development and refinement of the concepts. These concepts were then used to develop unique capabilities for the armed forces that dominated their enemies for centuries.

18 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, p. 239.
19 ibid., p. 236.

THE GUNPOWDER REVOLUTION

The advent of gunpowder weapons is usually accepted as when ancient warfare ends and medieval warfare begins. At the start of this new age, however, the weapons embodying the new technology and their firepower were not thoroughly understood and it took some time for their potential to be realised.

> Though outmoded and inadequate, the medieval combat formation of three massive 'battles'—dense blocks of mounted men and infantry—lingered on into the early years of the [16th] century. These unwieldy masses were particularly vulnerable to firearms and artillery.
>
> The Spanish took the lead in efforts to solve the problem by thoughtful experimentation and improvisation. Based on the experience of Córdoba (and possibly at his suggestion or instigation), in 1505 King Ferdinand created twenty units called *colunelas* (columns) each consisting of some 1000–1250 men: mixed pikemen, halberdiers, arquebusiers, and sword-and-buckler men, organised as five companies. This was the first clear-cut tactical formation based upon a coherent theory of weapons employment to be seen in Western Europe since the decline of the Roman Cohort.[20]

The Spanish took the lead in the process of experimenting with different combinations of infantry armed with the new gunpowder weapons and the traditional pike, halberd and sword. The aim of this experimentation was to combine in a single formation the benefits of foot armed with close combat weapons—which could engage in close combat with either cavalry or infantry—and foot armed with the musket, which provided significant firepower effects at longer range. It is interesting to note that in many ways this search for a combination of missile fire and close combat effects was based on a concept similar to that which motivated Alexander the Great to experiment with mixed pike, bow and javelin formations. The Spanish experimented over time with increasing the ratio of troops armed with gunpowder weapons to those armed with close combat weapons. In 1571 a muster of Spanish troops based in Holland showed that there were two missile firers to every five close combat troops. By 1601 this ration had become three firers to every close combat soldier.[21]

The opening of the 17th century saw the battlefields of Europe dominated by the results of Spanish experimentation with the 'Spanish square' being the favoured infantry formation in most armies.[22] The transition, however, was not yet complete. While the Spanish had taken the initial lead in this process of experimentation, it fell to the Dutch

20 ibid., p. 500.

21 Geoffrey Parker, 'Dynastic War 1494–1660' in Geoffrey Parker (ed.), *Cambridge Illustrated History of Warfare*, Cambridge University Press, Cambridge, 1995, p. 154.

22 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, p. 575.

to complete the transition from formations of mixed weapons to the entirely musket armed formations.

> Several Spanish commanders experimented with tactical systems designed to make optimum use of firepower, but none worked as well as the innovations of Maurice of Nassau, son of the prince of Orange defeated by Alba in 1568, who during the 1590s began to introduce his troops to 'exercises'—forming and reforming ranks, drilling and parading—in the manner advocated by Roman writers. It was while reading Aelian's *Tactics* in 1594 that Maurice's cousin, William Louis of Nassau, realized that rotating ranks of musketeers could replicate the continuous hail of fire achieved by the javelin and sling-shot throwers of the legions. This device overcame the basic weakness of the muzzle-loading musket—its slow rate of fire—because an infantry formation deployed in a series of ranks, the first firing together and then retiring to reload while the others did the same, would produce a continuous hail of lethal fire.[23]

The Dutch organised their infantry into formations of ten ranks of entirely musket-armed troops. Experimentation had determined that with ten ranks a continuous, uninterrupted barrage of musket fire could be maintained. However, the innovations of the Dutch were not generally incorporated by other nations as the Dutch rarely submitted their new organisation to the supreme test of battle. One who did take note of these changes was King Gustavus Adolphus of Sweden who incorporated these refinements, among others, into his reforms of the Swedish army.[24]

In addition to the reforms introduced by the Dutch, Gustavus adopted a lighter musket that fired a paper cartridge containing a pre-measured amount of gunpowder. These two innovations increased the rapidity of loading and firing the musket. Gustavus was then able to achieve the firepower produced by ten ranks of Dutch infantry with only six ranks of Swedish infantry. This new style of fighting proved its overwhelming superiority over all other methods when Gustavus obtained his victory at the battle of Breitenfeld in 1631.

Throughout this process of the evolution of infantry combat, experimentation had been central to the work of the Spanish, Dutch and Swedish innovators. Again the process was concept led, the obvious benefits of gunpowder weapons and the firepower they could deliver had to be integrated into defensible infantry formations. The concept of developing larger weapons and making them available on the battlefield in the form of mobile artillery had also undergone some development but more significant change was still to come in the age of Napoleon.

23 Parker, 'Dynastic War 1494–1660', p. 154.
24 ibid., p. 155; Jones, *The Art of War*, pp. 222–23.

In the gunpowder revolution the understanding of future capabilities and historical concepts combined eventually to develop a commanding form of combat as practiced by Gustavus Adolphus. Experimentation was central to the efforts of the Spanish, Dutch and Swedish armies in discovering a viable concept of warfighting.

NAPOLEON

Napoleon is recognised as one of the 'Great Captains' of history and his words and works are still profitably studied. Napoleon was fortunate in what he inherited from a great deal of French theory and experimentation that had taken place both before and after the French Revolution. In the field of infantry combat a great deal of theorising had taken place.

> Following defeats sustained in the Seven Years' War, French military experts sought a new tactical doctrine for the infantry. The relative advantages of fighting in line or column were carefully weighed. Each formation had its champions, and the result was what were known as *les grandes querelles*. Guibert—on balance—came out in favor of linear formations, but acknowledged the value of columns for moving into action, especially over broken ground. The protagonists of the column, most particularly Folard and Mesnil-Durand, discounted the effects of infantry fire power, and preached the all-importance of shock and weight. The Duc de Broglie experimented with the latter suggestions at the Camp of Vassieux in 1778, and found them largely impracticable; the eventual outcome was a compromise, embodied in the Provisional Drill-Book of 1788, which refused to be dogmatic on the matter but taught the advantages conferred in many situations by adoption of '*l'ordre mixte*'—a combination of line and column. This Drill-Book was reissued in an edited form in 1791, and formed the theoretical basis for the infantry tactics employed throughout the Revolution, Consulate and First Empire.[25]

Thus the infantry formations and tactics employed by Napoleon throughout his period of active campaigning were based on the results of theories and concepts tested and refined through experimentation. Napoleon himself also participated in, and benefited from, experiments conducted in the artillery arm. As a young, newly graduated officer in the artillery arm, Napoleon's intellectual abilities were noticeable and marked him out for one of his very first postings.

> The development of his military ideas was at first wholly an intellectual process, and much of this was certainly carried through during the year 1788–89, when he was a nineteen-year-old lieutenant stationed at the Artillery Training School at Auxonne. Besides being in command of the 'demonstration squad' charged with the duty of trying out new theories pertaining to his parent arm—an occupation

25 David Chandler, *The Campaigns of Napoleon*, Weidenfeld & Nicolson, London, 1998, p. 136f.

> stimulating enough in itself—the young Bonaparte also found time for intensive reading, using the comparatively well-stocked library of the school as the basic nourishment for his voracious mental appetites.[26]

With the command of the 'demonstration squad' Napoleon would have been at the forefront of experiments into the use and organisation of the French artillery. This experimental effort was a continuation of the work done by an earlier French artillery theorist, Jean Baptiste Vacquette de Gribeauval, who had finally succeeded, in the face of significant opposition, to have his ideas implemented in the Royal French Army by order of King Louis XVI in 1774.

> Gribeauval's reforms touched almost every aspect of French gunnery, Types of field artillery were standardized into three main categories (12-, 8- and 4-pounders), supplemented by a fixed proportion of 6" howitzers and mortars. Cannon were lightened by shortening the barrels, improving casting methods were introduced, and trails, carriages and caissons were redesigned. Thus the new-type 8-pounder, including trail and carriage, weighed 1,600 Kgs—as compared to 3,200 Kgs of the older cannon it replaced. Stronger, larger wheels and better harnessing arrangements improved mobility, whilst the improvement of sights, the introduction of inclination-markers and the issue of gunnery tables improved performance in action. The introduction of prepackaged rounds (serge bags containing shot and charge) speeded the rate of fire, and a new type of case shot was made available. ... Thus Napoleon inherited a reorganized and generally very effective artillery service.[27]

A characteristic of Napoleon's later combat operations was his employment of the '*grande batterie*', or massed artillery, to focus an overpowering concentration of artillery fire on a selected enemy position in order to literally blast a hole in the enemy line through which his infantry and cavalry could then attack. As well as being dependent on Gribeauval's and others' theoretical work, Napoleon probably developed the concept of the *grande batterie* while involved in the experimentation program conducted by the 'demonstration squad' of the French artillery arm.

Napoleon, therefore, benefited from programs of experimentation and reform within two of the three combat arms of the army, the infantry and the artillery. The experimentation that had taken place had developed all the tools that Napoleon, a master of the art of war, and the first to comprehend fully the possibilities offered by the new weapons and tactics, could now take and employ with such decisive effect.

26 ibid., p. 137.
27 ibid., p. 138f.

> For the first time since gunpowder had appeared on the battlefield, there was a substantial congruence among weapons, tactics and doctrine. The bayoneted flintlock musket and the smoothbore cannon had each been perfected to a point closely approaching its maximum potential. After centuries of experimentation, the tactical means of employing these weapons in combination with each other and with cavalry had been refined to the point where a skilful commander could exploit the full potential of his weapons and his arms to achieve decisive results with minimum cost.[28]

The characteristics of intellectual inquiry, military experimentation and professional mastery of the art of war that came to the fore in this period were not to be attributes that carried over into the next period for consideration: World War I.

The Napoleonic period provides an example of the benefits that can derive from experimentation. The form of infantry organisation and combat tactics that developed from the field exercises that were used to evaluate two opposing concepts resulted in the creation of a third, more effective, concept '*l'ordre mixte*'. The development of artillery concepts also provided a more effective artillery arm. In the hands of the consummate military professional, Napoleon, this new French Army became a powerful force that dominated Europe.

WORLD WAR I

So far in this chapter the historical examples considered have focused on situations where experimentation has been positively applied to produce successful outcomes. During World War I, however, more than a few examples exist where experimentation and its results were either misused or disregarded. Important lessons can be derived from these experiences in connection with military experimentation and therefore deserve to be highlighted for consideration.

The Von Schlieffen Plan

One of the first major operations carried out in World War I was the execution of the Von Schlieffen plan in 1914. The testing of the plan was carried out before the war in a number of war games, tactical exercises without troops, and live field exercises.

> Arguably the most decisive wargames of all time were played in 1905.
>
> That was the only year Count von Schlieffen's plan for a wide turning movement through neutral Belgium and Holland was wargamed before his retirement. Virtually all present were on the Kaiser's (German) team while two 1st Lieutenants played

28 Dupuy and Dupuy, *The Harper Encyclopedia of Military History*, p. 798.

> the armies of France, Britain, Belgium and Holland. The wargame concluded with the destruction of the France [sic] Army, so quickly that the British did not have time to come to her aid. The Kaiser was pleased.[29]

The obvious distortion of the experiment to favour the German cause worried the next Chief of the German General Staff, Helmuth von Moltke. Moltke approached the Kaiser and asked that he refrain from participating in future exercises as his presence stifled rigorous debate. Moltke then scrutinised the underpinning assumptions of the war game and completely updated the data that would be used in the next experiment.

> Moltke then used his more objective and comprehensive wargame to test the Schlieffen Plan. The game indicated the two armies on the outside of the great wheel would run out of ammunition two days *before* the campaign ended. Moltke saw to it that Germany organized the first two motorized units of any army, anywhere in the world—two ammunition supply battalions.[30]

In Moltke's replay the British were still too slow arriving in France to be of assistance in defending against the German offensive. The defeat of the French Army appeared to be still feasible to the German planners.

In Britain, however, similar wargaming exercises had revealed the same weakness in British plans for the mobilisation and transportation of their army to the continent.

> The most far-reaching conclusion drawn from the war game, however, was that since a German invasion of Belgium could be expected to succeed, France could not be expected to resist an attack on her own. This resulted, after 1906, in staff talks with the French also, and in the evolution of the Anglo-French Entente, on the strength of which France mobilized in 1914.[31]

To this point, aside from the Kaiser's war game, it appears that the experiments conducted have been used properly and their lessons applied correctly. This situation now changes.

The Battle of Tannenberg

In April 1914, with the threat of war looming, the Russian General staff commenced planning for an advance into East Prussia. The plans that were developed were wargamed using the two commanders who would have to carry out the actual operation, General

29 Roger Harrison, 'The Influence of War Gaming on the Schlieffen Plan', Georgetown University Graduate School, Washington DC, 1967, quoted in Matthew Caffrey, 'Toward a History Based Doctrine for Wargaming', *Air & Space Power Chronicles*, Fall 2000, p. 39.

30 Caffrey, 'Toward a History Based Doctrine for Wargaming', p. 40.

31 Andrew Wilson, *The Bomb and the Computer: Wargaming from Ancient Chinese Mapboard to Atomic Computer*, Delacorte Press, New York, 1969, p. 32.

Rennenkampf in command of the Russian First Army in the North and General Samsonov in command of the Russian Second Army in the south. The game revealed a serious weakness in the Russian plan.

> Because of the separation between the two armies, forced on the Russians by the geography of the region, the timing of the advance was crucial. Should one army begin its attack too late, the other would be exposed to a concentrated German counterattack. The game indicated that to avoid decisive defeat the Russian Second Army would have to begin its march three days before the advance of Rennekampf's First Army.[32]

The Germans, likewise anticipating the war on the Eastern Front and a Russian advance into East Prussia, had identified a similar weakness should the Russian armies advance simultaneously. The Russians, however, had made no adjustment to their original plan while the Germans had learned from their own war game exercise.

> Just four months later the same two Russian generals commanding the same two armies implemented what appears to be the exact same plan. Once again both armies made good initial progress. Once again they reached the area of lakes that made cooperation between the armies difficult. Now the real Germans placed a light screening force in front of the Russian's Northern Army and shifted the bulk of their forces to surround and destroy Russia's Southern Army—near the town of Tannenberg.[33]

The result of the Russians' failure to change their plans, to correct the weakness exposed by experimentation, was the disastrous defeat that they suffered at the Battle of Tannenberg where the Germans concentrated, first against Samsonov, then against Rennenkampf, and smashed both armies. But the Russians were not alone in ignoring the insights provided by experimentation.

The Battle of Neuve Chapelle

In early 1915 the British Army in France had conducted a series of experiments to determine the weight of artillery required firstly to cut gaps through German wire entanglements and, secondly, to destroy German trench lines. The results of these experiments were given to the planners for the next offensive.[34]

> In March 1915 Sir Henry Rawlinson's IV Corp attacked German positions at Neuve Chapelle. In preparation, Rawlinson took note of the length of German trench

32 Peter P. Perla, *The Art of Wargaming: A Guide for Professionals and Hobbyists, Naval Institute Press, Anapolis*, 1990, p. 49.

33 Caffrey, 'Toward a History Based Doctrine for Wargaming', p. 40.

34 Robin Prior and Trevor Wilson, *Command on the Western Front: The Military Career of Sir Henry Rawlinson 1914–18*, Blackwell, Oxford, 1992, pp. 30–31.

> needing to be subdued, and calculated the number of shells required for the task. The length of trench was not great and consisted only of a single line. Rawlinson was able to direct against it the required number of shells and the German line was duly overrun. That proved the limit of his advance.[35]

The application of the information provided by experimentation through the use of an appropriate weight of artillery attack had produced success. But this happy tale has no happy ending.

> It had been assumed that initial success would open the way to exploitation, but events proved otherwise. The Germans brought in reinforcements and created a new defensive line. Rawlinson's artillery had no opportunity to register the position of this line, the shells missed their mark, and all follow-up attacks failed.
>
> Thereafter in 1915, British endeavours on the Western Front proved quite in vain. Aubers Ridge, Givenchy, and Loos are names of unhappy memory in British military annals. The predominant reason for failure lay in the ratio of available artillery to the length of trench under attack. No commander (including Rawlinson) repeated IV Corp's calculation before Neuve Chapelle, presumably because it was feared that the answer would not come out right. ... the deficiency was clearly recognised at Loos, when poison gas was employed in an attempt to make good the shortfall in artillery ammunition.[36]

Two main points stand out from these passages. Firstly, in just about all British offensives before 1918 commanders expected and planned for a breakthrough of the German lines and held cavalry divisions in readiness to exploit such a rupture of the German defence. They believed a vigorous pursuit might ultimately lead to a rapid end to the war. During the whole of the war on the Western Front no such breakthrough occurred for the British, the French or the Germans. The maintenance of cavalry divisions proved a waste of manpower, horsepower and the resources consumed in their upkeep.[37]

The second point is that 'the ratio of available artillery to the length of trench under attack' actually decreased in the British offensives that followed Neuve Chapelle despite the evidence of experimental results and the validation of those results in the laboratory of actual combat in the initial success at Neuve Chapelle (see Table 2.1). Such a situation calls into serious question the competency, and professional mastery of those who commanded on the Western Front.

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35 Robin Prior and Trevor Wilson, *Passchendaele the Untold Story*, Scribe Publications, Melbourne, 2002, p. 18.

36 ibid.

37 See Prior and Wilson, *Command on the Western Front*, pp. 305–08, for the continuing expectation of Haig—at the battle of Amiens in August 1918—that a breakthrough might be achieved, cavalry might exploit the rupture and distant objectives seized. Also included is an informative discussion of the mismatched coupling of cavalry and tanks in the exploitation role.

Battle	Date	Frontage (in yards)	Artillery pieces	Frontage per artillery piece
Neuve Chapelle	Apr 1915	2,000	342	5.85 yards
Aubers Ridge	May 1915	2,400	342	7.01 yards
Givenchy	Jul 1915	6,000	400	15.00 yards
Loos	Sep 1915	11,200	484	23.14 yards
The Somme	Jul 1916	25,000	1,434	17.43 yards

Table 2.1 – Early British Offensives and their Artillery Support

The German 'Michael' Offensive

With the defeat of Russia in late 1917, Germany now had an opportunity to concentrate her whole military might on the Western Front against the British and the French, and before the new American ally could transport significant forces into the theatre. In keeping with German Army practice the coming German offensive, codenamed 'Michael', was wargamed.

> The Germans tested and rehearsed their plan for this last-ditch attack in several strategic games, all of which indicated that it seemed to have little chance to achieve decisive success.[38]

Delbruck, a prominent German observer of the time, writing in his defence journal during the war criticised the General Staff's actions.

> He stated that the wargames had roughly predicted the indecisive outcomes that took place—yet the General Staff went ahead. He claimed that if representatives of the Foreign Ministry were present at the wargames they would have realized that the initial advances would have caused panic in allied capitals. If before the offensives had lost momentum, he claimed, had Germany offered generous peace terms (like giving back—oh—most of Belgium) the offer might have been accepted. Now Delbruck feared Germany would not get nearly such good terms. He was right.[39]

38 Perla, *The Art of Wargaming*, p. 41.
39 Caffrey, 'Toward a History Based Doctrine for Wargaming', p. 41.

Like the Russians and the British before them, the Germans failed to accept the results of their experimentation and pursued a course of action that was based on no sound strategy but simply on hope.

It is apparent that, in many cases, the higher level commanders of the day did not have a correct concept of how war was to be fought. They appear not to have comprehended the absolute requirement for adequate artillery preparation and support; that infantry without artillery support could achieve little; that a decisive rupture (breakthrough) of the enemy defence followed by a vigorous pursuit that led to early victory was unattainable; and that cavalry had no place at all on the machine-gun and artillery swept quagmire of the battlefield.

The history of experimentation in World War I is a perplexing one. Three of the major combatants all carried out appropriate experimental activities and in some cases applied the results correctly. However, all three at other times also disregarded the insights offered by experimentation and consequently failed in their ensuing operations. In their disregard of experimental results the responsible commanders relied instead on their own warfighting concepts or simply on hope. Identifying valid concepts and understanding the implications of new technology, weapons and organisations is the very reason that military experimentation programs are pursued by professional armed forces. World War I provides a strong example of why this is required.

THE INTER-WAR PERIOD

German development of the 'Blitzkrieg'

In the postwar armed forces allowed by the Treaty of Versailles, Germany was severely limited to what capabilities it could field. However, the tools of historical analysis and experimentation allowed Germany to conceive and develop a revolutionary new form of warfare. Indeed, the transformation of Germany's armed forces in the inter-war period as a result of a continual program of concept-led experimentation and innovation has to rank as probably the leading example of what can be achieved by this process.

The first step in the German process was to establish a sound understanding of the war they had just lost. Some 57 committees were set up to re-examine World War I. The results of this analysis were embodied in a 1924 doctrinal publication on troop leadership. This doctrine stressed 'flexibility, initiative at all levels, exploitation, and leadership from the front'.[40] The sound basis of leadership that flowed from this historical analysis provided an important foundation for the operations of the armoured forces the Germans were experimenting with.

40 Williamson A. Murray, 'The World in Conflict' in Geoffrey Parker (ed.), *Cambridge Illustrated History of Warfare*, Cambridge University Press, Cambridge, 1995, p. 299.

The initial concept for the development and employment of armoured forces in Germany drew heavily on the theoretical and experimental work conducted by the British. One of the principal architects of the German armoured plans, Hienz Guderian, recorded the source of his inspiration:

> It was principally the books and articles of the Englishmen, Fuller, Liddell Hart and Martel, that excited my interest and gave me food for thought. These far-sighted soldiers were even then trying to make of the tank something more than just an infantry support weapon. They envisaged it in relationship to the growing motorization of our age, and thus they became the pioneers of a new type of warfare on the largest scale.
>
> I learned from them the concentration of armor, as employed at the battle of Cambrai. Further, it was Liddell Hart who emphasized the use of armored forces for long-range strokes, operations against the opposing army's communications, and also proposed a type of armored division combining panzer and panzer-infantry units. Deeply impressed by these ideas I tried to develop them in a sense practicable for our own army. So I owe many suggestions of our further development to Captain Liddell Hart.[41]

With the beginnings of an overall concept firmly based, the Germans began a series of annual experimental exercises that occurred over the period 1921 to 1939. The focus of these experiments covered many topics: the movement and coordination of motorised infantry; reconnaissance operations; employing and countering anti-tank defences, combining tanks, infantry and other troops in a panzer unit of increasing size (battalion, then brigade and eventually division), definition of tank types and roles, tank armament, tank protection, and the coordination of aircraft with armoured operations.[42] As the Versailles Treaty had prohibited Germany from possessing tanks, the early experiments had to utilise surrogate vehicles, which included canvas-covered frames, pushed around the exercise field by soldiers. However, this lack of actual equipment did not prevent the Germans from usefully experimenting with the capabilities that tanks were expected to deliver. From this experimental program was developed the form of mobile, armoured warfare that was given the name of 'Blitzkrieg'. This new form of warfare burst upon Europe in 1939 and immediately proved superior to all other methods of warfighting.

German U-boat development

In the realm of naval warfare the Germans also relied on experimentation to refine their plans for the conduct of the anticipated maritime war against Britain using the weapon that so nearly brought German success in World War I, the U-boat. In the winter of 1938 the Officer Commanding U-boats, Captain Karl Doenitz, held a war game designed

41 Heinz Guderian, *Panzer Leader*, Ballantine Books, New York, 1967, p. 10.
42 Hienz Guderian, *Achtung-Panzer!*, Arms and Armour Press, London, 1992, pp. 160–73, 191–99.

to explore the issues of implementing the 'group tactics' that he had earlier proposed. During the war these tactics would come to be known by the Allies as 'wolfpack tactics'. The 1938 war game focused on the command and organisation of group attacks, the location of enemy convoys and the massing of further U-boats for the final attack.

There were three main findings that were highlighted by the execution of the war game. First, at least 300 U-boats would be required to successfully prosecute a maritime campaign against Britain. Second, Doenitz found it impractical to exercise complete control of U-boat searches and attacks from his ashore headquarters. Consequently, changes were implemented so that his headquarters would only direct the search operations while command of the actual group attack was placed in the hands of a new on-site commander in a U-boat to be specially equipped with extra communications capabilities. Doenitz's final point was that with the current U-boat fleet strength (56 U-boats by war's outbreak[43]), plus expected new construction, he could not inflict anything more than 'a few pin pricks' against British merchant shipping in the next few years.[44] When war came the revised 'wolfpack tactics' proved to be all too effective, but Doenitz's finding that 300 U-boats would be required also proved valid and Germany did not have a sufficiently large force to conclude the campaign successfully.

In contrast to these examples of successful concept development and experimentation it is useful to examine one situation where the limited concept development and experimentation conducted, produced doctrine that failed the test of actual combat.

American development of unescorted strategic bomber doctrine

The doctrine developed by the American Army Air Corps in the inter-war period relied solidly on the premise that its heavy bombers could destroy the key industries of an enemy that made possible their war effort. In order to hit the small targets, which these industries represented, the Air Corps recognised the need to operate in daylight in order to achieve a high degree of precision in their bombing. Daylight operations would, however, also present the enemy with the best conditions for attacking the bombers with their defensive fighter aircraft and anti-aircraft artillery.

The Air Corps' doctrine assumed these threats would be diminished and countered by a number of factors. First, the experience of a few experiments suggested that locating the bombers would be exceptionally difficult.

> In 1938 Air Corps maneuvers, pursuit [fighter] units had been unable to locate inward-bound bombers except on the occasions when the bomber crews intentionally revealed their positions by radio transmissions, thus allowing the

43 Jones, *The Art of War*, p. 590.
44 Perla, *The Art of Wargaming*, pp. 42–43.

> pursuit pilots to get some intercept training. In short the theorem that 'a well planned and coordinated bombardment attack, once launched, cannot be stopped' was heavily based on the belief that pursuit aircraft would have great difficulty locating bombardment formations.[45]

Therefore, in a worst case situation the bombers would only be faced by a fraction of the enemy's defensive fighter aircraft and should not be overwhelmed if they operated in large formations themselves. Second, by grouping the bombers in tight defensive formations and arming them with heavy defensive armament they would present the fighters with a target that would be too difficult to attack successfully. Finally, by flying and bombing from high altitude the bombers could operate beyond the range of anti-aircraft artillery fire.[46]

Until late 1941, before the Americans became involved, the evidence of British and German failures in daylight, unescorted and escorted, bomber operations did not result in any change in American doctrine. Senior Air Corps leaders who visited England explained these failures away by attributing bomber losses to lack of defensive armament in comparison to American bombers (particularly in the rear quarter); use of vulnerable dive bombing techniques; use of large inflexible formations and poor air discipline. While admitting that fighter escort of bombers might be advantageous, the lack of such an escort 'should not justify the abandoning of important missions'.[47] Curiously, little mention seems to have been made of the defences significantly increased ability to concentrate its defensive fighters through the use of radar.

In mid-1941 with war a serious possibility America began fundamental planning for its involvement in the war. The plan for the air war formalised the primacy of unescorted, high-level, precision, daylight bombing in an air war against Germany while admitting the usefulness of fighter escort when it was available. Heavy bomber unit creation, however, was to take precedence after the needs of airbase safety had been met by the deployment of a minimum number of defensive fighter units.[48] The doctrine of unescorted, high-level, precision, daylight bombing, therefore, would govern the Air Corps's operations when it went to war.

A major test of Air Corps doctrine did not take place until the second half of 1943. In the period August to October 1943 the United States Army Air Force (USAAF) in Europe began unescorted penetration raids deep into Germany. Two raids of this period stand out, first and second Schweinfurt. The first raid took place on 17 August and was carried

45 Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907–1960*, Volume 1, Air University Press, Maxwell AFB, 1989, p. 100.

46 Martha Byrd, *Kenneth N. Walker: Airpower's Untempered Crusader*, Air University Press, Maxwell AFB, 1997, pp. 32–33.

47 Futrell, *Ideas, Concepts, Doctrine*, pp. 97–99.

48 ibid., pp. 108–11.

out by 200 B-17 bombers. Thirty-six did not return—a loss rate of 18 per cent. The second raid took place on 14 October and involved 228 bombers who suffered losses of 62 aircraft (27 per cent of the force) and 138 aircraft (61 per cent of the force) damaged to varying degree, including write-offs. Following the second raid deep penetration operations without escort were suspended.[49] Pre-war doctrine governing heavy bomber operations had proved unsound.

The problem with the USAAF's doctrine was that although it recognised the lessons of some limited experimentation it did not take into account all the evidence that became available to it over time. The effectiveness of radar in controlling the concentration and commitment of fighters against intruding bomber formations had been amply established in the Battle of Britain in 1940 and in the early daylight raids against Germany carried out by the Royal Air Force (RAF). In those same operations fighter aircraft clearly demonstrated their ability to penetrate the defences of a bomber formation and shoot down bombers without suffering prohibitive losses to themselves. This stubborn adherence to established doctrine by senior USAAF leaders was indicative of a fundamental problem:

> These pre-World War II aviation officers faced a complex scenario wherein experience was thin, money scarce, and encouragement scant. They based their arguments on theory, speculation and faith.[50]

Like the generals of World War I, the USAAF bomber commanders' concept of how war in the air should be fought, until October 1943, relied not on the evidence of experimentation and actual combat experience, but more on faith and hope.[51]

Probably the best example of how CD&E can be used to drive the development of capability in all its forms can be found in the experience of the German armed forces of the inter-war period. Historical analysis provided a concept of command and control that perfectly matched the operating methods that were developed. New concepts and ideas were actively sought, developed and evaluated through comprehensive experimentation. In contrast the bomber commanders of the same period emulated the World War I generals and relied on their own unproven concepts in the development of the unescorted daylight bomber doctrine. The evidence of radars performance, the ability to concentrate defensive fighters, and the increased firepower of fighter aircraft were all dismissed. In this period both the need for valid experimentation, as well as the impressive results it can enable, were each demonstrated.

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49 The United States Strategic Bombing Survey, *The United States Strategic Bombing Surveys (European War) (Pacific War)*, Air University Press, Maxwell AFB, 1987, pp. 14–15.

50 Byrd, *Kenneth N. Walker*, p. 37.

51 Alan Stephens, 'The True Believers: Air Power Between the Wars' in Alan Stephens (ed.), *The War in the Air 1914–1994*, Aerospace Centre, Canberra, 1994, pp. 21–49.

WORLD WAR II

The amount of concept development and experimentation that took place in World War II was prodigious. In the aerospace realm alone the war saw the first use of integrated air defence systems, electronic warfare, airborne radars, air-to-surface guided missiles, cruise missiles, ballistic missiles, jet fighters, jet bombers, surface-to-air guided missiles, and ultimately two atomic bombs. The developmental and experimental effort represented by this short list alone is monumental. Two examples from this war will suffice to illustrate some of the important principles that relate to experimental programs: the RAF's 1943 Ruhr Dams raid; and the German development of the vengeance weapons, the V-1 cruise missile and V-2 ballistic missile.

The 1943 Ruhr Dams Raid

The initial concept of attacking the German dams supplying the vital war industries of the Ruhr area originated in 1937 with plans developed by the British Air Staff. Although at that time means were not available to effectively carry out a raid against the dams, the plan was kept in mind and reviewed in the ensuing years. As part of the ongoing planning three dams had been identified as being particularly worthy of attack: the Möhne, Sorpe and Eder dams.[52]

In parallel to this official planning an aircraft designer at the company of Vickers-Armstrong, Barnes Wallis, had independently been studying the methods and results of attacking these important targets. Eventually, in July 1940 Wallis became involved in the official effort designed to breach the dams. From July 1940 until April 1942 the experimentation and research done by this combined team focused on destroying the dams using a much larger aircraft, flying at unprecedented height and dropping a larger bomb than then existed. In April 1942 Wallis radically changed direction when he conceived of the idea of using a bouncing bomb of smaller size that could be delivered at low-level by a current model bomber, the Lancaster.[53]

When the decision to proceed to execution was made in late February 1943, the organisers faced some large problems. A special squadron to carry out the attack, number 617, was yet to form; the explosive required was only newly developed; the bomb casing material had not yet been created; the Lancaster bombers that would carry the weapon had to be considerably modified; no method of maintaining a precisely accurate bombing height existed; and no means for determining the correct weapon release point had been discovered. All these problems would have to be addressed before the next period of suitable weather and dam water levels occurred in mid May, only ten weeks time.

52 John Sweetman, *Operation Chastise*, Jane's Publishing Company, London, 1982, pp. 1–6.
53 ibid., pp. 196–200.

In addition to an intensive training program undertaken by No 617 Squadron, considerable scientific and engineering experimentation was required to solve most of the outstanding problems, though the height and release point problems were solved simply. The height problem was solved by mounting two spotlights on the aircraft's fuselage pointed downward and toward each other so that at the precise dropping height the circles of light formed by the spotlights formed a figure eight on the surface of the water. The release point problem was solved when it was noticed that the target dams each had two towers mounted on their walls. By using the known distance between these towers, a simple, triangular, wood frame was constructed with a peephole on one corner and a nail in each of the other two corners. The frame was so arranged that, when looking through the peephole, the nails lined up with the dam towers at the correct release position.[54] Some crews achieved the same effect by placing grease pencil marks at the appropriate distances on the bomb-aimer's clear perspex panel and using a piece of string to mark the correct position of the eye when referencing the pencil marks.[55] With all these problems solved the first dropping of a full-scale, inert weapon was completed by No 617 Squadron on 11 May 1943. The first drop of a fully armed weapon followed on 13 May, only three days before the actual operation was carried out.[56]

On the night of 16/17 May 1943, nineteen Lancasters of No 617 Squadron carried out the attack on the dams. Of the nineteen aircraft dispatched, five were shot down before they reached their targets, one was so damaged by anti-aircraft fire that it had to return to base, and one bomber flew so low that it hit the surface of the North Sea resulting in the loss of its bomb and also returned to base. This left just twelve aircraft to carry out the attacks. Five aircraft attacked the Möhne dam and breached it, three attacked the Eder and breached it, two attacked the Sorpe for no result and one attacked the Ennepe for no result. The final aircraft could not find its target in misty conditions and returned to base with its weapon. After they had bombed, three other aircraft were lost on their return journeys, resulting in a total loss of eight aircraft on the raid, or 42 per cent of the force committed.[57]

With such losses the obvious question is 'was the raid worth it?' In judging the answer to this question the damage inflicted across a broad spectrum of activities needs to be considered. The obvious damage included disruption or destruction of water supply, electricity generation, steel production, housing, infrastructure, roads, railways, and agricultural production. Less obvious results included a significant construction and repair effort that was required to make good the damage inflicted, the diversion of up to 10,000 troops (that Germany could ill afford to lose) to the defence of dams throughout

54 ibid., pp. 66–67.

55 ibid., pp. 69–70.

56 ibid., p. 74.

57 Martin Middlebrook and Chris Everitt, *The Bomber Command War Diaries: An Operational Reference Book 1939–1945*, Midland Publishing, Leicester, 2000, pp. 386–88; Sweetman, *Operation Chastise*, p. 140.

Germany. Finally, a not insignificant impact was had on both German and British morale. When the full effects of the raid are considered the answer to the question is probably in the affirmative.[58]

A feature of this raid is the relatively limited amount of resources that were expended on the research, development and experimentation that underpinned the whole project. Only a single bomber squadron was employed in the whole program, and the use of other facilities and resources were not allowed to interfere with the ongoing British war effort. For a relatively small investment Britain had been able to accomplish a significant victory at a time in the war when it was desperately needed. In stark contrast to this frugal effort was the German vengeance weapon development that resulted in the creation of the V-1 and V-2 weapons.

The German vengeance weapons

The Germans began development work on the V-1 and V-2 weapon systems in 1936 and 1924 respectively.[59] These two programs would eventually produce a total of approximately 33,000 V-1 flying-bombs and about 6000 V-2 missiles.[60] By 1942 the effects of the RAF's Bomber Command raids were beginning to have an impact on Germany's war effort and, thereafter, greater importance was given to these two programs. Priority effort was given to the programs even though it was realised that decisive results could not be achieved with the weapons due to their inaccuracy. However, Hitler's desire for 'vengeance' ensured the programs proceeded. Even with the increased priority placed on the projects there was still much development and experimental work to be completed. Due to the time taken to complete this preparatory work the V-1 campaign against Britain did not commence in earnest until June 1944, while the V-2 campaign began in September of the same year.[61] In the course of both campaigns only 4000 V-1s and 3000 V-2s landed on Britain.[62]

To produce this result a considerable effort was required of Germany. In financial terms it is estimated that the total cost of these two programs approached one quarter of the cost of the Manhattan Project that produced the atomic bombs.[63] In human terms it required the permanent commitment of almost 10,000 workers to carry out production, let alone the commitment of some of Germany's top research scientists.[64] The effort not

58 Sweetman, *Operation Chastise*, pp. 179–87.

59 The United States Strategic Bombing Survey (USSBS), *The United States Strategic Bombing Survey: Volume II*, Garland Publishing, London, 1976, pp. 113, 116.

60 ibid., pp. 114, 120a.

61 R.V. Jones, *Most Secret War: British Scientific Intelligence 1939–1945*, Coronet Books, London, 1979, pp. 528, 578.

62 Williamson A. Murray, 'The World at War' in Geoffrey Parker (ed.), *Cambridge Illustrated History of Warfare*, pp. 326–27.

63 ibid.

64 USSBS, *The United States Strategic Bombing Survey*, pp. 117–18.

only absorbed financial and human resources but also severely degraded Germany's ability to produce other combat aircraft. The United States Strategic Bombing Survey estimated that in 1944 alone, the resources consumed by the V weapons programs could, alternatively, have been used to produce 24,000 more fighter aircraft.[65] With so large an allocation of national resources in these projects there was a correspondingly large expectation of the result that these weapons would have on Germany's enemies.

The cost of these experimental developments was enormous when compared with the disproportionately minor effects they generated. A great number of the weapons produced by these programs, 8000 V-1s (or 24 per cent of total production) and 3000 V-2s (or 50 per cent of total production), were consumed in experimental development alone and therefore had no impact on the Allies.[66] Each of the 4000 V-1s and 3000 V-2s that landed in Britain carried a 2000-pound warhead, or roughly one fifth of the bombload of a single Lancaster bomber. At this stage in the war Bomber Command, alone, was regularly mounting raids by night involving 800 aircraft. The entire V-1 contribution therefore equated to a single night's work by Bomber Command, while the V-2 contribution did not even reach this level but came close to producing an effect similar to a single major raid by Bomber Command. For the national wealth and resources expended on these weapon systems, this was not a significant return.[67]

The case of the V weapons is a situation where the concept behind their employment and effect was so promising that, in the eyes of some, the detail of just how much these weapons would cost, and how effective they might really prove was overlooked. Not only were the financial and human costs overlooked but it also appears that no apparent consideration was given to the defences that might be constructed to defend against the V-1 in particular. Over the course of the V-1 campaign these defences had become increasingly effective and they destroyed about 50 per cent of all V-1s launched against Britain.[68] The other point to be made in regard to these programs is that experimentation should have highlighted the problems of cost, production, inaccuracy, the impact on other weapons programs, and the overall force mix that would develop should production priority be given to these weapons.

The two examples selected in the World War II period provide some important lessons for the capability development process. The British example indicates the importance of retaining knowledge of all concepts, even failed ones, as a future change may alter its viability. The frugal development of specialist capabilities and execution of the operation had little or no impact of force structure or on other capabilities. In contrast the German vengeance weapon programs were exorbitantly expensive, relied on immature technology, seriously affected overall force structure and only produced minor effects.

65 Murray, 'The World at War', pp. 326–27.
66 USSBS, *The United States Strategic Bombing Survey*, pp. 115, 120.
67 Murray, 'The World at War', pp. 326–27.
68 USSBS, *The United States Strategic Bombing Survey*, pp. 112–13.

SUMMARY

In summary this chapter has sought to demonstrate that concept-led experimentation is nothing new. Concepts that have formed in the minds of those who have studied the art and science of war have given rise to experimental programs in every age. In some cases, these concepts have been correct evaluations of the circumstances of their day; others have struggled to refine the initial thought into a practical system, while others have got completely the wrong concept in mind. In considering those who have most successfully translated concept into practice, there is a strong correlation with professional mastery. Those who have mastered the profession of arms have been most successful in this translation process. Those who have lacked this mastery have relied on flawed concepts to the detriment of themselves, their forces and their nations. As a force that holds the principle of professional mastery as being fundamental, it is to be expected that the RAAF will make full use of concept-led experimentation programs to understand the future and guide its efforts to prepare effectively for that future now.

CHAPTER 3
DEFENCE ORGANISATION FOR CD&E

This chapter draws heavily upon the work done in Defence's Strategic Policy Division by the Directorate of Future Warfighting (DFW) in producing their *Concept Development and Experimentation Plan 2004–06*. As part the management of the Concept Development and Experimentation (CD&E) effort this plan is presented to the Defence Capability Committee (DCC) on an annual basis. In this plan DFW details the significant resources committed by Defence to CD&E and outlines the organisation that supports this process throughout the whole ADO.[1] Future CD&E activities for the coming years are also outlined in broad detail.

The concepts developed by CD&E provide support to capability development decisions that forecast the position of the ADF in the medium to long-term time frame. CD&E processes have the flexibility to influence periods from five years out to where future characteristics can reasonably be determined, typically not longer than 20–30 years.[2]

CD&E activities draw on elements of the Concept Development and Experimentation Framework (CDEF). The CDEF is being developed to describe the philosophical, organisational, analytical and technical foundations of the CD&E program. The CDEF is a philosophy for guiding CD&E and provides the foundation elements to support an integrated approach to CD&E. CD&E programs draw on these foundations to select the elements required for conducting the activities involved in the various CD&E programs within Defence.[3]

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1 Directorate of Future Warfighting (DFW), Strategic Policy Division, *Concept Development and Experimentation Plan 2004–06* (RESTRICTED Document), Department of Defence, Canberra, 2003.

2 ibid., p. 1.

3 ibid.

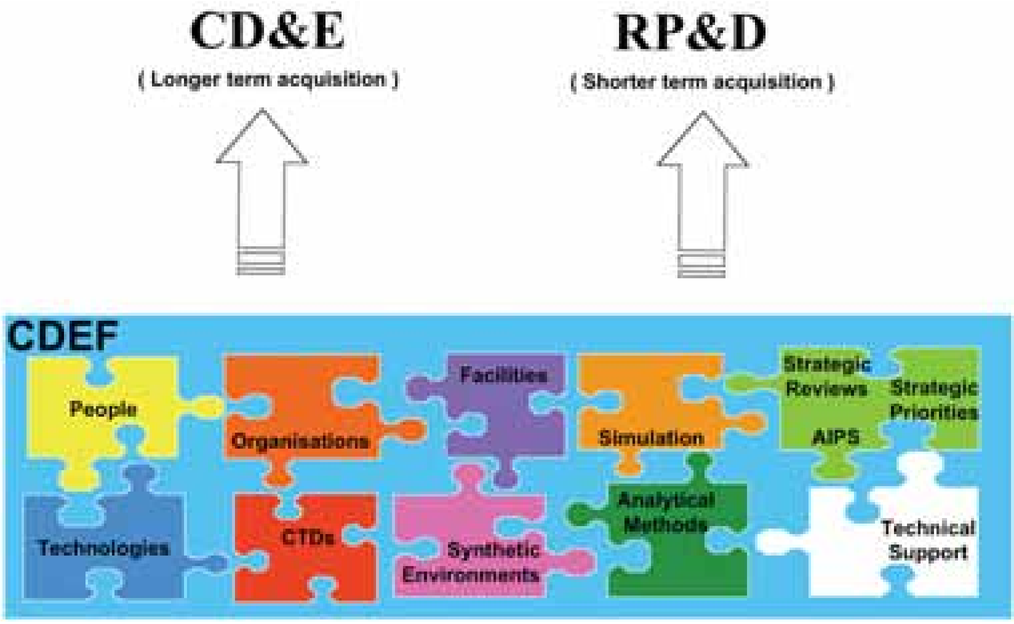

Figure 3.1 – Concept Development and Experimentation Framework[4]

HIGHER LEVEL MANAGEMENT OF CD&E

Coordination of CD&E across Defence is a large and complicated task. As CD&E is emerging and different parts of the ADO are at different levels of maturity in the process, the approach adopted has been to build links progressively between CD&E efforts across the ADO on a cooperative basis. The mechanisms for achieving coordination of CD&E effort are contained within the governance function performed by the DCC, the Defence Experimentation Board (DEB) and the Defence Futures and Experimentation Forum (DFEF).

The DCC retains overall responsibility for establishing priorities for CD&E. It considers and approves the CD&E Plan presented to it on an annual basis. The plan is first presented to the DEB, which recommends the CD&E Plan to the DCC.

The DEB will determine the focus area for Joint Experimentation, approve objectives and endorse ADO involvement in multinational experimentation. It will also deconflict and coordinate single Service experimentation and act as a clearing house for information related to experimentation. The Terms of Reference and membership of the DEB are contained at Annex C.

4 ibid.

The DFEF has representation from the multinational, joint and single Service experimentation programs by uniformed officers of wing commander/lieutenant colonel/ commander rank and lead DSTO analysts. Supporting organisations such as the ADF Warfare Centre (ADFWC), the Australian Defence Simulation Office (ADSO) and the Office of the Chief Information Officer (OCIO) are invited to send representatives as they deem necessary. The forum meets every second month to develop CD&E processes further, discuss experimentation issues and coordinate experimental activities. Military Strategy Branch provides the Chairman of the DFEF, who is the Director Future Warfare Concepts; and the Secretary, the Deputy Director Future Warfare Concepts.

Multinational and joint experimentation outcomes are reported to the DEB in reports raised by the Directorate of Future Warfare Concepts (DFWC) and by client reports raised by DSTO. Single Service experimentation programs will report to their respective Service headquarters and brief the DEB on the results of their experimentation efforts. A CD&E progress report, consolidated by the DFWC, will be presented to the DEB in the first quarter of each year.[5]

Coordinating CD&E efforts across the ADO provides a number of benefits. Through coordination all stakeholders obtain better visibility of the individual experimental aims and receive timely dissemination of results. This helps to ensure that the most important priorities are being addressed. Coordination results in a more efficient CD&E program, by reducing unnecessary duplication and allowing experiments to be better focused. A more comprehensive experimentation program is also achieved by tapping into the synergies between different experiments, allowing the different analytical methods to complement each other, and allowing earlier experiments to identify key issues for later experiments or analysis. Finally, deconfliction of activities can be achieved in an environment where resources, particularly staff expertise, are limited.

PRODUCTS OF CD&E

The products from the concept development process will be delivered in a number of different formats. The process will begin with a discussion paper as a first draft concept paper. After experimental review, and other comment and feedback has been incorporated into the document, these will then develop into concept papers for endorsement by either the Chiefs of Service Committee (COSC), or the respective Chief of Service. These concept papers should be reviewed ideally every three years to ensure their currency and may also be developed into roadmaps, where required, to describe how a concept will be implemented.

5 ibid., pp. 13–14.

Experimentation will also deliver a number of outcomes from the activities conducted. Recommendations for refining the concepts tested by the experiment will be made based on the post-experimental analysis. Requirements may also be identified for the development of subordinate and supporting concepts, and for new training, doctrine, tactics, techniques and procedures to implement the concept or elements of the concept. Experiments may also identify broad impacts on the Defence Capability Planning Guidance (DCPG), the fundamental inputs to capability (FIC), and first order cost analysis that influence higher level defence capability planning.

DCPG describes a process that includes capability guidance, capability assessment, options development, and prioritisation and programming. A DCPG Steering Group, at two-star level, manages the process and coordinates with the DEB to ensure the CD&E program continues to support the capability development process. The outcomes of experimentation will be incorporated in DCPG databases in order to assist decision-makers in making capability development decisions.[6]

CONCEPT DEVELOPMENT

As articulated in *Force 2020* and *Future Warfighting Concept*, concept development plays an essential part in the process of understanding and preparing for the future and also as a vital precursor activity for military experimentation. Indeed, the two activities combined together form the essential transformational engine in the overall process of moving the ADF from the present and into the future.

A military concept may be described in the following way:

> A military concept is the description of a method or scheme for employing specified military capabilities in the achievement of a stated objective or aim. This description may range from broad to narrow. It may range from describing the employment of military forces in the broadest terms and at the highest levels to specifying the employment of a particular technology system or the application of a particular training system.[7]

Essentially a military concept describes the way that operations are carried out. The existence of such concepts in the past becomes evident in the study of military history and may be found in the manuals and doctrine of the day or may be deduced by historical analysis. For example, the USAAF's unescorted strategic bomber doctrine of the pre-war period was well described and detailed in a range of USAAF manuals and other

6 ibid., p. 3.

7 John F. Schmitt, *A Practical Guide for Developing and Writing Military Concepts*, A Defense Adaptive Red Team Working Paper #02-4, Hicks and Associates, McLean VA, 2002, p. 3.

publications issued before the war. In contrast, the German 'Blitzkreig' was not so well documented and a complete description of its methods and requirements has only been developed through historical analysis. Historical analysis is one of the roles assigned to the Air Power Development Centre (APDC) in support of the CD&E process. Understanding historical concepts benefited William of Nassau as he struggled with how to produce a continuous volume of fire at the enemy, and was the first step taken by the Germans in the inter-war period when they studied the factors leading to operational success in World War I. In both instances historical concepts led to the development of superior current concepts.

Current concepts of how the ADF will conduct its operations can be found in the doctrine, manuals, instructions and training systems of the separate Services and at a joint level as well. It takes into account the existing organisation, equipment, procedures and training of the current force. While a significant effort is made to capture the essential elements of our warfighting practices in these documents, it is likely that emerging concepts may not yet be codified (for example a detailed concept covering the use of uninhabited aerial vehicles (UAVs)). Operations in these emerging areas rely more loosely on concepts of how future operations may be conducted.

Future concepts are the area of prime importance for the CD&E process. A future concept describes how we anticipate we will operate in a future environment with emerging capabilities and organisations. To describe this situation it becomes necessary to spell out what assumptions we have made with regard to the future environment in all its aspects. For the RAAF, the responsibility to conduct futures analysis in support of the Air Force's CD&E program has been assigned to the APDC. A number of alternative futures are possible as we do not know for a certainty the way global events and trends will actually occur. For this reason a number of different concepts may be developed for the same future time period but under differing circumstances. The assumptions contained in these concepts are not proved but are only possible, probable or most likely. 'Future concepts catalyse concept-led innovation and are the intellectual basis for debate, experimentation, testing, evaluation and development of future capabilities.'[8]

The relationship of historical, current and future concepts can be connected with the stages of Defence's Capability Systems Life Cycle over time, as in Figure 3.2.

8 Paul Willis, Peter Dortmans, Neville Curtis and Niem Tri, *Army's Concept Framework – Exploiting Concepts as Agents for Land Force Development*, Paper presented to the Land Warfare Conference, Adelaide, 2003.

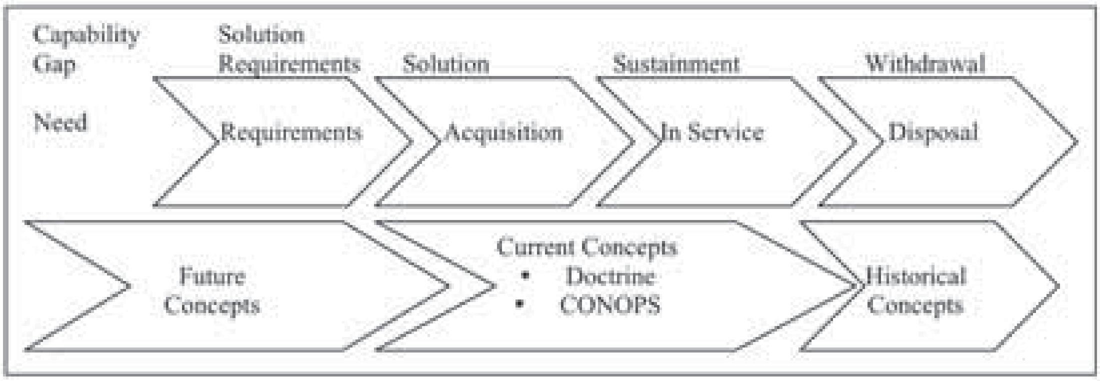

Figure 3.2 – Capability Systems Life Cycle, Concepts and Time[9]

Future concepts are a key product of CD&E. The concept begins as an idea, theory or hypothesis about the way we expect to conduct operations or employ capabilities in the future. It seeks to inform policy and future capability development. There are two reasons why a new operating concept may become necessary.

First, there may occur a change in situation. A concept may be developed to propose a response to a fundamental change in situation or newly identified military problem. A new combination of political, social, economic, technological or other reasons may have led to this problem. It may also be the result of new objectives in an existing situation.

The second reason for creating a new operating concept can be a change in the means available for carrying out a military activity. A concept may be developed to propose a better solution than currently exists to an existing military problem. This better solution may be made possible by some societal, technological, organisational, doctrinal, tactical or other development that did not exist previously. It may also be necessitated by the failure of an existing operating concept.[10]

In the RAAF the responsibility for managing the concept development process has been allocated to the APDC. Concept development is the process of generating, exploring, refining and validating new ideas. Typically, this is a staged approach that involves generating a broad concept and range of ideas by staff processes, working groups or exploratory experiments. After concept generation the next job is that of exploring the concept through discussion and competition between different candidate ideas. After determination of the most promising concept we need to refine the concept through the assessment of promising ideas by constructing a full operating concept. Experimentation may be used to develop the concept, evaluate its utility, and provide an analysis of the concept in a range of potential scenarios.

9 ibid.

10 DFW, *Concept Development and Experimentation Plan 2004–06*, p. 3.

Hierarchy of concepts

The variable scale of operations that a concept may describe points to the existence of a number of concepts that describe activity at strategic, operational and tactical levels and is also suggestive of the need for these concepts to be coordinated and interrelated. The purpose of the hierarchy is to describe how joint concepts are related to each other and how single Service and functional concepts support them.

The Australian Approach to Warfare provides the underlying themes and key influences on the ADF approach to operations. It reflects a balance between our historical experience of warfare and how we might meet future challenges on future battlefields. *Force 2020* builds on *The Australian Approach to Warfare* and sets a vision for the ADF in 2020. It seeks to develop a shared understanding of future opportunities and challenges, and identify what we must do today to prepare for them. It provides guidance for CD&E and requires links to overseas experimentation to maximise combined operations capabilities. The third book in the series, the *Future Warfighting Concept*, is the capstone concept for ADF warfighting and provides detailed guidance on the Defence vision for CD&E to develop warfighting concepts and enabling concepts further, particularly through joint and multinational experimentation.[11]

Elements and characteristics of future concepts

To be useful, concepts must contain information describing a number of elements essential to an understanding of how the capabilities addressed by the concept are to be used. The elements discussed here are not an exhaustive list but instead are an outline of a minimal set of requirements.

Purpose. A statement of the purpose, or purposes, for the development of the concept is important in establishing the use to which the concept is to be put. As a concept develops the purposes for which it may be used may also change. An initial conceptual draft may be used to initiate study, discussion and debate. After this interaction the concept may now be ready to be subjected to experimental assessment, comment and revision. After experimental validation the concept may be ready for proposal as a capability acquisition project and may also be approved as providing an authoritative context for the development of lower level concepts.[12]

Time horizon, assumptions and risks. The time period is a critical parameter that needs explicit definition in a concept. Such a statement establishes the context of the concept with regard to technology, force structures and other important FICs. Any assumptions that have been made in the development of the concept need to be outlined so that their continued validity and applicability can be monitored and assessed throughout the life

11 ibid., p. 4.

12 Schmitt, *A Practical Guide for Developing and Writing Military Concepts*, p. 15.

of the concept. Similarly, the risks to the viability of a concept need to be identified so that they also can be continually monitored and assessed. With these items identified the limits of the concept also obtain some definition.[13]

Description of the military problem. The whole reason for developing a future military concept is to address a military problem whose existence has been identified in a future time frame. An explanation of that problem is vital to an understanding of how the proposed concept will address that problem. 'Equally important, it establishes the conditions under which the concept does not apply.'[14] The military problem should also be provided with a context that may include descriptions of the environmental, geographical, political and military characteristics that influence both friendly and enemy dispositions and actions. The military characteristics of the concept would ideally include a description of the threat, which covers the equipment, technology, organisation, weaponry and tactics of an opponent.[15]

Synopsis of the central idea. This synopsis will be a 'how' statement of the way in which the concept will operate to solve the military problem described above. The synopsis can be considered as a concept of the concept that captures the essence of the original thought or idea that led to the creation of the concept.[16] For example, a possible synopsis for the future military problem of enhanced enemy air combat capabilities might explain how we will counter these capabilities through the employment of stealth, which will degrade the enemy's ability to both detect and engage our platforms. The concept outlined in the synopsis should also be robust enough to support the development of subordinate concepts.[17]

Application and integration of military functions. In this section the concept should describe how the different functions envisioned would be applied and in what way they will integrate into a cohesive operating system. Functional areas such as command and control, fires, manoeuvre, sustainment and security are general areas that may be addressed. These functions are essentially what military forces do in order to carry out the military missions allocated to them under the concept. The relative importance of each function and their relationships to each other should also be spelled out.[18] For example, the importance of stealth to JSF operations may demand that the AESA radar be used only for fire control of air-to-air missile firings and then only at the last moment and for the shortest period necessary to support the missile.

13 ibid.
14 ibid., p. 16.
15 ibid.
16 ibid., pp. 16–18.
17 Willis, Dortmans, Curtis and Tri, *Army's Concept Framework.*
18 Schmitt, *A Practical Guide for Developing and Writing Military Concepts*, p. 18.

Necessary capabilities. The capabilities required by the concept to undertake successfully the missions and tasks assigned to it in the concept should be spelled out. These capabilities should be as generic as possible and not specify particular equipment solutions, methods, tactics or services as being required. For example, an 'ability to suppress enemy air defences' is a preferable statement of necessary capability to the 'ability to carry the HARM missile', unless there are exceptional circumstances that exclude all solutions except the High-Speed Anti-Radiation Missile (HARM).[19]

Spatial and temporal dimensions. All military operations are conducted in a specific time frame and in a defined area of operations. The physical and other characteristics of the environment have previously been described. In this section specific detail should be provided on what ranges may have to be traversed, what area might have to be covered, for how long the effects may have to be sustained, and what deployment time frames are involved. This section may also include comments on the operational tempo to be achieved and may also outline a general sequence of events required for the fielding, operation and sustainment of the capability.

The foregoing then outlines the basic elements required of a military concept for it to be most useful. When these elements are provided within a concept, it can more easily be tested and validated by the experimentation processes of the RAAF and authorised for the development of subordinate and other concepts within the RAAF and the ADO. As concept development grows and matures within the RAAF and the ADO, the inputs to the RAAF's experimental capability will expand and the combined effects of CD&E will flow on to the capability development processes of the RAAF and the ADF.

EXPERIMENTATION

Experimentation receives its tasking from concept development and is used to develop and explore these concepts to identify and recommend any changes required to achieve significant advances in future capabilities.[20] Experimentation and concept development are therefore intimately intertwined. Each phase of the concept development process is made more robust by experimentation.

While not every decision relating to concept development and capability development requires experimentation, it is a powerful tool that can allow us a better understanding of a range of issues associated with concepts and capability, especially complex problems that conventional approaches have difficulty addressing. Experimentation provides a vehicle for development of concepts through setting context, the environment and a

19 ibid., p. 19; Willis, Dortmans, Curtis and Tri, *Army's Concept Framework*.

20 Department of Defence, *Force 2020*, Department of Defence, Canberra, 2002.

threat on which to test the concept. Experimentation is a powerful tool for supporting capability development. It provides decision support information for capability development through the ability to test current and future systems in scenarios. The outcomes of experimentation are a critical input into the DCPG process in the early stages and become more specific as the concepts and experimentation become well defined.

Within the ADO, experimentation operates according to two key principles that recognise the limited resources available to the ADO. Firstly, the choice of experimental tools should be dictated by the fidelity required for the problem to be addressed. In general, high-level 'broad brush' questions are best addressed by low fidelity, low resource models, while higher fidelity tools are more appropriate for more narrowly focused questions. Secondly, experimentation that is focused on specific questions is more likely to yield useful insights than exploratory experimentation. However, such exploratory experimentation is often required to identify the specific questions that yield such beneficial results. Moving to the point at which such specific questions can be framed must be a priority of the process.

Defence experimentation is conducted in four broad categories as shown in Figure 3.3 and as discussed below.[21]

Level 1	Multinational (Whole-of-Force)		
Level 2	Joint		
Level 3	Maritime	Land	Aerospace
Level 4	Individual systems or platforms		

Figure 3.3 – Four Levels of Defence Experimentation

The highest level of experimentation within the ADF is the multinational experiment, which involves activities that have a whole-of-force perspective. This experimentation is carried out in collaboration with other nations, such as the United States, Canada, New Zealand, United Kingdom and the NATO countries. The ADF role in these experiments may be either as observers of the CD&E work or as participants in collaborative work to inform and develop combined concepts and interoperability processes.[22]

21 DFW, *Concept Development and Experimentation Plan 2004–06*, pp. 4–5.
22 ibid., p. 7.

The next level of experimentation is that involving joint experimentation. At this level all three Services participate to examine whole-of-force issues for the ADF. This will also include issues regarding the whole-of-government or whole-of-nation contribution to operations. Joint experimentation is organised by the Department through a jointly staffed branch responsible for matters involving military strategy.[23]

Most relevant to this work is the next level of experimentation, the single Service experiment. At the single Service level, experimentation will examine issues in the respective environment and issues of a joint nature from the single Service perspective. However, experience has shown that even in single Service issues the other Services have valuable inputs to contribute. Each Service gains valuable insights into joint force capabilities from active participation in each other's single Service experiments. Indeed, the best way to conduct these experiments is to hold single Service experiments in a joint environment.

The final and most detailed level of experimentation is that involving individual systems and platforms. These experiments examine individual platforms or a collection of platforms or systems and how they contribute to one or a few military roles. These experiments are usually not conducted as a whole-of-force combat effectiveness study. This category includes project level collaboration that may involve other nations.[24]

While Figure 3.3 shows the experimentation programs as separate activities, there is a great deal of interaction and support across the programs not displayed. DSTO has major supporting tasks in each of the multinational, joint and single Service experimentation programs, in addition to the system and platform level experimentation function shown in Figure 3.3.

Multinational experimentation

CD&E promotes innovation and efficiency while avoiding duplication by building a vibrant network of partners engaged in the sharing of information through collaborative CD&E. The ADO is involved in multinational collaborative experimentation through a number of activities that explore concepts and capabilities in a whole-of-force environment. A primary focus has been engagement with the United States Joint Forces Command (USJFCOM). USJFCOM is the transformation laboratory for the US Department of Defense. The J9 branch is the Joint Experimentation Directorate, tasked to develop, explore, test and validate 21st century warfighting concepts. Through the USJFCOM program of Multinational Experimentation (MNE), the ADO is collaboratively involved in CD&E with the United States, United Kingdom, Canada, Germany, and France. The

23 This is currently the Directorate of Future Warfare (DFW) in the Military Strategy Branch (MSB) of the Strategic Policy Division (SPD) of the Department of Defence.

24 DFW, *Concept Development and Experimentation Plan 2004–06*, pp. 5–6.

MNE series commenced in 2001 with Multinational Limited Objective Experiment 1. Importantly, outcomes from multinational experimentation are able to guide and support the work in our national experimentation programs.

Other force level multinational experimentation includes the Joint Warrior Interoperability Demonstration, Unified Quest, Global Engagement and Joint Urban Warrior war games. Increasingly, USJFCOM is becoming a central point of contact and coordinator for these US joint experiments.

Multinational collaboration also occurs at the Service level, as between the RAN and the USN in Fleet Battle Experiment Kilo, and at project level; the New Air Combat Capability (JSF) project being an example. These activities usually remain set in a Service or platform context, so are reported within those categories. Within this framework, these activities are an important part of CD&E and are multinational in nature, however, remain within categories three and four.[25]

Joint experimentation

The aim of the joint experimentation program is:

> To examine, validate and further develop the *Future Warfighting Concept* and to develop an understanding of the whole of force requirements inherent in successfully executing operations according to the concept.[26]

The conduct of experimentation in support of the joint experimental campaign aims to assist in the concept development of the *Future Warfighting Concept* and its subordinate concepts. Experimentation will also provide context guidance and insights for single Service experimentation and provide insights and decision support information for DCPG. In this way experimental support for joint experimentation will continue the development of the CD&E processes.

Joint experimentation is conducted as an annual program to examine and analyse a hypothesis through a series of activities. The program may vary from year to year but will generally include an issues seminar, a scoping seminar, a series of Limited Objective Experiments (LOEs), and a larger seminar or war game to confirm the results produced by the previous activities.

The issues seminar should draw on outcomes and insights from the previous series of joint experimentation activities and identify the overall hypothesis to be addressed. The seminar should identify the concept and issues to be investigated and outline the major

25 ibid., pp. 6–7.
26 ibid., p. 5.

deliverables. The recommendations that result from the issues seminar are then presented to the DEB for endorsement. The scoping seminar should confirm how the activities are to be conducted. The analysis methodology, preparation work required and resource requirements for the program are also identified. Participation in the scoping seminar should be based on the membership of the DFEF.[27]

Single Service experimentation

The Services have experimentation programs that constitute the third category of Defence experimentation. Single Service experimentation primarily focuses on single Service concepts or capability issues. Each Service has it own experimentation program with different governance arrangements, funding issues and objectives. In order to make results more readily acceptable, external agencies, the context and situation should, as far as possible, be developed by the wider experimentation community and be agreed upon for all to use.

A question that often arises in connection with single Service experimentation is whether or not the three Services' individual experimental organisations should be combined into a single joint organisation, which would manage and conduct experimental activity for all three Services. In support of this proposal it is argued that all military operations are carried out in a joint environment and that all three Services should have direct input into all experimental activity. Although the 'jointness' of this approach is commendable a number of disadvantages would result from such an arrangement.

Traditionally the Services are reticent to contribute their own funds and personnel to joint organisations over which they have no direct control. This lack of control also extends to the joint bodies reporting of results to the ADO. Any 'bad news', such as the impracticality of operating concepts or adverse experimental findings, will embarrass the affected Service if it is not intimately involved in the conceptual and experimental processes. The release of such information by a third party also has implications for the single Service Chiefs and their reporting and accountability functions to the CDF and to government. But most importantly there are many activities where only the single Service has the appropriate expertise to determine the correct tactics to be used, and where it is the only force directly involved in the operation concerned. For instance, the manner in which an F/A-18 or JSF positions itself to attack an enemy air threat and subsequently employs its weapons must be driven by Air Force doctrine, tactics and weapon system capabilities. If there is any Army or Navy interest in this detailed Air Force activity, they must take second place behind the operational demands of the air elements engaged. Similarly, any Air Force interest in the siting of the Army's anti-tank weapons or the Navy's radar picket ships would also be of secondary importance. For these reasons the retention of the single Services concept development and experimentation activities

27 ibid., p. 7.

within the respective Services themselves is a more effective method of conducting this form of experimentation.

Navy Innovation Strategy

The Navy Innovation Strategy (NIS) is a CD&E framework to enable Navy to better inform maritime capability requirements. To transform the Fleet-in-Being through the Enhanced Fleet to the Future Fleet, the Navy has adopted a modernisation methodology that is strategy, effects and capability-based. This approach utilises experimental concepts within a joint and combined environment to guide the development of capability requirements. The NIS will focus on the 15-year period beginning approximately 10 years from the experiment, to inform enhanced fleet capability development decisions and scope the future fleet requirements. The NIS has three phases, the first being the identification of required future missions and effects and the development of maritime operating concepts. Following this, experimentation and analysis of these concepts will be undertaken to refine and improve the concepts until they can be validated. Finally, validated concepts will be implemented and their associated capabilities will be brought into service.

Structure. The program is managed by the directorate established within Navy Headquarters that deals with naval strategy and futures,[28] and is implemented in two parts. The first part is concerned with concept development, which is achieved through a working group that has been created for this purpose.[29] This working group will develop the Future Maritime Operational Concepts (FMOC). The second part of the NIS is the Maritime Experimental Framework (MEXF), within which experiments, war games, technical demonstrations, operations research and sea trials are conducted and analysed in order to validate (or invalidate) and refine concepts and inform capability development.

Governance. The MEXF consists of a three-tier governance and management structure that is headed by the Navy Capability Committee (NCC). Subordinate to the NCC is a working group[30] that has been created to provide direction and oversight to the Navy's element responsible for actually organising and executing the experimental program.[31] The working group consists of representatives from the executive element, naval capability development, Maritime Headquarters and naval operations analysis. The director of the executive element reports the outcomes of the previous 12 months MEXF activities along with proposals for the following 18 months activities to the NCC in the first quarter of each year.

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28 Currently the Directorate of Navy Strategy and Futures (DNSF).

29 Currently the Australian Maritime Concept Development Group (AMCDG).

30 Currently the NIS Working Group (NISWG).

Activities. The MEXF conducts activities as an annual program of seminars and LOEs, which lead to the major experimental activity, *Headmark*, generally conducted in October of each year. The requirement for seminars and LOEs will be determined by the working group and may be conducted by the executive element or by the relevant Force Element Group (FEG). The number of seminars and LOEs organised to address the issues proposed for that year may vary from year to year, depending on the hypothesis being tested and the depth of analysis required.[32]

Army Experimentation Framework

The Army's approach to continuously modernising its capabilities and force structure is concept-led and capability-based. The program, the Army Experimental Framework (AEF), is a basis within which future options for each of the Army's outputs and sub-outputs can be progressively tested and developed.

Vision. The AEF provides the analysis of capability requirements and options to better inform the planning and delivery of land warfare capabilities within the future joint and combined environment. It provides the discipline, tools and processes to test and refine concepts and capabilities well in advance of their introduction. The AEF uses the analytical process, which is based on a generic operations analysis problem solving methodology (model-test-model), inside a project management framework to provide analytical rigour to inform force development decisions.

Structure. An experiment management section, located at the Land Warfare Development Centre (LWDC), Puckapunyal, is tasked with managing the AEF program. This section is part of the Army's structure[33] that is responsible for contribution to, and delivery of, the Army Continuous Modernisation Process and provides the experimentation support to investigate the emerging concepts and capability requirements developed by the process.

Governance. Governance is provided by a steering group that includes senior representatives from Army futures and capability development areas, the Commander LWDC, and a senior scientist from DSTO's Land Operations Division. This group provides direction to the AEF and sets priorities for experimentation. The experiment management section and DSTO both report on the AEF's activities to the Army Capability Management Committee in December each year.

Activities. The AEF employs an annual program of LOEs and the culminating activity, the *Headline* Experiment, in October each year. The annual AEF program explores a

31 Currently called Navy Strategic Policy and Futures (NSPF).

32 DFW, *Concept Development and Experimentation Plan 2004–06*, p. 8.

33 As part of the Force Development Group (FDG).

focal question or hypothesis. Four LOEs are conducted in order to breakdown the focal question into sub-components that can be analysed. The *Headline* experiment will aim to confirm the insights drawn from the aggregated data and produce the results to answer the hypothesis posed.[34]

Air Force Experimentation Capability

The Air Force Experimentation Capability (AFEC) is the framework to assist in the long-term planning and development of Air Force. The AFEC adopts a concept-led spiral development process guided by the tenets of the CDEF.

Scope. Air Force experimentation is designed to assist in the exploration and validation of joint level concepts and the Air Force's subordinate single Service operational concepts. These concepts will therefore have direct application in the Air Force's capability development and management processes. In particular, they should provide guidance and context for activities such as force structure studies, project related studies, technology reviews and concept technology demonstrator programs.

Governance. As with the Army and the Navy, the Air Force has placed its experimental activities under the control of its highest capability development body, the Air Force Capability Committee (AFCC). The AFCC approves the experimentation plan and the program of activities annually, prior to seeking funding from the Deputy Chief of Air Force (DCAF). The AFCC has also followed the practice of the Army and the Navy in establishing a separate board to provide regular oversight of experimentation.[35] The two branches within Air Force Headquarters (AFHQ) that deal with capability development and strategic planning jointly chair this oversight board at the Director General level. The board sets priorities for experimentation and endorses the RAAF Experimentation Development Plan and the Program of Activities developed by the experimental executive agency, the Air Force Experimentation Office (AFEO).

The AFEO has been established within AFHQ as part of the APDC to plan, manage and coordinate Air Force experimentation activities, including Air Force participation in multinational experimentation, joint experimentation, and also in the Army and Navy programs. The AFEO also manages the DSTO supporting task plans and the interaction with relevant project related activities.

Activities. The AFEC program of activities is based on a rolling program of small-scale events or Limited Objective Activities (LOAs). The LOAs are designed to explore individual elements of overall operational concepts derived from the relevant joint level concepts. The nature of the experimentation process means that it is capable of

34 DFW, *Concept Development and Experimentation Plan 2004–06*, pp. 8–9.
35 Currently called the Air Force Experimentation Board (AFEB).

rapidly producing some 'quick look' insights into the viability and ramifications of various concepts. As more iterative cycles are completed, the level of confidence in the experimentation outcomes will grow, forming a firmer basis for Air Force capability development decisions.[36]

System / platform experimentation

The fourth category of CD&E concerns the examination of individual platforms/systems, as well as a collection of platforms/systems and investigates how they contribute to the capabilities and effects produced by Defence. This is not usually done as a whole-of-force combat effectiveness study. The aim of this experimentation is to enhance Defence's understanding of the required capability and to help identify and resolve problems with the concept of operations. Most of the experimentation activity in this category is conducted by DSTO, Capability Systems Division (CSD) and the Office of Chief Information Officer (OCIO).

CSD develops policy guidance on the management of present ADF capabilities and develops future capabilities to support Defence's mission. In sponsoring and developing capability proposals, CSD sponsors experimentation or supports experimentation activities.

The OCIO participates in concept development and the CD&E program and uses its insights gained thereby to progress further the development of the Defence Information Environment (DIE). By participating in CD&E activities the OCIO is able to ensure the information environment of future concepts and their supporting information architectures are tested. Such collaboration is crucial in ensuring that the DIE meets the objectives of its guiding concept (Information Superiority and Support) and is able to support joint and single Service operational concepts that are being developed.[37]

ANALYTICAL INFRASTRUCTURE

The CD&E process is fundamentally an analytical approach to the development of new concepts and capabilities. It requires significant supporting infrastructure, which is described as the foundation in the CDEF. Key support elements for the CD&E process include DSTO, Senior Concept Developers, Australian Illustrative Planning Scenarios, simulation and modelling, facilities and the knowledge management of tools, processes and results.

36 DFW, *Concept Development and Experimentation Plan 2004–06*, pp. 9–10.
37 ibid., p. 10.

Role of DSTO

DSTO involvement in experimentation is considerable. DSTO provides the expertise to Defence experimentation in experimental design, data capture, analytical methods and supporting tools. Multinational and joint experimentation are supported primarily by Defence Systems Analysis Division (DSAD). Single Service experimentation programs are supported by their respective operations divisions, Maritime, Land and Air Operations Division. Details of the support provided and the funding agreements are contained in the relevant DSTO Task Plans. These task plans are the agreements between DSTO and the sponsor organisations for the milestones and deliverables as part of the experimentation programs.

DSTO also conducts a range of fourth category system and platform experimentation for specific projects and capability outcomes. These experiments are primarily provided by the DSTO technical divisions and include research and development (R&D) tasks. Additionally, DSTO provides the technical expertise to support the provision of constructive and virtual simulation models.[38]

Senior Concept Developers

The concept of employing Senior Concept Developers (SCDs) drawn from the pool of recently retired senior military officers to assist with CD&E has been used to very good effect in multinational and joint experimentation. They provide an important senior perspective to activities, which would not otherwise be possible given the limited time availability of currently serving senior ADF officers. It is also expected that, by being associated with CD&E over a number of years, SCDs will also provide important continuity in the CD&E programs.

Role. The purpose of the SCD is to leverage knowledge, experience, expertise and high level influence in the refinement of concepts and the conduct of experimentation. The potential employment roles for SCDs includes senior reviewer of concepts, senior advisor or mentor in the development of the experimentation processes, facilitator of senior level discussions, and role player as commander or senior decision-maker.

Management. The key to effective employment of SCDs is their selection and management. For any individual to be selected as an SCD, approval is to be sought from the current respective Service Chief. Responsibility for the management of the SCD program rests with the department's branch responsible for military strategy. A pool of approximately 10 to 12 SCDs, with appropriate representation across the Services, is managed by Military Strategy Branch (MSB).[39]

38 ibid., pp. 10–11.
39 ibid., p. 11.

Australian Illustrative Planning Scenarios

The Australian Illustrative Planning Scenarios (AIPS) provide a context for deriving strategic tasks in the experimentation process. They constitute a key tool that supports CD&E in all activities and at all levels of experimentation. The benefits of using the AIPS include the ability to produce coherent and reusable analysis, an understanding of force flexibility and risk, and a stronger basis for strategic dialogue. The current set of AIPS was endorsed by COSC in February 2002 and is under review to better meet the evolving needs of concept and capability developers.

The AIPS are governed by a set of business rules that set out how they should be used. Generally, the AIPS are to be used for all policy formulation and capability development requiring strategic level context. AIPS may be modified with agreement from Policy Guidance and Analysis Division (PGA) to ensure consistency in the key characteristics. It is proposed that a priority be assigned to individual AIPS through linkage to the Military Strategic Priorities (MSPs). The AIPS and MSPs are highly sensitive and remain classified. They are available on the Defence Secret Network (DSN) and should not be declassified.[40]

Simulation and modelling

There are a number of simulation and models currently supporting Defence experimentation. Some of these are described in Annex A. Simulation and modelling tools are key mechanisms supporting experimentation, which is designed to improve the process of concept and capability development. This is accomplished by allowing the assessment of options in the context of how they will be employed and permitting a broader range of participants to be involved in the development, and integration of each option. The quantitative and qualitative assessment of each approach allows the strengths of each approach to be identified and exploited. These tools provide a structured environment in which to mimic the actual decisions involved in conflict, thus ensuring the issue is explored in necessary depth and breadth.

The selection of the most appropriate tool for the subject under examination is important to the conduct of the experiment and also for the validity of its findings. No single tool will meet all the analytical requirements of every experiment. For example, the Extended Air Defence Simulation (EADSIM) simulator provides an excellent tool for conducting and analysing engagements that involve large numbers of both Blue and Red platforms. However, the EADSIM model for the JSF's sensor suite is, of necessity, an approximation of those sensors performance that lacks fidelity in comparison with the highly detailed models of those same sensors that have been developed by the JSF's manufacturer, Lockheed Martin. While EADSIM would be the preferred tool

40 ibid.

in experiments involving large numbers of engagement platforms, Lockheed Martin's models would be the preferred tools in experiments designed to establish the performance characteristics of the JSF's sensors.

At the moment the simulation tools and models available to Defence as a whole are limited and a number of strategic and operational activities have to rely instead on human adjudication. This limited availability is influenced by both the small number of tools acquired and by the limited accessibility of those that have been obtained. The development of these tools and models is an important activity in the effort to support Defence's experimentation program.[41]

Simulation and analytical tool development

In order to support future experimentation a continued investment in the development of simulation and analytical tools is required. The primary responsibility for simulation acquisition and development rests with the Australian Defence Simulation Office (ADSO) and DSTO. The ADSO maintains responsibility for policy formulation, management of simulation issues and the acquisition of models on behalf of Defence, excepting DSTO. DSTO acquires simulation tools and maintains the operation of a range of models to support their tasks, which in turn supports experimentation.

Wargaming is an essential tool to experimentation programs. Further development will be required to refine the process and techniques of desktop wargaming to support tactical, operational and strategic level wargaming, and matrix gaming to support multi-sided strategic wargaming.

The Joint Simulation Capability (JSC), to be delivered under project JP 2079, will provide a new simulation capability that readily adapts new and existing simulations to support decision-making and training in a difficult and dynamic strategic environment. The JSC will provide more coherence and consistency in the application of simulation systems. It will put in place the people, processes and systems, standards and protocols that will enable Defence to extract the maximum benefit from its simulation capabilities to address issues of value, cost and risk.

The JSC will support CD&E by facilitating the combination of simulations for greater effect, improving the management of information and data in Defence simulations. The reuse of simulations and their underlying data and methodologies will become possible and this will improve the confidence that can be had in the simulation outputs while reducing costs in developing simulations. An aim of the JSC is that it will contribute to adequate through-life support for simulations and data to ensure systems are supportable

41 ibid., p. 13.

and adaptable to changing requirements. It will also facilitate the verification, validation and accreditation of simulations and aid in maintaining interoperability with the US to leverage the benefit of collaborative experimentation. In a significant way the JSC will contribute to the achievement of the Defence vision for simulation.[42]

Experimentation facility requirements

The majority of ADO experimentation is sponsored through four major programs, Joint Experimentation, the NIS, the AEF and the AFEC. Of these only the AEF has a dedicated experimental facility. The others have no dedicated experimental facility and make use of conference and meeting rooms in the Canberra area as well as the DSTO facilities around the country.

The Army Wargame and Experimentation Facility located at Puckapunyal provides an ideal environment for the conduct of experimentation. It provides a briefing room, a number of planning and syndicate rooms, also suitable for wargaming, and the computing infrastructure to support data capture and analysis. The facility is able to provide physical and network security to allow the conduct of experiments at the SECRET classification level. Additionally, the Puckapunyal area has the accommodation and mess facilities to support participants drawn from outside organisations.[43]

In order to improve the quality and consistency of experimentation, a project has recently been established to provide a joint facility for the three Services' experimentation programs. The project will provide the physical facilities and computing equipment for the Services but the provision of computer software packages and tools will be the responsibility of the single Services. The facility to be built will be located in the Canberra area.

Distributed / networked solutions

With the construction of a joint experimentation facility and the installation therein of the AFEC's simulation tools and models, an important hub in the ASE will have been established. The whole RAAF may benefit from the AFEC's resources by providing wider access to these tools through the RAAF's RESTRICTED and SECRET networks. Such access will permit the AFEC to conduct distributed experiments involving participants with specialist knowledge at remote sites around Australia. A greater number of RAAF personnel will be able to participate in, or observe, experimental events and they will benefit directly from the experience they gain from them, thereby enhancing their professional mastery. Even when it is considered necessary to bring together all the participants in an experiment to one location, a networked AFEC will allow other interested personnel to observe, which in turn may lead to the generation

42 ibid.
43 ibid.

of an increased number of suggestions and ideas that can feed the CD&E process.[44] In addition, those concepts that are being experimented with may attract a greater degree of discussion, comment and review from wider audience involvement. Furthermore, capability decisions based on the results of such activities will be more transparent to a larger number of RAAF members, allowing them to understand better the reasons for the decision, and making it more likely that they will actively support the RAAF's actions in the wider ADO and Australian community. This will be a significant change to how some capability decisions have been made and announced in the past; such as with the JSF, where a large effort was required to 'sell' the decision, both within and outside the RAAF, after it was made.

The advantages of a networked experimental capability have been recognised by the USJFCOM, which has established, what it terms, a Distributed Continuous Experimentation Environment (DCEE). This facility is designed to be an experimentation Intranet that establishes a permanent laboratory that is capable of continuously conducting various experimental events, locally or globally as required by its users. The DCEE provides a range of simulation and analysis tools to users that can include any of the American armed forces and other departments, and also includes allied nations.[45]

Knowledge management of tools, processes and results

A critical element in the ongoing successful management of CD&E activities is the ability to record accurately the performance (positive and negative) and characteristics (strengths, weaknesses, opportunities and threats) of the different tools and processes that have been employed in all events that make up an experimental program. The assessments made with regard to the concepts and capabilities that have been experimented with, and the data and logic that supports those assessments, must also be recorded. This data should be recorded not only for those concepts and capabilities that have been validated and further developed, but also for those that have proved impracticable and have been set aside. The 1943 Ruhr Dams raid that was described in Chapter 2 demonstrates the importance of retaining the knowledge of failed concepts. The original concept for the raids was first proposed in 1937 when it was rejected as no aircraft in service, or in the process of design, had the ability to carry the size of bomb required, let alone lift it to the required release height. By 1943 changes in aircraft capability, explosive materials, bomb design and manufacturing processes enabled the concept to be revisited and successfully carried out. A change in the means available altered the viability of a concept that promised significant outcomes. With the current rapid pace of technological development, such changes in the means available are more, rather than less, likely to occur.

44 Many of the Air Force's current experiments involve only one or two representatives from the relevant project offices and FEGs. With the ability to observe an experiment via the RAAF's Intranets, this number of participants could be considerably increased.

45 USJFCOM, *Distributed Continuous Experimentation Environment (DCEE)*, http://www.jfcom.mil/about/fact_dcee.htm, accessed 11 May 2004.

In addition to the ability to record the information mentioned above, all those involved in the development of concepts, the design and execution of experiments, and the analysis of CD&E results will need to have access to the recorded data. With this information being readily available new CD&E initiatives will be able to benefit from past experience and select the most appropriate tools and processes for the events connected to their development and analysis. The benefits to Defence will be the most efficient use of time and resources, the production of reliable data for analysis, and an assessment of a capability that is based on sound evidence which can be reproduced.

The effective management of the knowledge developed through the conduct of CD&E activities can assist in overcoming the problem resulting from the regular posting of military personnel involved in the three Services' CD&E programs. By making the experience and knowledge of past activities available to newly appointed CD&E staff, they can more rapidly develop an understanding and mastery of their Service's CD&E initiatives. DSTO also plays a major role in knowledge management as its staff is specifically trained in the processes of science that have application to experiment design, data capture, analysis and the reporting of results. Indeed, in contrast to military personnel their profession is centred on the principles of scientific experimentation. Their longer tenure in positions connected to CD&E also makes them a valuable source of knowledge and experience to the Services.

LINKAGES WITH OTHER CAPABILITY DEVELOPMENT EFFORT

Concept Technology Demonstrators

The Concept Technology Demonstrator (CTD) program was included in the Defence 2000 White Paper and is funded in the Defence Capability Plan. The aim of the program is to provide opportunities to demonstrate whether advanced technology can provide significant enhancement in priority ADF capability areas. The CTD Project Office in DSTO coordinates the program, with Defence advertising for CTD proposals mid-year then seeking sponsors within the ADO for the proposals received. Sponsored proposals are then reviewed and prioritised and a shortlist is recommended for funding.

One of the selection criteria by which CTDs are evaluated is that they must offer a significant capability enhancement that has clear links to strategic policy as defined by the White Paper. Additionally, the product of the CTD must be ready for transition to a capability that Defence could reasonably be expected to acquire. The CTD timing will be aimed at quickly demonstrating whether the technology initiative should be taken further or dropped. The technology involved must be well understood, and must demonstrate near-operational capability in a maximum of three to five years. CTDs should concentrate on identified areas of Australian self-reliance by addressing unique Australian operational or geographical conditions, establishing or maintaining an Australian technological lead or providing a capability not available from overseas. Risk management must be built into the project, and proposals are to clearly identify milestones and points of review over the course of the CTD. Finally, the conduct of the CTD must be justified by its cost benefit.[46]

Rapid Prototyping and Development

Rapid Prototyping and Development (RP&D) is an emerging process that will interact and relate with CD&E activity. It will operate as a process alongside CD&E looking at shorter time frame investigation and acquisition. It will need to be closely aligned with future concepts and experimentation outcomes in order for the ADF to remain on a path to the future force described in *Force 2020* and *Future Warfighting Concept*. If this alignment does not exist RP&D will also require rapid concept development. RP&D will also interact and use outcomes from the CTD program.

RP&D is a means to identify risk early, conduct intervention activities to address risk and ensure the rapid provision of capability to warfighters. The establishment of the RP&D Organisation occurred in the second half of 2004. This capability has been recommended as fundamental to the implementation of Network Centric Warfare (NCW) to the ADF. Prototyping must be iterative and possess the following hallmarks. It must operate in fast cycles, with little segments of development. There must be an early visualisation of the product, a crisp definition of initial requirements, early user testing and continued user development. There must exist an enhanced communication within the development organisation, and there must be enhanced feedback to both users and stakeholders.

The RP&D Organisation will be a permanent establishment that brings together personnel from Defence and defence industry. The organisation will fulfil a number of functions. It will identify and test new technologies, concepts, procedures and organisations that can be inserted into the existing structure of the ADF. The process will provide early identification of problems associated with the implementation of a new capability and RP&D may also be used as an intervention activity to redress the problem or address risk.

When capability proposals that demand rapid acquisition are submitted to the organisation the requirements of the proposal can be quickly assessed against existing industry products and services, as well as those that are still in an emergent state, by the industry representatives on staff. The Defence staff of the organisation will also have the ability to engage contractor staff from industry on a temporary basis to support the assessment of complex proposals. By bringing industry into this organisation Defence will benefit by gaining a better understanding and exploitation of the total defence industry capability in the national interest. Finally, RP&D will also provide for the rapid delivery of capability to warfighters when the need is identified.[47]

46 DFW, *Concept Development and Experimentation Plan 2004–06*, p. 15.

TRAINING AND OPERATIONAL USES

The focus of experimentation as discussed so far has been entirely on capability development. However, the tools and processes used to conduct experimental activity also have application in Air Force training and in the planning of air operations.

Training

Initial officer training. In the RAAF's current Junior Officer Initial Course (JOIC) provision is made for each FEG, the Army and the Navy to instruct the course in the roles, missions, capabilities and equipment of the respective organisations. Each FEG and Service is allotted two hours for their presentation, resulting in ten hours of instruction on this subject. The aim of this series of presentations is to familiarise the students with the capabilities of each of these forces and to give them some idea about how they relate to each other.

An alternative to teaching these matters by lecture or brief would be to present the students with a scenario that requires these same force elements to be employed in a joint operation. The students would then have to develop a simple plan with the provision of expert advice from the Service and FEG representatives who would normally provide the informational presentations. A final session would then be used to execute the plan through a war game, utilising the simulation tools that support the AFEC. In this way the students would be involved in 'learning by doing', which is one of the most powerful ways of teaching and learning about a subject. A further benefit would be that the students would become familiar with the AFEC and some of its capabilities. This in turn, hopefully, would encourage the development within the RAAF of a culture of experimentation, not only in the development of capability but also in the solution of operational problems and in the execution of operational tasks.

Squadron leader training. As with JOIC, the RAAF's Squadron Leader Course (SLC) includes presentations by the RAAF's FEGs, the Army and the Navy. The purpose of these presentations is the same as for JOIC but the information presented is of a more detailed and specific nature. This course could also benefit from the teaching of these subjects through a scenario-based, planning and execution exercise using experimentation tools. At the squadron leader level the demands made of the students would be more difficult and involve the students in making decisions concerning complex matters. Examples of some of these matters can include selecting enemy centres of gravity, generating targeting priorities, developing an air campaign plan, identifying which tasks can be executed simultaneously and which must be executed sequentially, and calculating the supply and logistics requirements of the plan. Such an exercise would further strengthen the development of an experimentation culture within the RAAF and provide the RAAF's

47 ibid., pp. 15–16.

executive level officers with a more comprehensive understanding of how the RAAF conducts operations.

Wing commander training. At the wing commander level the training provided by the RAAF to those who achieve this rank is divided into two separate avenues. The majority of officers complete the six week residential Wing Commander Course (WCC) while a select few benefit from the year long Command and Staff Course held at the Command and Staff College (CSC). At CSC the students participate in an extended training activity entitled *Aces Pegasus*. In this exercise students fill the senior staff positions in a simulated Combined Air Operations Centre (CAOC) and are exposed to a wide range of air power roles and activities. The benefits to the students from this exercise are significant and they develop a high level of understanding about the CAOC and the practicalities of planning and running an air campaign. The students on the WCC do not participate in a similar exercise and thereby miss out on the benefits associated with *Aces Pegasus*. A simulated exercise developed for the SLC could readily be adapted for use on the WCC, providing the students some of the benefits that *Aces Pegasus* provides the CSC students. The requirements placed on the WCC students would, of course, be more demanding than those expected of the SLC students.

Comparison with officer training overseas. The lack of simulated training exercises in the RAAF's officer training courses compares unfavourably with the training provided in the American, British and Canadian air forces. In the USAF all officers in their first year of commissioned service are required to undertake the Air and Space Basic Course that involves the students in a simulated exercise where they occupy the senior planning and executive positions in a CAOC. The students are required to develop an air campaign plan, targeting plan, master air attack plan, air tasking orders and to consider the logistical requirements of their plans.[48] In the RAF officer cadets during their initial officer training are involved in a similar exercise in the British Combined Operations Centre (COC). Again the students occupy senior executive positions in the COC and are involved in both the planning and execution of air operations through the COC.[49] In the Canadian Air Force efforts are currently under way to develop and introduce a simulated exercise, similar to the American and British models, in their Basic Officer Training course. At the squadron leader/major level and at the wing commander/lieutenant colonel level similar exercises are run for the instruction and experience of the students in the USAF and RAF, while the Canadians are in the process of instituting such methods. In comparison, within the RAAF only a few officers with good prospects for promotion to wing commander undergo similar training.

48 USAF, *Air and Space Basic Course Curriculum*, http://asbc.maxwell.af.mil/phase_a1700.htm, accessed 25 October 2004.

49 RAF College Cranwell, Directorate of Initial Officer Training, Course Structure, *Simulated Operational Exercise*, http://www.air-cadets.org/Organisation/DIOT/week22.htm, accessed 25 October 2004.

Unit training. With squadron leaders and wing commanders exposed to experimental processes, simulations and tools during their post-graduate RAAF training, it can be expected that the employment of such methods will be more widely used in the unit training activities of the RAAF's squadrons, units and formations. These exercises can be used to train the unit's personnel about the unit's role, capabilities and the factors that can influence the conduct of its operational activities.

Air operations planning

Mission planning. The mission planning conducted by RAAF operational units is largely a manual process of developing a plan in accordance with formation and unit standing instructions, modified for the latest experience and professional opinion. No method exists to conduct mission rehearsal or to analyse the potential chances of success without employing real aircraft to actually fly the mission in accordance with the proposed plan. A number of simulation packages and their associated tools, that are beginning to come into service in the ADO, offer a remedy to this situation.

Extended Air Defence Simulation (EADSIM), Joint Semi-Automated Forces (JSAF) and Battle Model (see Annex A) are three simulations that are currently in service with either DSTO or ADFWC. Each of these packages allows a mission to be simulated in a detailed environment that may model terrain, weather, sensors, weapons and a range of other factors. While training is required to use these tools successfully, their availability via RAAF computer networks will allow a person so trained to continue to use their expertise even when they are posted to new squadrons or other positions. Of course, not every mission requires such planning but more complex or higher risk missions could be refined and rehearsed without the high cost of actually flying the mission profile.

Campaign planning. As with mission planning, the higher level planning conducted by a number of Australian headquarters of joint operations and their associated air campaign plans is still largely a manual affair. The Strategic Operations Division (SOD) of Headquarters Australian Defence Force (HQADF), Headquarters Australian Theatre (HQAST) and Headquarters Air Command (HQAC) all employ the Joint Military Appreciation Process (JMAP) in their planning activities. As part of JMAP, a Course of Action (COA) analysis is carried out of alternative friendly and enemy courses of action. COA analysis includes the use of wargaming techniques, which at the moment are still mainly manual processes. The simulation tools proposed for mission planning can also provide the tools to conduct COA analysis. Some of these tools allow a scenario to be executed rapidly a large number of times and can provide a Monte Carlo analysis of the probabilities of occurrence, success or failure that are associated with the major events in a draft plan. The level of confidence held in a plan that has been analysed in this fashion will be greater than for a plan that has only been manually executed two or three times.

As can be seen from the structure outlined in this chapter, Defence has committed significant resources to the implementation of the CD&E process within the individual Services, DSTO and the wider ADO. This commitment of resources is indicative of the level of importance attached to CD&E by the most senior levels of command and management in Defence.

ANNEXES:

A. Simulations and tools supporting experimentation

B. Simulated exercises in foreign officer training

C. Terms of reference: Defence Experimentation Board

SIMULATIONS AND TOOLS SUPPORTING EXPERIMENTATION

Simulation/Model Name: AIR 6000 Phase 2A New Aerospace Combat Capability (NACC)

Description: The NACC project is determining the ADF requirements for the new air combat capability for the 2012–30 time frame. The JSF (F-35) capability is being assessed as the expected manned element to satisfy those requirements. Phase 2A will be the first part of the delivery of the new capability. Research simulators and experimentation are being used in support of the assessment. The concept of training devices is still to be determined.

Simulation/Model Name: AIR 8000 Phase 1 C-130H Refurbishment

Description: AIR 8000 Phase 1 aims to refurbish the Royal Australian Air Force C-130H Hercules transport aircraft. This proposal would see a major refurbishment of the existing C-130H fleet to extend the platform Life of Type out until at least 2020. As well as any required structural modification, the refurbishment would provide Global Air Traffic management compliant avionics and systems, and also provide for a commonality upgrade to the Full Flight Simulator.

Simulation/Model Name: Advanced Medium-Range Air-to-Air Missile (AMRAAM)

Description: Contractor supplied 6DOF (Six Degrees of Freedom) simulations, such as WinASP and ARS, are available for performance analysis. Weapons System Division (WSD) is developing an in-house MSTARS AMRAAM simulation to support additional performance evaluation studies in the Centre for Evaluation, Simulation and Analysis of Weapons (CESAW).

Simulation/Model Name: Advanced Short-Range Air-to-Air Missile (ASRAAM)

Description: Contractor supplied 5 and 6DOF simulations for performance analysis. The MBD missile-closed-loop-model (MCLM) is the most detailed model, which includes a target scene and seeker algorithm model. WSD is developing an in-house MSTARS version of ASRAAM to support additional performance evaluation studies in the CESAW, which will include development of a hardware-in-loop (HIL) model.

Simulation/Model Name: Centre for Evaluation, Simulation and Analysis of Weapons (CESAW)

Description: The CESAW comprises a suite of configuration controlled reusable tools, model libraries, analysis methodologies, interface standards and frameworks. This enables modellers in WSD and beyond to access and use existing models for the analysis of weapons systems or their components. Users will be able to test new component models without necessarily having to worry about modelling an entire weapon or system. The CESAW is also intended to be a vehicle for encouraging commonality among simulations, and collaboration between work areas. The tools available within the CESAW include architectural tools, simulation frameworks, revision control tools, validated component models, a centralised repository that is regularly backed up, and visualisation tools (such as Viewpoint). MSTARS, Mars, SimFramework, DIVA (see separate entries) and a Generic Telemetry Viewer (GTV) are some of the technologies that underpin the CESAW. The CESAW is intended to simplify and encourage the reuse and promulgation of weapon system models, and to tie together diverse weapon research and evaluation areas, such as propulsion, seekers, guidance, fusing and lethality.

Simulation/Model Name: DIVA

Description: DIVA is a standard visualisation interface, which relieves the simulation programmer from having to hard-code their simulation to a specific viewer, or of having to tailor the simulation for more than one viewer.

Simulation/Model Name: DUEL

Description: DUEL is a PC-based, one-versus-one, air combat simulation tool for analysing and comparing the performance of two opposing missiles in realistic combat scenarios. DUEL uses WSD's GEMM to represent a large number of air-to-air missiles.

Simulation/Model Name: DUEL-3D

Description: DUEL-3D is a PC-based, interactive air-combat missile simulation tool. DUEL-3D features realistic virtual reality graphics, interactive aircraft models and virtual reality headsets to provide the user with a full 360 degree viewing environment. The user can fly the aircraft via a joystick, engage an opposing aircraft, fire missiles and review the engagement outcomes. The program allows the user to fly against the computer or another human player on a networked PC. DUEL-3D uses WSD's GEMM to represent a large number of air-to-air missiles.

Simulation/Model Name: Extended Air Defence Simulation (EADSIM)

Description: EADSIM is a third-party-sourced mission-level simulation tool, which enables an experienced analyst to explore the interaction of weapons, launch platforms, radars, countermeasures, etc. within a complex environment that includes terrain. Weapons Systems Division has considerable experience in the use of this tool and in the analysis of results.

Simulation/Model Name: ESA299 Simulation Support to Network Centric Warfare Dynamic Agents Representation of Networks of System (DARNOS)

Description: DARNOS is designed to allow Defence to set up and explore different network topologies/performance, explore the impacts on the interaction between component systems and assess the merits of information management options. This project is an initial development activity and is not structured to provide a 'production' system.

Simulation/Model Name: ESA301 Simulation Support to Operational Level Headquarters

Description: This Minor Project is designed to introduce the Joint Semi-Automated Forces (JSAF) product into Australian service to provide simulation support to training for operational level headquarters. It is expected that JSAF will also be able to support experimentation to the joint and multinational level, Course of Action analysis in operational level headquarters and individual training at the Australian Defence College and ADFWC. JSAF is a military-off-the-shelf product from the US Department of Defense and will require modification and development to allow population of the database with appropriate ADF data.

Simulation/Model Name: Evolved Seasparrow Missile (ESSM)

Description: A fly-out model of the Evolved Seasparrow Missile. For evaluation purposes WSD has access to an all-digital IBM Mathematical Formula Translation System (FORTRAN) model of the weapon, sourced from the prime contractor.

Simulation/Model Name: Generic Missile Model (GEMM)

Description: GEMM is a modular, portable, reusable three-degree-of-freedom missile model that can be used to simulate most types of air-to-air, surface-to-air and air-to-surface weapons in real-time. It is augmented by a suite of well-validated weapon data files representing the majority of missiles of interest in the Australia/Pacific region, including regional threat weapons.

Simulation/Model Name: Generic Template Model (GTEM)

Description: The GTEM is a working model of a generic missile. The individual missile component models can easily be replaced with more specialised models.

Simulation/Model Name: Harpoon 3 Simulator

Description: A commercially available simulator involving primarily air and sea platforms. Includes terrain, weather, weapons, platforms, communications and sensor models. Although originally designed for recreational use the program can also be used for simple simulations not requiring high fidelity modelling.

Simulation/Model Name: Harpoon Weapon System Simulator

Description: A fly-out model of the Harpoon missile is integrated with a fire control tactical development model, 3D visualisation, and geographic information system capability.

Simulation/Model Name: Joint Semi-Automated Forces (JSAF)

Description: JSAF is a collection of high-level architecture (HLA)-based simulation federates used to model military entities, including air, ground and naval individual combatants and aggregate units with their associated behaviours. JSAF is an entity level, interactive constructive simulation that can be used for training and experimentation activities at the operational and tactical level of war.

Simulation/Model Name: Joint Theatre Level Simulation (JTLS)

Description: JTLS is an interactive, computer-assisted simulation that models multisided air, ground and naval combat with logistical, Special Operation Force (SOF), and intelligence support at the operational and strategic level of war.

Simulation/Model Name: JP 129 Phase 2 Airborne Surveillance for Land Operations

Description: JP 129 Phase 2 will acquire a Tactical Uninhabited Aerial Vehicle (TUAV) system capable of providing airborne surveillance, reconnaissance, and target acquisition to support land operations. These TUAVs are anticipated to be in service by 2007.

Simulation/Model Name: JP 2070 Phase 3 Lightweight Torpedo Replacement

Description: A simulator is required to replicate the MU90 weapon so that tactics can be developed. In due course, it may also be used for training, research and contributing to a joint database of weapon performance. The supplier is likely to be Deputy Chief of Navy (France) and he has been asked to develop a proposal.

Simulation/Model Name: JP 2097 Phase 1 REDFIN-Enhancement to Special Operations Capability

Description: JP 2097 intends to use a range of simulation tools to inform acquisition (R&D through DSTO) and then to contribute to training, mission planning and rehearsal. Exact requirements are yet to be defined as is the amount/portion of investment required for the simulation systems.

Simulation/Model Name: LAND 400 Phase 1 Survivability of Ground Forces

Description: This project seeks to enhance survivability of land forces in combat operations through the provision of transformational warfighting systems. These new systems, based on manned and unmanned air and land platforms, will incrementally replace legacy combat, combat support and combat service support systems currently fielded in the Army Combined Arms Teams. These systems will have very high commonality within their fleets and be interoperable with coalition nations.

Simulation/Model Name: LAND 75 Phase 3, 4 Battlefield Command Support System

Description: There is scope in the project to provide an interface between Battlefield Command Support System (BCSS) /Battlefield Management System (BMS) and simulation environments such as JANUS. The details have yet to be costed. There is also a BCSS Useability Laboratory being set up by DSTO Land Operations Division Human Factors area to provide a BCSS Simulation environment for training and evaluation of Human Factors aspects for future releases of BCSS.

Simulation/Model Name: Mars-Modelling Architecture Standard

Description: Mars is a C++ modelling architecture standard and tool suite suitable for building high fidelity component models of missiles and other platforms. A model written to the Mars standard will be portable to a large range of synthetic environments, including Hardware-in-the-Loop and SimFramework. 6DOF missile models with current or near-future implementation in Mars include the GTEM, MSTARS, ASRAAM and ESSM.

Simulation/Model Name: Missile Engagement & Coverage Analysis (MECA)

Description: MECA is a PC-based missile simulation tool for the analysis of air-to-air and surface-to-air missiles. MECA allows the user to simulate kinematic missile fly-outs and automatically generate weapon engagement zones. MECA uses WSD's Generic Missile Model (GEMM) to represent a large number of anti-air missiles.

Simulation/Model Name: Munition Simulation Tools and Resources (MSTARS)

Description: MSTARS is a Matlab/Simulink-based graphical weapon simulation, designed to permit 'plug and play' swapping of simulated weapon components. Its starting-point components are also implemented in C++ to the Mars standard. New weapon components may be programmed in a wide range of languages, including Simulink, VisSim and C/C++.

Simulation/Model Name: SEA 1397 GTS Concept Demonstrator

Description: The GTS Concept Demonstrator (GTS CD) is being used to test and evaluate the development of Nulka Anti-ship Missile Decoy system installed on major fleet units (Destroyers and Frigates). The airborne GTS CD is mounted on a Learjet and can simulate radar signals emitted by an air-to-surface missile causing the ship's missile defence system to perform all reactions to the threat. Tenix is contracted to operate and maintain the GTS CD for DMO.

Simulation/Model Name: SEA 1418 Phase 1 Maritime Ranges

Description: SEA 1418 Phase 1 provided weapon telemetry and multi-influence measurement ranges. These ranges, as part of a normal range software application, have the capacity to be used for the following: user training, reconstruction of activities based on collected data, modelling of data (collected or from elsewhere), experimentation of activities based on the particular range, and validation of range performance prior to activity.

Simulation/Model Name: SEA 1428 Phase 2B/3, Evolved Sea Sparrow Missile

Description: SEA 1428 will continue the support of International Simulations (INTSIM)—the simulation tool for the ESSM. INTSIM is used in both combat system development and firing support modelling. SEA 1428 Phase 2B/3 seeks to introduce the ESSM system into the Anzac Class ships (08-HMAS *Ballarat*, 09-HMAS *Toowoomba*, and 10-HMAS *Perth*) and to retro-fit the system into HMAS *Anzac* and HMAS *Arunta*. The simulation component could include training systems for targeting and firing (such as BAE System's Ship Air Defence Model (SADM)), and changes to existing simulators (Tactical Trainer at HMAS *Watson*).

Simulation/Model Name: SimFramework

Description: An in-process simulation architecture written in C++ that supports simulations built from componentised models wrapped to common user-defined data interfaces. Through an easy-to-use script file it allows the user to define a scenario, initialise models and define data logging requirements. In addition there exists the ability to manipulate the timing of model propagation and data exchange and also to define data filtering between models.

Simulation/Model Name: Strike

Description: Strike is a PC-based, surface-to-air versus air-to-ground missile simulation tool. Strike allows the user to examine the performance of surface-to-air missiles against strike aircraft flying realistic strike missions. Strike uses WSD's Generic Missile Model (GEMM) to represent a large number of surface-to-air missiles.

Simulation/Model Name: Syrus

Description: Workforce forecasting tool, simulating trends and policy outcomes.

Simulation/Model Name: TacOps ANZAC

Description: TacOps ANZAC is a tactical decision game (also sometimes called a constructive simulation or war game) that runs on a desktop computer. It is a military adaptation of a commercial recreational computer war game named 'TacOps'. The Australian Department of Defence has licensed TacOps ANZAC for free distribution to all members of the Australian and New Zealand Defence Forces. The intent of the TacOps ANZAC license is:

a) To provide an economical, limited fidelity, unclassified, tactical level battle simulation that can run on an average desktop computer and that can be freely distributed to Australian and New Zealand Defence Forces personnel.

b) To support limited usage in supervised training activities, particularly where time, money, or personnel limitations discourage the use of more sophisticated training simulations. TacOps ANZAC is intended only to augment, not replace, the usage of more sophisticated training simulations.

c) To create and exploit semi-recreational training opportunities through widespread distribution to junior personnel.

Simulation/Model Name: Tactical Data Network Emulator

Description: Emulates tactical data links over a Virtual Local Area Network (VLAN) enabled ethernet network.

Simulation/Model Name: Terminal Effects Modelling System (TEMS)

Description: TEMS is a terminal effects simulation tool that is able to use component models running on different operating systems over a network.

Simulation/Model Name: THUNDER

Description: THUNDER is a stochastic, two-sided analytical simulation of campaign-level military operations developed in the 1980s under the auspices of the Air Force Studies and Analysis Agency (AFSAA).

Simulation/Model Name: Virtual Maritime System Generic Missile Model (GEMM) Federate

Description: WSD's GEMM implemented as an HLA federate that interoperates within the Ministry of Defence's Virtual Maritime System Architecture.

Simulation/Model Name: Virtual Maritime System Harpoon Federate

Description: WSD's Harpoon MatrixX Model plus a basic Fire Control Model implemented as an HLA federate compliant with the Virtual Maritime System Federation Object Model.

Simulation/Model Name: Weapons End-to-End Simulation Capability

Description: The capability is in the form of a template Windows-based simulation application for modelling mission-level scenarios in which weapons systems are the primary focus. The application is built on the SimFramework simulation architecture. The template application provides a staring point for development of applications tailored to specific user requirements by adding in model and analysis modules.

Simulation/Model Name: WSD Legacy Simulations

Description: Many ADF weapons are no longer subject to development, upgrade or tactical evaluation. AIM-9, AIM-7, RBS-70 and Rapier are examples of these weapons. WSD has a repository of legacy simulations relating to many such weapons. These simulations are not actively being maintained, and often do not take advantage of modern simulation methods, languages and visualisation tools. Nonetheless, the mathematical models and weapon data comprising such simulations remain valid.

SIMULATED EXERCISES IN FOREIGN OFFICER TRAINING

USAF

Junior officer

Students are given the initial *Blue Thunder II* scenario information (eg. start of exercise reports, intelligence updates, background papers, operational environment research information, etc.) with direction to begin their initial planning for their air campaign. They will use these documents and their own discretion to develop their Air Campaign Plan. During this planning, they will need to look at force bed-down locations, force allocation, and an overall concept of operations. At the end of the lesson, students will brief their campaign plan to the Joint Force Air Component Commander (JFACC) and then input their satellite pass requests into the graphical user interface (GUI).

Students are given current Air Force Command Exercise System (ACES) reports to continue Master Air Attack Plan development. During the execution phase, they will consider logistical and sustainment factors, target selection, force allocation, and the overall concept of operations in light of the current situation. Students brief the JFACC on their progress and plan. They incorporate the JFACC's guidance into the Master Air Attack Plan (MAAP) to maximise the impact of friendly forces. At the end of each game turn, students input their data into the database.[50]

Squadron leader / major

The Air Force Employment Exercise is a tool book based war game that gives the students the opportunity to employ air forces against a formidable opponent—another flight. In this seminar, the flight will develop a plan for executing the war game software.[51]

Wing commander / lieutenant colonel

The Joint Air Operations course introduces students to the people, processes, and products involved in planning, directing and executing joint air operations in support of the joint force commander's campaign plan. The course specifically emphasises Joint Force Air Component Commander responsibilities and Air Operations Centre functions, culminating in a comprehensive war game that allows the students to apply their knowledge and skills. The war game recreates the stresses involved in planning and

50 USAF, *Air and Space Basic Course Curriculum*, http://asbc.maxwell.af.mil/phase_a1700.htm, accessed 25 October 2004.

51 USAF, Squadron Officers School Curriculum, *Area S1000 – Profession of Arms Studies*, http://sos.maxwell.af.mil/phase_s1200.htm, 25 October 2004.

executing air operations. Students are tasked to build a theatre-wide plan for joint air operations from which several air tasking orders will be derived.[52]

RAF

Junior officer

At the culmination of their training, cadets take part in a week-long exercise, Exercise *Peacekeeper*, which simulates deployed operations. Cadets carry out tasks in a challenging environment, fulfilling executive roles in a simulated Combined Operations Centre. The exercise is similar to those conducted in preparation for war or peacekeeping roles by the Services at large and requires the application of all the previous 21 weeks of training.[53]

52 USAF, Air Command and Staff College, Course Outline, http://wwwacsc.maxwell.af.mil, accessed 25 October 2004.

53 Directorate of Initial Officer Training, Simulated Operational Exercise, Course Structure, RAF College Cranwell, http://www.air-cadets.org/Organisation/DIOT/week22.htm, 25 October 2004.

TERMS OF REFERENCE
DEFENCE EXPERIMENTATION BOARD

BACKGROUND

1. HPGA, DCIO and HCS have agreed to Concept Development and Experimentation (CD&E) as a vehicle for Joint Capability Development, and to co-sponsor the CD&E Plan for DCC approval.

   Concept Development and Experimentation is the application of the structure and methods of experimental science with the aim of exploring innovative methods of operation, especially to assess their feasibility, evaluate their utility relative to current methods, or determine their limits.

2. The Defence Experimentation Board (DEB) is to be formed to provide a focus for supporting and facilitating the coordinating of Defence CD&E, and to oversee the development of the Defence Experimentation Framework (DEF). The Board will:

   a. recommend the CD&E Plan to the DCC,

   b. consider and approve the CD&E Business Plan,

   c. develop and approve detailed TOR for the Joint Experiment,

   d. deconflict and coordinate experimentation within Defence, and

   e. act as a clearing house for information related to experimentation.

DEB OBJECTIVES

3. The DEB objectives are:

   a. to formulate CD&E policy and priorities for endorsement by senior Defence Committees (such as DCC and DIEC) and ensure wide dissemination of this information;

   b. to facilitate the coordination and planning of CD&E experimentation and analysis activities in the ADO as directed by the CD&E Plan;

   c. to provide visibility of CD&E within the ADO;

   d. to guide/oversee the development of the DEF;

   e. to promote the building of enduring knowledge about CD&E programs, methodologies, technologies and facilities;

f. to facilitate linkages with external organisations that could partner with Defence CD&E programs (national and international, industry and government); and

g. to promote the application of ADO lessons learnt from past, current and future activities into CD&E exploration.

MEMBERSHIP

4. Membership of the DEB is based on Defence sectors that have ongoing experimentation programs. DEB membership will consist of HPGA, who will be the Chairman, HCS and DCIO. Permanently invited members will be the nominated representatives from the single Service Headquarters, DSTO, ADFWC, DMO, DIO, ADSO and FASCIR.

ACTIVITIES

5. The DEB will meet on a regular basis, timed to coincide with the development of relevant experimentation programs (in practice this will mean four to six meetings per year). Minutes will be kept by the Secretariat.

6. The DEB secretariat will maintain a shared calendar of CD&E events.

REPORTING AND OVERSIGHT

7. The DEB will report outcomes and recommendations to appropriate senior Defence Committees.

R. SHALDERS, CSC, RAN	**S. CARMODY**
VADM	
VCDF	**DEPSEC SP**
Nov 02	Nov 02

CHAPTER 4
TRANSLATING CONCEPTS AND EXPERIMENTAL RESULTS INTO CAPABILITY

What has been discussed so far is the higher level, and the RAAF single Service, organisation and conduct of experimental activity. To be useful, however, the Concept Development and Experimentation (CD&E) process must fulfil the requirements set for it by the CDF in the *Future Warfighting Concept* of influencing the capability development process.

> The experimental process is not enough in itself, however: the results of experimentation must be integrated into the capability development process. Such integration requires an ability to capture and cross-test findings gained from experimentation, and use this information to complement the judgment of senior decision-makers. When this integration is achieved, we will have a powerful way to inject new thinking into acquisition, organisation and doctrine development projects.[1]

In order to understand how experimentation can have this powerful effect on capability we will now look at how experimentation influences the capability development and acquisition processes of the ADO.

The processes involved in the life cycle management of the ADF's capabilities were explained in detail in 2002, when the Vice Chief of the Defence Force (VCDF) published the *Capability Systems Life Cycle Management Manual* (*CSLCMM*). As suggested by its title, the *CSLCMM* focuses on the whole life cycle of a capability, from identification of a capability gap or need, through to the disposal of the capability's components. The *CSLCMM* also recognises that there are a number of diverse elements that all contribute to the fielding of a capability.

The *CSLCMM* defines a capability as 'the power to achieve a desired operational effect in a nominated environment within a specified time and to sustain that effect for a designated period'.[2] This capability is delivered by systems that receive fundamental inputs to capability (FIC) from the sources shown in Figure 4.1. Each one of these FICs can affect the way the capability performs its function and delivers its effects. By

1 Department of Defence, *Future Warfighting Concept*, Department of Defence, Canberra, 2003, p. 42.
2 Vice Chief of the Defence Force, *Capability Systems Life Cycle Management Manual (CSLCMM)*, Department of Defence, Canberra, 2002, p. 1.

recognising that a capability is made up by the connected contributions of a number of elements, the *CSLCMM* has, as one of its objectives, the aim that all elements of a capability must be addressed, as a whole, at every stage of its development and existence. Through this approach the problem of optimising a single element and then trying to integrate it back into the overall capability system may be avoided.

Another important aspect to be taken into account is that a capability never operates in a completely isolated environment. The capability will always need to interface with other ‘related capability systems’ in the external environment that is inhabited by the other capability systems of the ADF and also those of other nations. Any problem experienced within a single capability has the potential to have the flow-on effect of degrading the performance of the whole network of related capability systems.

This consideration of all elements of a capability and the wider operational environment must also be reflected in the approach taken in ADF experimentation. Experimentation should always bear in mind each of the FIC that make up a specific capability system and the interrelated capabilities that contribute to, and depend on, its performance.

Figure 4.1 – Fundamental Inputs to Capability[3]

As already mentioned, the capability life cycle as described by the *CSLCMM* covers the entire life of a capability, from the development of an initial concept of its operation through to its disposal. Figure 4.2 illustrates the various stages of this life cycle and outlines what inputs are required by each phase, what outputs flow from each phase, and who is accountable for the management of the capability’s progress through each phase.

The text highlighted in blue indicates the documents that are influenced by, or flow from the CD&E process. In the needs analysis phase the obvious inputs from the

3 ibid., p. 1-2.

experimentation process are analytical studies and experimental results. Other items that are not contained in the *CSLCMM* but that also provide inputs to needs analysis are those highlighted in red: validated concepts and doctrine. Validated concepts being the result of experimental experience with future capabilities, while doctrine reflects the knowledge gained from past and current experience with fielded military capabilities.

The text highlighted in red indicates additional items that may be included in the capability development process and that are also influenced by the CD&E process.

	Needs Analysis	**Requirements Phase**	**Acquisition Phase**	**In-Service Phase**	**Disposal Phase**
	Identification of capability gaps and opportunities	Development of solution requirements	Implement / acquire the solution	Sustainment of the capability	Withdrawal from service
Input	Strategic Policy Military Strategy Analytical Studies Joint Military Experiments Validated Concepts Doctrine	Capability Options Document (COD) Operational Concept Document (OCD) Function and Performance Specification (FPS) Industry Engagement	Endorsed Documents from Requirements Phase Tendering and Contracting Documents	CDF Preparedness Directive (CPD) AST Operational Preparedness Requirement (ASTOPR) Directed Level of Capability (DLOC) Customer Service Agreements (CSA) Operational Performance Agreements (OPA) Concept of Operations (CONOPS)	Endorsed Documents from Requirements Phase Transition to Service of Future Capability
Output	Defence Capability Planning Guidance (DCPG)	First Pass Approval Defence Capability Plan (DCP) Second Pass (Project) Approval	Future Capability	Preparedness Through Life Support Modifications/ Upgrades and Life of Type Extensions (LOTE) Updates to Doctrine	Phase out and sale of assets
Accountable	DEPSEC SP/ VCDF	VCDF	USDM/ DEPSEC CS/ Output Executives	USDM/DEPSEC CS/ Output Executives	USDM/ DEPSEC CS/ Output Executives
Final Authority	Government	Government	Government	Government	Government

Figure 4.2 – Capability Life Cycle Management[4]

4 ibid., Annex A to Chapter 1.

NEEDS ANALYSIS

The needs analysis phase is concerned with capability analysis, which is the process of identifying current or prospective capability gaps. As this phase relies heavily on the joint warfighting concepts and experimental insights provided by the CD&E process it is worth looking at this phase in greater detail. The *CSLCMM* outlines a four-stage process for conducting this analysis.

> **First stage.** This involves the use of AIPS and the development of complementary [joint warfighting concepts] which describe in broad terms how strategic and operational tasks are to be performed and the broad range of capabilities this might require.
>
> **Second stage.** During this stage the extent to which the ADF could carry out operational tasks given current and approved future capabilities is analysed. This includes an assessment of the levels of performance that could be achieved. Of particular importance is the need to identify prospective degradation in task performance that will result when platforms or combat systems reach their planned Life of Type. Many ADF capabilities have multiple roles and can be used to carry out similar tasks. It is necessary to ensure that areas of potential overlap or duplication are carefully noted. Subject matter experts and technical regulatory authorities can provide advice on legislative and regulatory issues affecting capability.
>
> **Third stage.** In this stage initial judgments are made on what broad level of task performance is likely to be acceptable in the future. This is usually expressed in broad quantitative terms and should include judgments on the risks of not being able to perform operational tasks to that level.
>
> **Fourth stage.** This involves examining if the ADF could realise improvements in the way in which current and approved future capabilities could be used in performing operational tasks. Doctrinal, organisational and training solutions should be considered first, as these are generally the least expensive and the easiest to implement. In simple terms, this means looking at different ways to conduct and support operations with existing capability inputs. If, however, it is concluded that there are operational tasks or elements of operational tasks for which the minimum acceptable level of performance is higher than that achievable, it will usually be necessary to develop options for investing in future capability.[5]

The first two stages of this process rely on the CD&E process for a number of their inputs. The requirement for analytical studies and joint military experiments is expressly stated in Figure 4.2. However, the joint warfighting concepts mentioned in the first stage of needs analysis constitute an essential input to the required analysis but are conspicuous by their absence from Figure 4.2. For this reason Validated Concepts has been added

5 ibid., p. 2-6.

to Figure 4.2 and highlighted in red text to indicate that it is an addition to the original document. The fourth stage of needs analysis also draws on the CD&E outputs and also mentions the need to examine doctrine and changes to doctrine in determining the need to acquire a new capability. Again, Doctrine is absent from Figure 4.2 and has been added for the same reasons and in like manner to Validated Concepts.

A main output from the needs analysis phase is the Defence Capability Planning Guidance (DCPG) document, which provides detail of the total framework of Defence capabilities. In the DCPG all capability development projects are linked back to the government strategic policy to indicate which capabilities provide the specific effects required by government. The functional relationship between different Defence capabilities is also identified. The DCPG also includes a brief statement on the current status of all Defence capabilities, change drivers that may affect them both now and in the future and what future developments are expected to take place in fields related to the capability. The judgments made on these considerations

> … need to be informed by an understanding of how the ADF is likely to perform strategic and operational tasks, both now and in the future (in about a 10–15 year time frame), the impact of technology and the mix of capabilities that could be required.[6]

It is the CD&E that provides an opportunity for the ADF to experience the future and thereby develop the understanding necessary to analyse capability requirements, opportunities and needs.

REQUIREMENTS DEFINITION

In the needs analysis phase, the information and documentation produced by the CD&E process require little or no amendment to be useful in the analysis conducted in that phase. In the requirements definition phase, however, the validated concepts and experimental observations undergo a significant translation from the broad to the very specific and from 'warfighter speak' to 'engineering speak'.[7] An output of this translational process is a set of documents that defines the capability requirement in detail. When the document set is approved by capability managers they are passed to DMO to acquire a specific solution system that will meet the identified capability need. Three principal aspects of the capability will be given greater definition; the functions it is to perform, the level of performance required and the conditions under which this is to be achieved.[8] This information progressively obtains greater definition as it advances

6 ibid., p. 2-8.
7 Mick Spiers and Rob Dobson, *Operational Concept Document Policy Development*, Department of Defence, Canberra, 2002, p. 2.
8 VCDF, *CSLCMM*, p. 3-1.

through the requirements phase. This phase has two major milestones that a capability proposal must pass through to become an acquisition project. These milestones are the first and second pass approval of the proposal.

Two-pass process. Defence has established the two-pass approval process in order to fulfil a number of purposes, one of which is to meet the requirements of government.

> The Government's desire to have greater involvement in Defence decisions has led to a two-pass approval process for Defence projects. The first pass is fundamentally to approve the capability sought by Defence along with broad options to be further evaluated. The second pass is to approve the project budget, schedule, risk, capability and often the solution class. The Vice Chief of the Defence Force (VCDF) has documented this two-pass process in a document entitled 'Capability Systems Life Cycle Management Guide 2001', which is now used as the reference for lower-level process definition and process improvement.[9]

This two-pass process also provides the Government early involvement in the considerations and decisions that face Defence. For proposals that are unusually complex, controversial or expensive, the Government also has the ability, at first pass consideration, to stipulate additional review requirements that have to be met by the proposal before it can proceed to second pass consideration.[10]

First-pass. The requirements phase requires the preparation of the Preliminary Concept Options Document (PCOD) to support the first-pass consideration of the capability by the DCC. The primary inputs to the preparation of the PCOD include validated concepts and the results of experimental activities that relate to the capability. These important inputs will have direct relevance to most of the categories of information that are contained in the structure of the PCOD (see Annex A). In the PCOD the language used will be 'plain English' as it used to inform a wide range of personnel of varying background who may not be military professionals.

With first-pass approval, government agreement is obtained in connection with the broad functions and performance of the proposed capability. The proposed year of decision and an in-service date (ISD) are also identified. Generic options that can provide a solution and which are to be explored in detail are enumerated. Indicative timings for each option are included in this detail. In developing these options the expenditure of Commonwealth funds may be necessary and approval can be given at this time for that expenditure if it is beyond Defence delegations.

9 Spiers and Dobson, *OCD Policy Development*, p. 1.

10 VCDF, *CSLCMM*, p. 3-2.

If a capability proposal obtains first-pass approval, it will be included in the Major Capital Investment plan that includes all major proposals that have obtained first-pass approval, as well as those that have received second-pass authorisation to proceed with formal acquisition-project establishment and capital expenditure. If acquisition activity is to commence within the next four years the proposal will also be included in the Defence Capability Plan (DCP). The DCP is a plan agreed between Defence and Government on the development of future capability and requires the approval of the National Security Committee of Cabinet to change.

Second-pass. In the second-pass, Defence seeks formal project approval, usually as part of the annual budget process. Projects with multiple acquisition phases will usually have multiple second-pass approvals. It occurs when options have been clearly defined and evaluated and a proposal has reached the stage of requiring formal government approval to proceed to the acquisition phase. The second-pass seeks government approval for Defence to seek formal offers from suppliers that lead to the selection of a capability solution and the expenditure of capital investment funds. Agreement is also obtained on the boundaries of the preferred solution, especially in terms of capability, cost and schedule.

To support the second-pass consideration of the capability proposal, the PCOD is further developed from the generic to the specific to provide greater detail on each of the viable options for delivering the capability. The resulting document is called the Capability Options Document (COD), which is a larger and more comprehensive document than the PCOD (see Annex A). The products of CD&E also influence the COD, like the PCOD. For second-pass consideration the COD is, however, still only a brief document designed to inform senior level decision-makers on the critical aspects of the capability proposal. The even more detailed information required to commence acquisition activity, obtain industry proposals and write contractual requirements is provided in another set of documents that have as their foundation the Operational Concept Document (OCD) (see Annex B).

The OCD's life begins in the requirements phase, usually prior to first-pass consideration, but continues to develop through the acquisition phase. The OCD goes far beyond the description of the capability provided in the PCOD and COD and includes comprehensive descriptions of all functions that a capability must perform within a range of detailed scenarios. The OCD is written in 'warfighter speak' and is used by engineers to formulate a Function and Performance Specification (FPS), which is written in 'engineer speak'. The Test Concept Document (TCD) is the other document that is based upon the OCD and contains the expectations of the warfighter and those involved in verification and validation activities of how the performance of the capability can be tested. The TCD will normally evolve into the acquisition projects official Test and Evaluation Master Plan (TEMP). The development of both the FPS and TCD usually commences after first-pass approval has been obtained.

The outline of the purpose and structure of an OCD as contained in the *CSLCMM* is contained in Annex B. An examination of this outline indicates how many items in the OCD can draw directly upon the results of concept development and experimentation. The sections of the OCD that deal with operations, operational needs, capability system overview, operational environment, support environment and operational scenarios, may all draw on the results of CD&E. Indeed, many of these matters will already have been examined in some depth during the development of related concepts and in the conduct of experiments involving the capability. As previously mentioned, the OCD will continue to be developed during the acquisition phase.

ACQUISITION

In the acquisition phase the OCD document set (OCD, FPS and TCD) that has been authorised at second-pass approval is used to provide the documentary foundation for the project's acquisition activity. While the PCOD and COD translate the results of CD&E into a business case that supports a capability decision, the OCD document set continues the translational process and provides a set of specifications that support the more detailed and specific requirements of acquisition activity. Throughout the acquisition phase the OCD, FPS and TCD will continue to be developed and refined based on the project's interaction with capability staff, the contractor and regulatory authorities.

Changes to the capability being acquired may result from shortfalls in performance, capability performance that exceeds requirements, alternative methods of operation, changing regulatory requirements, and a range of other unforseen events that will affect the capability system being acquired. All these impacts on the capability must be reflected by changes made to the OCD set of documents. In this way the key capability documents that detail the characteristics of the capability will reflect the original conceptual and experimental expectations and will also contain the modifications that have been made to those expectations by the experience of designing and producing the actual system components. Toward the end of the acquisition phase the OCD, and other acquisition documents, can provide useful input to the development of the Concept of Operations (CONOPS) document that carries over into the in-service period of the capability's life cycle.

Of course the major element that is born of the acquisition process, and which reflects the results of CD&E, is the actual capability system itself. With its introduction into service the capability now enters into its in-service period.

IN-SERVICE PERIOD

During the in-service period of the capability life cycle the CONOPS that began development in the acquisition process will be included as an element of the Weapon System Plan (WSP), which is produced by the Force Element Group (FEG) that operates and manages the capability. As part of the WSP the CONOPS will provide a high-level description to the wider ADF of how the FEG intends to operate the capability in a range of operational scenarios and will indicate the important interactions of the capability with other related capabilities. The CONOPS will also influence the development of lower level tactical procedures (TACPROCS) that will guide operators in the employment of the capability in its operational roles. It is important that the CONOPS should be fully developed and maintained throughout the capability's in-service life. It should reflect any change in circumstances that may significantly affect the capability, such as modifications, mid-life upgrades, accumulation of fatigue and obsolescence, to name but a few changes. Such changes may also occur in related capabilities that will impact the subject capability in the performance of its roles.

While most newly acquired capabilities provide increased abilities compared with the systems they replace, their effects usually still fit within existing doctrinal frameworks. However, some acquisitions may provide capability enhancements that are so significant, or deliver a capability that is completely new, that the doctrinal framework of the Air Force may need to be updated. For the RAAF the approaching introduction into service of stealth aircraft (the JSF), AEW&C and unihabited aerial vehicles will cause the RAAF to examine the effects associated with these capabilities to determine if existing doctrine needs to be revised. Doctrinal principles are usually those that have stood the test of time and which have demonstrated an enduring applicability. Due to the enduring nature of these principles they do not change frequently and a sound case for their amendment will need to be developed through the conduct of actual exercises and operations that involve the new capability. CD&E results may be suggestive of the coming change but actual experience is required to validate these results and confirm the need to update doctrine.

In this chapter a role for CD&E has been identified in highlighting an existing or potential capability gap during the needs analysis work conducted at the beginning of the capability life cycle. In the requirements phase business cases are developed to address these gaps and they are also reliant on CD&E to develop capability options for resolving the capability shortfall. The PCOD and COD support the consideration of these business cases and the decision to proceed with acquisition. In the acquisition phase the OCD document set further defines the capabilities of the solution system that has been selected by Defence. The detailed operational scenarios that are a key feature of the OCD will also relate directly to CD&E activity that has been undertaken in connection with the capability. Finally, the results of the conceptual and experimental activity that has occurred throughout the whole process will be included in the CONOPS and TACPROCS that will support the capability throughout its in-service life.

CD&E provides a ‘powerful way of injecting new thinking’ into capability development by discovering, proving and demonstrating essential information about capabilities, their effects and their characteristics, and making this knowledge available to Defence’s senior decision-makers and operators at every stage of the capability life cycle.

ANNEXES:

A. Preliminary Capability Options Document

B. Operational Concept Document

PRELIMINARY CAPABILITY OPTIONS DOCUMENT

The Preliminary Capability Options Document (PCOD) should not normally exceed five pages in length, excluding the cover sheet.

The Capability Options Document (COD) should be as short as practical, referring to details in the Operational Concept Document (OCD), Function and Performance Specification (FPS), Test and Evaluation Concept (T&EC) and Project Management Plan (PMP) wherever practical.

Serial	Heading	PCOD (Supports First Pass)	COD (Supports Second Pass)
1.	Cover sheet	a. project number and title b. sponsor division c. responsible branch d. contact appointment e. endorsed by (signature block) after Defence Capability and Investment Committee approval	Cover sheet as for PCOD
2.	References	List any key policy, strategy, concept and other capability documents that have a direct and fundamental influence on the PCOD and which an officer may wish to consult	As for PCOD
3.	Description	A brief but clear description of the capability including its boundaries	As for PCOD
4.	Background and previous committee consultation	Not required in PCOD	If necessary, a brief background on the project and the outcomes of any previous committee consideration

5.	Purpose	A succinct statement of the purpose of the capability, generally expressed in terms of operational, logistic or management effects	Refer to OCD
6.	Justification	a. refer briefly to any strategy, policy, concept or other source from which the need has been derived b. note any Government decisions, including those contained in strategic policy documents, including the White Paper, that have a direct bearing on the need c. make reference to the Defence Capability Planning Guidance (DCPG) d. summarise the current or prospective capability gap to be reduced in terms of: (1) the effects that can be achieved with current and approved capabilities, expressed qualitatively and quantitatively; (2) the effects that need to be achieved; and (3) the resultant capability gap and its attached risks	Refer to OCD

7.	Relationship to other capabilities	a. make reference to the DCPG b. a brief summary of the functional relationship between the proposed capability and other current, approved and unapproved capabilities with which it has a direct interface c. the summary should highlight complementarities, overlaps and duplications	Refer to OCD
8.	Function and Performance	A brief summary of: a. functions to be performed (what the capability system must do) b. performance levels (how well the capability system must perform its functions) c. performance conditions (the environment in which functions are to be performed)	Refer where practical to OCD or FPS where function and performance should be dealt with comprehensively Priorities for function and performance should be classified as either essential, important or desirable; or be weighted individually for a total score of 100 The acid test for function and performance descriptions is that they: a. are achievable b. are affordable c. are unambiguous d. can be related to operational scenarios e. recognise major constraints and risks
9.	Timings	Proposed year of decision and In-Service date	As for PCOD
10.	Capability System Options	A summary of the broad generic options that have been considered, including the identification of: a. those options that should be discarded b. the option(s) that should be developed further	A description of each particular option considered feasible within the boundaries of the preferred generic option(s). a. it is important that particular options are both technically feasible and affordable b. the level of confidence in these judgments will grow as a project matures

<table>
<tr>
<td>11.</td>
<td>Financial Considerations</td>
<td>For each generic option:

a. an estimate of the capital investment cost expressed as a cost band

b. a broad estimate of the LCC, expressed as a cost band, to be incurred by the proposed capability divided into:

(1) capital investment costs, and

(2) gross operating costs supported by an estimate of the net impact on the operating budget

c. whether or not PF is a feasible option</td>
<td>a. for each option, the estimated Life Cycle Costs (LCC) reduced to net present value as appropriate

b. LCC must be divided into:

(1) project costs, and

(2) operating costs supported by an estimate of the net impact on the operating budget

c. if appropriate, justification for pursuing a Private Finance (PF) option. PF options must be compared with a Project Cost Benchmark

d. sufficient detail should be provided to enable a clear understanding of the impact on:

(1) unapproved Major Capital Investment Program,

(2) operating statements,

(3) balance sheets, and

(4) cash flow statements

e. the importance of clearly identifying the following is emphasised:

(1) gross increases in recurrent operating expenses, especially those incurred by people and through life support (TLS);

(2) compensating reductions including those realised by the phase out and disposal of current capability systems; and

(3) net increases in recurrent operating costs

A Finance annex is often required

A useful guide to cost estimating for major capital investment projects is contained in Capital Equipment Procurement Manual (CEPMAN), Chapter 5</td>
</tr>
</table>

12.	Preparedness	Not required in a PCOD	For each option: a. a description in appropriate detail of the people, training, and TLS implications of the levels of readiness and sustainability that could be expected of the capability b. reserve stocks, especially for ammunition, may require particular consideration
13.	Workforce Planning	For each generic option a general statement on the implications of the proposed capability system for the Defence Working Plan (DWP)	For each option: a. an estimate of the workforce requirements including numbers and if appropriate, competencies critical to the capability that may be difficult to establish or sustain b. how these workforce requirements will be accommodated within the DWP
14.	Training	If required, a brief statement on any critical training needs for each generic option	If necessary, an outline training needs analysis for each option.

15.	Through Life Support	For each generic option a broad description of the TLS concept with particular reference to: a. the outline maintenance concept including industry involvement b. major facilities issues including ranges and training areas	For each option a description in appropriate detail of the TLS concept with particular emphasis on the following elements of ILS (refer to OCD if possible): a. engineering support b. maintenance support c. supply support, including requirements for operating and reserve stocks d. packaging, handling, storage and transportation e. data management f. people g. training and training support h. facilities i. support and test equipment j. computer support k. radiofrequency spectrum requirements and costs, in compliance with DI(G) ADMIN 05–9—*Projects involving the Provisions/Utilization of Communications-Electronics Equipment—Approval Process* and DI(G) OPS 07–14—*Management of Defence use of the Radio Frequency Spectrum*
16.	Environmental Protection	If necessary, a brief statement for each generic option on any critical environmental protection issues	For each option, an outline of clearances required under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
17.	Information Environment	a. a brief statement of the place of each generic option in the Defence Information Environment b. critical information exchange requirements should be highlighted	For each option: a. a description of the place of the capability system in the Joint Command Support Environment or Defence Management Support Environment b. a statement of critical information exchange requirements c. the level of compliance with the DEA

18.	Industry Engagement	A brief summary of: a. opportunities for industry engagement (by major sector) for each generic option b. likely impact on any strategic industry capabilities c. identification of essential and desirable TLS capabilities to be provided by indigenous industry	For each option: a. a summary of opportunities for industry involvement (by major sector) during each phase of the life cycle b. any Government policy implications for industry, especially industry sector capabilities
19.	Interoperability	A brief summary of key interoperability requirements for each generic option including: a. within the Australian Defence Force (ADF) b. with allies, especially the United States (US) c. with the civil infrastructure	For each option, a summary with details as necessary on operability: a. within the ADF b. with allies, especially the US c. with the civil infrastructure
20.	Collaboration	Identify broad opportunities for international collaboration for each generic option	For each option, an appropriately detailed summary of either the opportunities for international collaboration or the essentiality of such arrangements
21.	Acquisition Strategy	For each generic option, a brief summary of the likely acquisition strategy	For each option, a description of the preferred acquisition strategy which could include considerations of: a. PF proposals b. evolutionary acquisition
22.	Numbers of Platforms and Systems	A broad estimate of the likely number of major platforms or combat systems likely to be required for each generic option	a. for each option, a statement of the number of major platforms or combat systems likely to be acquired b. reference should be made to the OCD

23.	Science and Technology	For each generic option: a. a brief summary of the proposed level of science and technology support (including analysis) for all phases of the life cycle b. include key questions and assumptions to be addressed by OA c. indicate CTD that may precede or are part of the project	For each option: a. a detailed description of science and technology requirements, including Research and Development (R&D), Operations Analysis (OA), Capability and Technology Demonstrator (CTD) and T&E b. details on continued Defence Science and Technology Organisation involvement during the life cycle c. broad judgments on the likelihood of the need for progressive upgrades during the in-service phase
24.	Major Risks and Hurdles	For each generic option: a. a brief summary of the major operational, financial or technological hurdles that will have to be cleared if the proposal is to be successfully implemented b. if the hurdles have to be cleared before Second Pass, reference should be made to timings, risks and the funding required	For each option, the major hurdles and risks to be cleared during the Acquisition phase
25.	Access to Radiofrequency Spectrum	For each generic option, a brief summary of: a. anticipated spectrum requirements b. criticality of spectrum access to capability c. potential impact of spectrum access on project progression d. DCRA advice of anticipated spectrum access	For each option, a brief summary of: a. anticipated spectrum requirements b. criticality of spectrum access to capability c. potential impact of spectrum access on project progression d. DCRA advice of anticipated spectrum access
26.	Risk Management	For each generic option a brief summary of the major risks to capability, cost and schedule and how they will be managed	For each option, a summary of the major risks to capability, cost and schedule and how they will be managed, including likely risk treatment measures

27.	Occupational Health and Safety	Not required in PCOD	For each option, a summary of key Occupational Health and Safety issues and how they will be managed
28.	Annexes	Annex for outline PMP	a. annexes for OCD, FPS, T&EC and PMP b. a Finance annex could be included

OPERATIONAL CONCEPT DOCUMENT

REFERENCE:

A. American Institute of Aeronautics and Astronautics/American National Standards Institute G018-1992—*Guide for the Preparation of Operational Concept Documents.*

INTRODUCTION

1. The purpose of an Operational Concept Document (OCD) is to translate a statement of need to reduce a current or prospective capability gap into terms that will allow for the preparation of a Function and Performance Specification. The OCD informs those accountable for developing, acquiring, operating and supporting a capability system of the desired characteristics of the capability to be developed. As such, the OCD also represents the primary reference for determining fitness-for-purpose. It is therefore the framework within which a capability is developed and evaluated.

   Of particular importance is the need for an OCD to express concepts in a way that is meaningful to those who manage the acquisition of platforms and combat systems.

2. An OCD should have a narrative style and wherever possible be supported by graphics, including flow charts. It must describe an operational context in which the proposed capability will be employed and the needs of the people who will operate and support it as they are part of the system.

3. The OCD must therefore be meaningful to a wide audience with a diverse range of technical and managerial backgrounds. This requires, among other things, the need to retain an awareness that a capability system may consist of several levels where elements at each lower level may be considered as sub-systems of the overall capability.

4. The first step in generating an OCD is to establish a clear definition of the capability boundaries, thereby establishing clearly what is inside the system and what is outside it.

5. The key to a successful OCD is the development of relevant operational scenarios. These describe how a capability is to be used from an operational point of view. They discuss how the capability will function in various modes of employment and explain how it will interact with its external environment. A good scenario is one that describes how a capability is to be operated and supported during a specific mission, mode of employment, or sequence of events.

6. A modest set of key scenarios is usually necessary. Each should focus on a particular area of interest and not attempt to cover all aspects at once. It is often useful to develop a typical and more likely scenario first as a baseline for those that are less likely or more demanding.

7. A well-developed OCD will establish:

   a. key operational processes relevant to the capability,

   b. the functions the capability is to perform,

   c. the standards and conditions under which those functions are to be achieved,

   d. the functional hierarchy of the capability, and

   e. key data and control flows between the capability and users.

8. A guide to the content of an OCD (reference A) is contained in Appendix 1.[11]

APPENDIX:

1. Operational Concept Document Format

11 Department of Defence, *Capability Systems Life Cycle Management Manual*, Annex D to Chapter 3, Department of Defence, Canberra, 2002, p. 3D.

APPENDIX 1 – OPERATIONAL CONCEPT DOCUMENT FORMAT

1.0 SCOPE

Identify the project number and title, sponsor division, responsible branch and contact appointment.

1.1 Title

This section establishes the scope and purpose of the Operational Concept Document (OCD).

1.2 Capability system overview

Describe briefly the purpose of the capability to which the OCD applies.

1.3 Document overview

Summarise the purpose, the intended audience and outline contents of the OCD.

2.0 REFERENCES

List the title of all documents referred to in the OCD.

3.0 OPERATIONS

This section describes operational concepts from the perspective of the commander or manager who controls the employment of the total capability being considered. Commanders and managers are external to and not part of the capability system.

This section must be developed without any reference to a likely solution in order to provide a clear context for the employment of the capability.

Factors that should be addressed include:

– operational and tactical concepts, operational policies and constraints;

– a description of who the users are and what they do; and

– when and in what order operational activities occur.

3.1 Operational overview

3.1.1 Mission (purpose) – Describe the primary and if necessary, the secondary mission of the capability. Factors such as the threat, geography and operational or tactical concepts should be explored briefly.

3.1.2 Operational policies – Highlight any key operational policies that shape how the mission is achieved.

3.1.3 Operational constraints – List and describe the key constraints that govern or limit how the mission is achieved.

3.1.4 Existing operational environment – Describe the current physical operational environment in terms of relevant Fundamental Inputs to Capability (FIC).

3.1.5 Existing support environment – Describe the current support environment in terms of relevant FIC.

3.2 People

3.2.1 People profile – List in terms of key competencies, the groups of people involved in achieving the mission.

3.2.2 Organisational structure – Describe how these groups of people fit into the overall organisational structure. Key functional relationships between each element should be identified.

3.2.3 People interactions – Describe how these groups of people interact, both within and between organisational elements.

3.2.4 People activities– Discuss in broad terms the activities conducted by each group of people in achieving the mission.

3.3 Operational processes

Discuss the operational processes followed to achieve the mission. Process models that illustrate the flow and sequence of events are especially useful. Where appropriate, processes may be decomposed to lower levels. The clear identification of inputs and outputs at each stage of a process is essential.

4.0 OPERATIONAL NEEDS

This section provides the bridge from the description of operations to the subsequent system overview. It describes the mission and people needs driving the requirement. The people needs to be described are those of the people who operate and support the capability, including those who conduct training.

4.1 Mission needs

Describe the mission needs that the capability system will satisfy.

4.2 People needs

Describe for each group of people the needs that the proposed capability should satisfy.

5.0 CAPABILITY SYSTEM OVERVIEW

This section should provide an overview of capability requirements, especially system functionality and the system architecture.

5.1 Capability system scope

Describe the scope of the system within the context of the mission.

5.2 Users (commanders and managers)

Identify the users (commanders or managers) of the capability. It is important to clearly describe the difference between the user and those who operate and support the capability. Both points of view, while potentially very different, are needed to ensure a well designed capability.

5.3 System interfaces

Identify the external interfaces of the proposed capability, including information exchange requirements.

5.4 System states and modes

Describe the operational states and modes and relate them to operational process and user activities.

5.5 System capabilities

Describe the overall capability requirement in terms of the functions to be performed.

5.6 System goals and objectives

(derived from operational scenarios, see Serial 8.0). Describe the overall capability goals and objectives, especially in terms of:

5.6.1. Performance levels (how well the capability system must perform its functions) in terms of:

a. quantity;
b. quality;
c. coverage (how far and wide);
d. time (when and for how long); and
e. availability.

5.6.2. Performance conditions (the environment in which functions are to be performed) including:

a. geographic environment;
b. nature of the threat;
c. through life support arrangements;
d. requirement to interface with other capability systems;
e. legislative, regulatory or policy constraints; and
f. anticipated radiofrequency spectrum requirements.

5.7 System architecture

Provide an overview of the capability system architecture.

6.0 OPERATIONAL ENVIRONMENT

This section describes the required operational environment in terms of relevant FIC.

7.0 SUPPORT ENVIRONMENT

This section describes the required support environment in terms of relevant FIC.

8.0 CAPABILITY SYSTEM OPERATIONAL SCENARIOS

This is the most important section of the OCD. It can contain a level of detail greater than other parts of the OCD because there can be several scenarios applicable to each operational process.

Scenarios should be kept to the minimum necessary to explain how the capability will be employed.

Scenarios should be based in the future and linked to Australia's Military Strategy, Joint Warfighting Concept and Australia's Indicative Planning Scenarios.

Scenarios are required to address normal conditions, demanding conditions, failure events and maintenance modes.

8.X Operational process

Identify each operational process that is to be supported by the capability and describe one or more scenarios for each of them.

8.X Scenario

Each scenario should include:

Overview – Summarise what the capability is to do in broad terms (related to mission) and how it is achieved.

Sequence – Cover factors such as the sequence of activities, information flow and decision points.

Performance – Summarise the functions, conditions and performance standards required by the scenario (see Serial 5.6).

Organisation – Discuss user, operator, organisational and support considerations.

System Environment – Identify the geographic environment, safety interface requirements with the external environment, safety and security needs.

CHAPTER 5
EXPERIMENTAL EXAMPLE – HEADWAY 04

SCENARIO DESIGN

Headway 04 was an experimental campaign of a series of events conducted over the whole of 2004. The program was designed to examine the ability of the force being acquired under the Defence Capability Plan (DCP), possibly supplemented by an area Ground Based Air Defence (GBAD) system, to provide area air and missile defence for a Joint Task Force operating in a regional littoral environment.

This scenario was first identified as needing further study as a result of conclusions developed at the culmination of the Navy's *Headmark* experiment in October 2003. Additional parties with an interest in the *Headway* experiment significantly increased in number during the *Headway* planning process, with the main interest coming from staff in the relevant project areas of the Defence Materiel Organisation (DMO) as well as from the single Service headquarters.

The primary RAAF interest in *Headway* 04 lay in developing joint concepts of operations (CONOPS) for the employment of RAAF assets in an expeditionary warfare environment. The usefulness of a Cooperative Engagement Capability (CEC) on board the Airborne Early Warning and Control (AEW&C) was also a matter of interest for the RAAF.

For the DMO project staff the *Headway* experiment provided the benefit of defining the future environment to a greater degree, which in turn aided their own project related studies. In particular there was a need for a better understanding of how the various components of the overall air defence system might operate together, and what the role of the individual elements might encompass.

The Army examined the question of the utility of a future GBAD system as an element of the joint air defence system exercised in *Headway* 04. This matter interested not only Army but also capability development staff of the other Services, as the lack of GBAD would place greater demands on the other Service's air-defence assets.

The experiment was set in the 2018 time frame, employing systems and capabilities that are likely to be available to the ADF and potential regional adversaries at that time.

The future RAAF capabilities that were included and played a significant part in the air defence battle were the F-35 Joint Strike Fighter (JSF) and AEW&C. For the RAN the Air Warfare Destroyer (AWD) and the enhanced ANZAC frigates provided organic air defence of the surface task group.

The future Red air force was equipped with Su-27 and Su-30 aircraft with the ability to employ advanced air-to-air missiles, including an AEW&C 'killer', and air-to-surface missiles with stand-off range. The naval threat consisted of fast, missile-carrying patrol boats and submarines armed with anti-ship missiles and torpedoes. On land the Red force had surface-to-surface missile batteries.

CONCEPTS

The essential concept underlying the employment of the various Blue capabilities was outlined in a Strengths, Weaknesses, Opportunities and Threats analysis before the conduct of the wargaming phase (see Annex B).

Blue and Red Orders of Battle

The following DCP iterations were determined as being representative of possible DCP force structures, within the guidelines and assumptions of the experiment. The first iteration represents the baseline force, about which changes were made to generate the range of variants.

Blue Order of Battle

	1	2	3	4	5	6	7	8	9	10	11
StEW	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y
LHD	2	2	2	2	2	2	2	2	2	2	2
LCH	2	2	2	2	2	2	2	2	2	2	2
LCU	4	4	4	4	4	4	4	4	4	4	4
HSV	2	2	2	2	2	2	2	2	2	2	2
MHC	4	4	4	4	4	4	4	4	4	4	4
FFH	2	2	2	2	2	2	2	2	2	2	2
JSF	4	0	6	4	4	4	4	4	4	4	F18
AAR	1	0	1	1	1	1	1	1	1	1	1
AEW&C	1	1	1	1	1	1	1	1	0	1	1
AWD	1	1	1	1	SM-6	1	1	1	1	SM-6	1
GBAD	0	0	0	0	0	0	1	0	0	0	0
CEC	N	N	N	N	N	N	Y	N	N	Y	N
Airborne Missile Threat AS	20	20	20	17	20	20	20	17	20	20	20

Table 5.1 – *Headway* 04 Blue Order of Battle

Notes:

The text highlighted in blue are the changes in a particular iteration from the baseline order of battle, Iteration 1.

For the JSF line all numbers refer to the number of JSF aircraft available in the scenario. F18 indicates the replacement of JSF with 4 x F/A-18 aircraft.

For the AWD line the number indicates the number of AWD platforms available. SM-6 indicates the replacement of all SM-2 missiles by SM-6 missiles.

The following threat iterations were determined as being representative of a range of threats that lie either side of the breaking point of the capability of all DCP-force iterations, within the guidelines and assumptions of the experiment.

Red Order of Battle

	Threat 1	Threat 2	Threat 3	Threat 4
FPB Each 2 x SS-N-22 6 x SS-N-25 Switchblade	1	2	2	2
Coastal battery 4 firing vehicles, each 4 x SS-N-25 Switchblade	1	1	1	2
SSG Each 4 x SSN-27 per salvo One salvo only	1	1	2	2
SU-30 Ground attack 4 x AS-14 + 2 x AA-12, or 4 x LGB + 2 x AA-12 Maritime strike 4 x AS-20 + 2 x AA-12, or 2 x AS-17 + 2 x AA-12	4	8	10	12
SU-27 Escort 4 x AA-11 + 4 x AA-12, or 4 x AA-10 + 4 x AA-12 AEW&C Killer 2 x AS-17 + 2 x AA-11	4	8	10	12
SA-342L Gazelle Attack Helicopter HOT ATGM	1	1	2	2

Table 5.2 – *Headway* 04 Red Order of Battle

WARGAMING

The wargaming phase was held in the last week of April and was aimed at gaining an understanding of the interplay between Blue (defending) and Red (attacking) forces and how the physical environment affects this interplay. Specifically, the games were designed to elicit information in the following areas:

Blue force disposition. The likely disposition of air, naval and land force components of an ADF expeditionary force at various stages of a littoral manoeuvre operation, in relation to one another and to the physical environment.

Blue tactical employment. The way in which AWD, JSF, AEW&C, GBAD and supplementary systems would work together under a variety of different tactical scenarios in defence of an expeditionary force in the littoral.

Red tactical employment. Methods that might be used by an intelligent adaptive adversary to confront an ADF expeditionary force in a littoral environment, given a range of air and missile assets at its disposal.

Environmental effects. Methods by which both Red and Blue teams might exploit the environment to their advantage, and mitigate adverse environmental effects.

The information gleaned from the wargaming phase was used to 'script' a series of tactical engagements, which would then be simulated in a high fidelity, analytical environment. The output from the analytical phase will be quantified and justifiable assessments of the effectiveness of the air and missile defence system under a variety of defined conditions.

ELEMENTS SUBJECTED TO HIGHER FIDELITY ANALYSIS / INVESTIGATION

The main variables that were examined in the analytical phase were the Blue force mix (in terms of both its elements as well as its scale), the air and missile threat (in terms of its elements and scale); the level of Blue force networking (with particular emphasis on the benefits that might accrue from cooperative engagement); and the level of strategic early warning and cueing available to the Blue force from a variety of Intelligence, Surveillance and Reconnaissance (ISR) sources not organic to the Joint Task Force (JTF) under consideration.

ANALYSIS PROCESS

The analysis phase employed a closed-loop, constructive simulation environment (EADSIM and/or Battle Model) to assess a range of tactical engagements under tightly controlled conditions. Air Operations Division led a cross-divisional DSTO effort in this phase of the experiment.

The aim was to examine changes in the effectiveness of Blue's air and missile defence caused by variations in the Blue and Red force mix, the level of Blue's networking and the level of strategic ISR available to the Blue force.

Up to 35 different iterations of the scenario were to be executed within EADSIM, using Monte Carlo runs of each to produce data sets for subsequent analysis. The number of runs were limited by the scheduled time available to prepare scenario 'scripts' for each iteration, program the model, execute the multiple runs and collect the data. Thirty-five iterations were considered the maximum number likely to be achieved.

The intent was to test variations of both the DCP task force assets assigned to the task and the size of the threat against each of the various task forces. The method employed was to determine up to ~12 variations of the DCP and run each against three to four variations of the opposing force. The opposing force was designed to be scaled such that the upper limit of this force that the DCP force can defend against could be determined.

Therefore, a number of threat iterations, assessed as ranging from below this threshold to above it, were required. Interpolation of test results should then provide where the actual threshold lies for each variation of the DCP force. By maintaining consistency in the set of threat iterations used against each DCP force variation, threshold values can be compared for each DCP variation. From this conclusions regarding the air defence capabilities, with respect to experiment objectives, should be obtainable.

RESULTS

The initial intention of the author was to employ the unclassified results of the *Headway* 04, DSTO analysis, to draw out a number of the findings that were generated by the experimental campaign. However, due to time constraints on the author and a number of other factors that delayed the analysis of the experiment, these results were not available. The author has instead drawn upon a number of observations that became apparent during the wargaming phase of *Headway* 04 and also upon a number of executions of the *Headway* 04 scenarios in the Harpoon 3 simulation. The following results therefore are not the official findings or opinions of the Air Force Experimentation Office or of DSTO's Air Operations Division, they are the views and opinions of the author only.

BLUE PLANS

The Blue players in the wargaming phase established a multi-layered defensive system. The outer layer comprised the JSF aircraft available for Combat Air Patrol (CAP). The AWD's SM-2 missiles provided the second layer of defence. The final, inner, layer included ESSM, naval guns, CIWS, EW, deception (chaff and Nulka decoys) and GBAD when it was available. The JSF CAP operated at medium risk in defending the JTF and the Army units ashore. Plans were established to reposition the AAR and AEW&C assets away from Red threats as they ingressed toward the JTF. The objective for the CAP was to attrite Red's strike platforms before they could launch their missiles. All others' defensive capabilities could engage Red aircraft if the opportunity arose but it was more likely that they would be forced to attrite any missiles/weapons that penetrated the outer defensive layers.

RED PLANS

The Red team employed two types of attack against the JTF. The first profile was a simultaneous, multi-axis attack designed to present more threats than the outer (CAP) layer could cope with, thereby enabling some strike assets to close to launch range for their air-to-surface missiles. The other method was a single axis attack, sometimes called a 'gorilla', which was designed to overwhelm the defence at a single point, mass Red firepower and ease Red control of the strike package.

A third method was discarded due to the time restrictions of the short strike window. This profile would have involved smaller elements attacking the JTF using either multiple or single axis approaches but over a prolonged time period. This profile is designed to present a continuous threat that can take advantage of a momentary weakness in the defence to ingress and launch its attack. This weakness could arise during a period when CAP aircraft refuel from the tanker or when one CAP flight is returning to base and a second flight is not yet on station.

JSF

One of the first observations to be made became evident during the wargaming phase of the experiment. At that time it was noted that there existed a clear distinction in the capabilities that the AWD and the JSF provided the task group.

Positives. The major capability provided by the JSF was the ability to attack the enemy strike and escort aircraft, while the AWD was largely left with the role of anti-missile defence. The JSF's ability to deploy rapidly to a threatened sector and stealthily engage enemy aircraft, combined with the characteristics of the AMRAAM missile, allowed it to engage enemy aircraft on highly advantageous terms. Out of 142 JSF sorties simulated in Harpoon 3 only two were destroyed by enemy action, while the losses sustained by Red certainly supported the hypothesis that the JSF could inflict unsustainable losses on Red aircraft (see Annex C).

The JSF also proved a flexible platform that could be armed with a variety of load-outs. These included the standard air-to-air load of four AMRAAMs, or a surface attack load of three AMRAAMs and three small diameter bombs (SDB). Each of these configurations preserved the full stealth advantages of the aircraft. At the expense of a reduction in stealth the JSF could also carry eight AMRAAMs.

The surface attack configuration allowed the JSF to participate in surface strikes against Red's fast patrol boats (FPBs). Potentially, JSF could also have been employed against Red ground targets identified by Army units ashore. The decision to trade off air-to-air armament for surface attack weapons needs serious consideration. JSFs armed with eight AMRAAM provided the most effective defence against Red air strikes. Even with reduced stealth the JSFs in this configuration were still able to reach launch range undetected. Indeed, it was only when the JSF was so armed that results were obtained where all strike aircraft were destroyed pre-launch (see Annex C).

The JSF's sensor suite also allowed the Blue team to employ JSFs as singletons, especially when supported by AEW&C, which enhanced flexibility. AEW&C also enabled the JSF to operate in a passive mode, which further increased its stealth advantage. Without AEW&C the preference was still to use JSF in pairs, though independent operations were still carried out.

A significant advantage that the JSF provided to the defence of the JTF was the disruption it caused to Red forces carrying out a multi-axis attack. This disruption forced Red launches to spread over a considerable time, up to six minutes. In comparison, when conducting a single axis attack Red was able to launch all of its weapons in around 30 seconds once in range. By increasing the time between first and last launch the anti-missile task of the JTF's other defences was greatly assisted as they could engage targets one after the other rather than all at once.

Negatives. Against in-flight air-to-surface missiles, however, the JSF was disadvantaged by the low number of air-to-air missiles that it carries and by the small chance of successfully engaging such a missile due to their small size, high speed and low altitude. The JSF's anti-missile potential was also reduced by any displacement of the JSF from the missile's flight path, which thus presented a crossing or retiring target to the JSF.

The limited weapon load of the JSF, except when carrying eight AMRAAM, meant that a single raid often completely exhausted the CAP's weapons.

AWD

In contrast to the JSF, the AWD played almost no role in engaging the enemy strike and escort aircraft. As the enemy was equipped with stand-off air-to-surface missiles (AS-17 and AS-20) that could be launched at least 40 nautical miles from their targets and from below the radar horizon, after only a brief pop-up manoeuvre to acquire a target, they were never within the engagement envelope of the AWD's SM-2 missiles long enough to be engaged.[1]

Positives. The AWD therefore was left with the role of engaging the incoming air-to-surface missiles as they crossed the radar horizon.[2] The AWD was more capable than the JSF of successfully engaging these missiles due to its much larger magazine of missiles, the greater ability of its weapons (in comparison with AMRAAM) against air-to-surface missiles, and its position at, or close to, the terminal point of the incoming missiles flight path. The AWD proved very difficult to overwhelm with conventional sub-sonic air-to-surface missiles.

While SM-6 was not tested in Harpoon 3, the capabilities incorporated in this capability would present a threat to all Red strike and escort aircraft before they could reach their launch range if AWD was supported by a CEC equipped AEW&C.

The inability of the AWD to engage enemy aircraft also provided insight into the current concept of how the AWD is to be equipped and operated.

Concept of AWD operations. The current plans for the acquisition of an AWD capability include the requirement for the inclusion of a CEC capability on the platform. However, as the AWD is the only Australian platform, at present, that is planned to be so equipped, the full benefits of CEC are not likely to be realised unless the AWD is operating with foreign forces equipped with CEC.

In foreign forces that employ CEC the normal concept of operations involves equipping AWD type platforms with CEC, but also installing CEC on a range of other platforms that can act as a picket for the AWD. In this organisation, when operating together, the picket and AWD platforms can establish an engagement network that increases the range at which the SM-2 missiles of the AWD can be employed.

For example, if an AWD and a picket ship (such as an ANZAC frigate) are both equipped with CEC and positioned 15 nautical miles apart (so as to maintain line of sight radio

1 If we assume that the radar on a AWD is 75 feet above the surface of the ocean, then at 40 nautical miles it will only 'see' an aircraft when it is at a height of 570 feet or higher.

2 For a radar 75 feet above the surface of the ocean the radar horizon for a missile flying at an altitude of 50 feet is approximately 19 nautical miles; or for a missile at 100 feet altitude, 23 nautical miles.

contact) then the AWD may use the picket's radar data, via CEC, to guide a SM-2 missile to a position where the picket's fire control radar can terminally guide the SM-2. In this way the AWD's SM-2 engagement range is significantly extended against low-flying targets such as sea-skimming air-to-surface missiles, as shown in Figure 5.1.

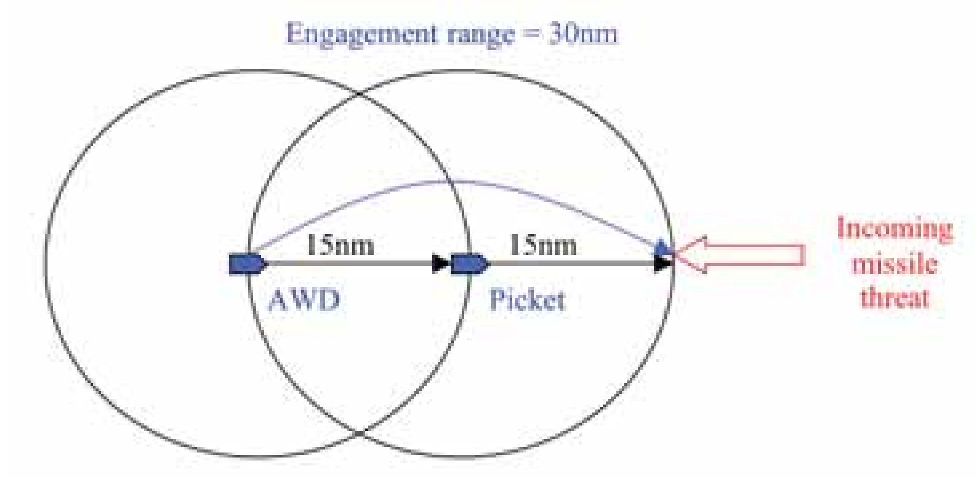


Figure 5.1 – AWD and Picket CEC Organisation

Furthermore, if an air platform equipped with CEC (such as an AEW&C) is available, then the engagement network can be extended even further until the maximum engagement range of the missile is reached, as in Figure 5.2.[3]

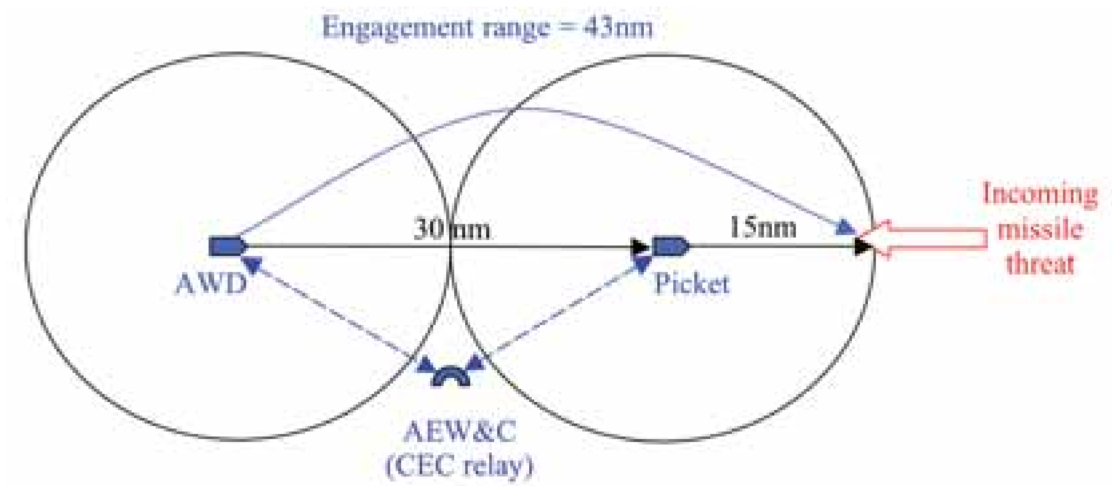


Figure 5.2 – CEC Range Extension

3 According to Janes, *All the Worlds Fighting Ships*, the maximum range of a SM-2 missile is 80 kilometres or 43 nautical miles.

As has been mentioned the AWD is the only ADF platform, thus far, to be approved for the installation of CEC. The advantages to Navy of fitting it to other surface and air platforms would suggest that these capability developments will, in time, become a priority for Navy.

Negatives. With roughly two surface-to-air missiles being required to destroy each incoming air-to-surface missile, the AWD's magazines provided only sufficient missiles to counter a single Red strike package if they were able to all launch their weapons. Without an ability to resupply at sea the AWD, and the JTF, were then faced with the need to withdraw from the missile threat environment or to be reinforced by another AWD.

In the littoral environment used for *Headway* 04 the AWD, and other vessels, suffered from the presence of major mountain ranges within 30 nautical miles of the beachhead. These ranges provided an obstacle to radar and allowed Red strikes from overland axes to approach using terrain masking until they were in launch range. The Army also suffered as these approaches enabled Red to attack their units unopposed except by JSF.

If Red possesses supersonic air-to-surface missiles, such as the AS-17, the defence of the JTF is greatly complicated. AWD's ability to deal with such missiles is considerably less than its ability against sub-sonic missiles.

AEW&C

Positives. The AEW&C provided the expected early detection of Red strikes and permitted JSF to remain passive when required. By prudent positioning the AEW&C was still able to maintain coverage of Red aircraft even in the presence of the AEW&C 'killer' threat.

Negatives. The possession by Red of an AEW&C 'killer' adversely affected the AEW&C by forcing it to reposition to locations that were not ideal for supporting the JTF.

The mountainous terrain inland from the beachhead presented some terrain masking opportunities for Red against the AEW&C's sensors. To counter this AEW&C or JSF had to be positioned to cover these holes in sensor coverage. This oriented the defensive assets to specific threat axes at the expense of all-round defence.

GBAD

Positives. The situation with regard to GBAD is somewhat obvious. With GBAD the Army units that were within range had some protection against air attack that was permanently available. The JTF also benefited in the single iteration where GBAD was present, as it had been positioned, coincidentally, so that it threatened any aircraft that utilised one of Red's previously terrain-masked, overland attack axes.

Negatives. Without GBAD the Army units were exposed. JSF provided good protection when it was available but there were occasions when it was not. The cover provided by the AWD was limited to close inshore and ceased somewhere between 5 and 30 nautical miles inland. The Army units also suffered when they and the Navy required simultaneous JSF support. While damage to Army units threatened the Army's ability to complete its tasks, damage to major naval assets threatened the viability of the whole joint operation. In this situation the Army lost out.

RED AIR CONSIDERATIONS

The results outlined above are important for the RAAF and the ADF but they also have implications for the Red side of the exercise. The whole conduct of air operations by conventional, fourth generation aircraft in the face of a JSF threat has to be seriously called into question. The theory, and experimental experience, indicates that Red aircraft can fly whole strike mission without ever detecting the opposing fighter defences while continually losing aircraft, and personnel, in large numbers. The motivation required to fly such a mission approaches that required of a suicide bomber.

The inclusion of an AWD in the targeted JTF further complicates the situation for the Red air force. 'Dumb' bombs, short-range precision guided weapons (such as laser-guided bombs), and short-range missiles (such as Maverick) are now completely ineffective due to the presence of the long-range SM-2 missile on the AWD. Stand-off range has become a must for any force trying to attack a naval force containing an AWD. These weapons are more expensive, require a higher level of maintenance to keep them in operational condition, demand greater capabilities from a launch aircraft, and require a higher level of training and expertise from the pilots who execute the mission.

The observations and results discussed in this chapter are the unclassified products of a simple analysis of the *Headway* 04 experimental activity. A more thorough and complete analysis is available in the detailed analysis conducted by DSTO. Of course the most sensitive findings of that study will be classified and of limited circulation. However, this simple treatment provides some idea of the value that an experimental program can provide to the RAAF and its members.

ANNEXES:

A. Some basic air combat principles
B. SWOT analysis of system components
C. Harpoon 3 simulation results

SOME BASIC AIR COMBAT PRINCIPLES

In any discussion involving air combat an understanding of some basic principles is essential as they influence the strategy and tactics of both combatants engaged in the conflict. The three principles to be covered are the nature of the radar horizon, the requirement to illuminate a target in order to be able to engage it with a weapon, and the environmental and kinematic impacts on missile performance.

RADAR HORIZON

The primary sensor on the military platforms included in the *Headway* 04 experiment is still the microwave radar. Radar operates on the principle of transmitting a radio frequency signal that will reflect off an object (such as an aircraft) and then being able to detect the reflected signal. Knowing the time of transmission, the time of reception, and the speed at which radio waves travel, the distance to the detected object can be calculated and displayed. Transmissions in the microwave frequency range provide the advantage of great accuracy, necessary for target engagement, but suffer the disadvantage of travelling in a straight line. This straight-line propagation over the curved surface of the earth results in limited low-level coverage for surface-based radars.

The equation used to calculate the relative radar horizon range (R, measured in nautical miles) between a target (t, at altitude measured in feet) and a radar antenna (a, at altitude measured in feet) is: $R = 1.23 (\sqrt{t} + \sqrt{a})$

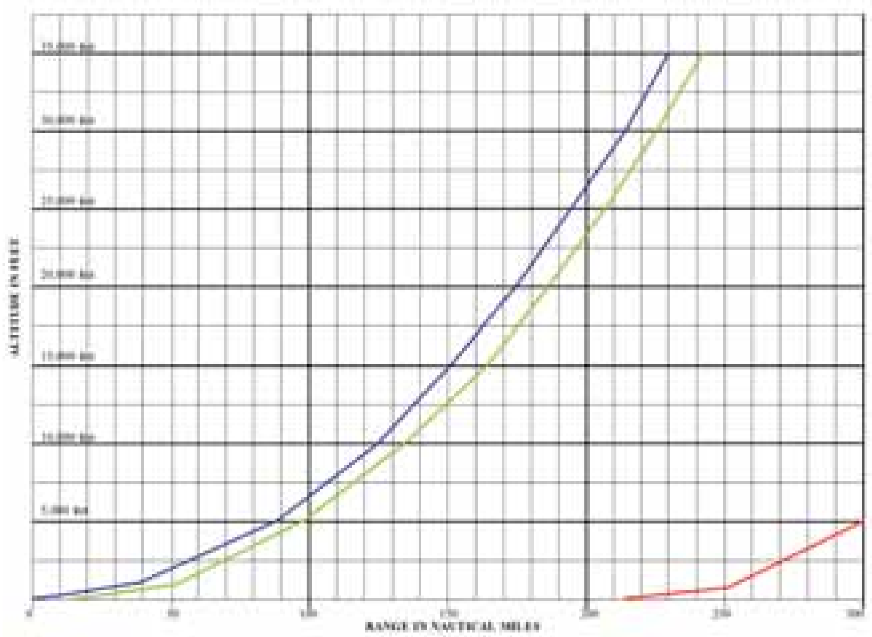
Using this equation the detection ranges for radars at three different altitudes is given in Table 5A.1.

Target altitude in feet	**Maximum detection range of a radar at 0 feet**	**Maximum detection range of a radar at 100 feet**	**Detection range of a radar at 30,000 feet (AEW&C)**
35,000	230 nautical miles	242 nautical miles	Beyond 300 nautical miles – Note 1
30,000	213	225	Beyond 300 nautical miles – Note 1
25,000	194	207	Beyond 300 nautical miles – Note 1
20,000	174	186	Beyond 300 nautical miles – Note 1
15,000	151	163	Beyond 300 nautical miles – Note 1
10,000	123	135	Beyond 300 nautical miles – Note 1
5,000	87	99	300 nautical miles
1,000	39	51	252
100	12	25	225
50	9	21	222
0	0	12	213

Table 5A.1 – Radar Detection Ranges

> Note 1 – At ranges beyond 300 nautical miles the detection range of airborne radar is limited primarily by its transmission power and the sensitivity of its receiver array.

The data in Table 5A.1 can also be displayed graphically as in Figure 5A.1.



Key: Radar horizon for surface-based radar at 0 feet
Radar horizon for surface-based radar at 100 feet
Radar horizon for an airborne radar at 30,000 feet

Figure 5A.1 – Radar Horizon

In Figure 5A.1, targets above the radar horizon line can be detected by the radar, while those below the line remain below the radar horizon and outside radar coverage. It should be noted that the AEW&C aircraft provide a significant advantage over surface-based radars in detecting low-level targets. This is due to their elevated position.

Radar illumination of target

Once a target has been detected within radar coverage it may be prosecuted by a number of weapon systems included in the *Headway* 04 scenarios. The air-to-air and surface-to-air missiles employed in the experiment use either semi-active radar homing, active radar homing or infra-red homing for their terminal guidance. Fire control radars are also used in the direction of gunfire against airborne targets.

Semi-active radar guidance. Semi-active radar homing is employed by surface-to-air missiles, such as the SM-2, ESSM and GBAD. The SM-2 missile may be launched and commanded to fly to an approximate intercept position but will require constant fire control radar illumination for the terminal homing phase of the intercept. For ESSM and GBAD this form of guidance requires the launching platform to illuminate the target constantly during the whole period of the missile's flight. These missiles operate by detecting the radar signal reflected from the target and they home on the source of the reflected radar energy. If radar illumination is interrupted at any time while the missile is still in flight, or during terminal guidance for the SM-2, it will lose guidance and fail to intercept its target even if illumination is restored. Obviously the target must be in radar coverage for the entire time of engagement for this form of guidance to be successful.

Active radar guidance. Active radar homing is employed by the AMRAAM and ADDER air-to-air missiles carried by Blue and Red forces respectively. Each of these missiles has an active radar sensor built into the missile. These missiles require the target's track to be held by the launching aircraft that communicates the information to the missile via a data link. The missile uses this information to calculate, and fly to, an intercept point with the target. After launch, updates of the target's position continue to be passed to the missile by the launching aircraft. When the missile reaches a position where the target should be within its radar field of view, it activates its own radar and uses it to guide its terminal flight independently. Before activation of the missile's radar the target's positional data has to be updated continually by the launching aircraft if the engagement is to be successful. The radar of the launching aircraft usually provides this data, though theoretically a third party, such as an AEW&C or AWD, could provide the information if they can update the launcher at the required rate and with data of the required accuracy.

Infra-red guidance. As an aircraft moves through the air it generates a number of sources of heat such as the engine exhaust plume and the heating of the aircraft body due to friction. Infra-red guided missiles incorporate a seeker head that can detect the heat signature generated by these sources. Red force's ARCHER and Blue force's ASRAAM missiles utilise this form of guidance. As with the active radar homing missiles these weapons can be launched on a track held by the firing aircraft, fly toward an intercept point (being updated in flight by the firer) until they acquire their target through the infra-red seeker head of the missile. The disadvantage of an infra-red missile is that detection usually occurs at closer ranges than radar detection.

The final weapon systems that employ radar support to engage aircraft and missiles are the anti-aircraft gunfire systems represented by the 127mm and 20mm (Phalanx) guns aboard the naval escorts. For these weapons radar does not provide guidance for the projectile, but detects the target and passes its positional and motion characteristics to the fire control computer directing the guns. For this form of air defence, radar illumination of the target is vital if it is to be effective.

Missile performance

One of the most misunderstood features of surface-to-air and air-to-air missiles is the effect a target's position and aspect have on the missile's ability to intercept the target. Many expect that a missile with a 25-kilometre range can intercept any target within that range. This is an incorrect assumption as can be shown by a simple example.

In our example we will use two aircraft, each flying at Mach 1, with the Blue fighter using a missile with a speed of Mach 2.5 and a range of 25 kilometres. In the time taken for the missile to travel 25 kilometres at Mach 2.5 the target aircraft will move 10 kilometres at Mach 1. Using this data we can graphically illustrate the effect of target aspect on the maximum employment range of the missile in some simple vector diagrams (see Figure 5A.2).

The ranges quoted above, and in Figure 5.2, apply to the missile when employed above 5000 feet where the air is thinner and friction is reduced. Below 5000 feet the air is denser, resulting in greater friction and reduced engagement ranges. This reduction can be substantial, even up to 50 per cent of the ranges cited.

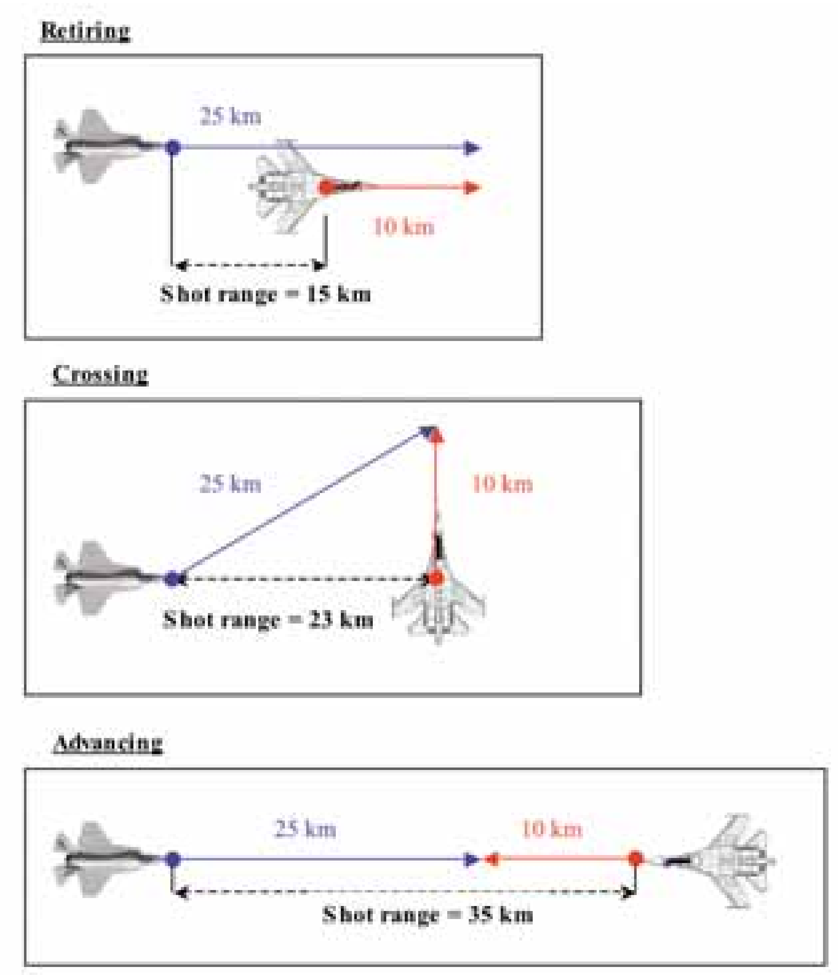


Figure 5A.2 – The effect of target aspect on missile shot ranges

From these diagrams it is apparent that a missile gains an engagement-range advantage from a target whose heading is directly toward the firing platform. The degree of this advantage is equal to the distance the target travels while the missile is in flight (10 kilometres). When a target is flying perpendicular to the launch aircraft's flight path the engagement range is slightly less than the missiles maximum range, while in the situation where the target is retiring the maximum engagement range is significantly reduced.

For targets that do not manoeuvre, such as most cruise missiles, the engagement ranges outlined above are the best that can be expected. For a target capable of manoeuvring these diagrams also suggest some simple counters that may be employed to defeat, or 'trash', a weapon fired against them. For the advancing target a turn in either direction of up to 90 degrees should be sufficient to remain outside the missile engagement envelope. For the crossing target a turn away from the launch aircraft will have the same effect. For the retiring target the option of turning away will not help and the only counter left to it is to increase speed and/or descend into the denser air closer to the surface of the earth.

For those employing air-to-air and surface-to-air missiles these simple counters to a maximum range shot can result in the wastage of scarce and expensive weapons. For these reasons most missile shots against manoeuvring targets are taken at even shorter ranges than those outlined in this example.

SWOT ANALYSIS OF SYSTEM COMPONENTS

JSF

Strengths

1. JSF is the only part of the engagement grid with the speed and reach to influence large areas. Given Strategic Early Warning (StEW) tracking (ie. tracking beyond detection range of organic aerospace surveillance sensors), intercepts may be possible in excess of 400 nautical miles from any element of the JTF.

2. Swing role capabilities allow the aircraft to be on-call for a variety of tasks—not just defence counter air. Improves effectiveness and flexibility of a small number of on-task aircraft.

3. Increased sensor coverage due to the use of advanced full-phased array radar and a powerful electronic support system. The inclusion of an advanced intra-flight data link allows electronic support data to be automatically swapped between aircraft within the flight and allows some passive detection, identification and tracking of other aircraft. Consequently it is less dependent on AEW&C. May be able to work effectively when provided with outer layer ISR information only (eg. from JORN).

4. Inter-aircraft data link and information sharing permits wider dispersion of aircraft compared with the F/A-18.

5. Information sharing (via data link) and stealth characteristics should translate to high kill ratios against fourth generation fighter threats. Likely to inflict unsustainable losses on attacking aircraft formations. May allow JSF to operate as singletons, thereby increasing effectiveness and area coverage of a small number of aircraft.

Weaknesses

1. Engagement of missiles, small tactical UAVs and helicopters may be problematical, requiring the presence of other engagement systems if these threats exist in a given scenario. Generally, JSF will not be able to engage missiles, except for very large, sub-sonic and probably long-range missiles.

2. Very resource intensive to maintain 24/7 coverage—even over one area at a time. Swing role versatility of JSF mitigates against this weakness by allowing on-station aircraft to be utilised for a variety of on-demand tasks. Nevertheless, CAP will remain ‘expensive’—particularly in terms of sortie generation rate and the number of crews required.

3. Lack of persistence. One Red raid is likely to deplete the fuel resources of the entire on-station CAP and leave a vulnerable period, while the on-station CAP returns to base and the next group comes forward.

4. Limited weapon load. It would be quite possible for one Red raid to deplete the entire CAP weapon load, again limiting persistence.

5. If air-to-air refuelling (AAR) is required, the maximum number of on-station JSF will be limited to typically four aircraft. Given this level of effort it would be very difficult, if not impossible, to develop a leak-proof outer layer defence against attacking aircraft armed with moderate range stand-off weapons, especially if there is no defined threat axis.

Opportunities

A longer-range air-to-air missile (than AMRAAM) would allow greater exploitation of Blue's ISR capabilities. This capability would push the intercept range out further from ZZ and widen the sector a single JSF formation could guard. However, this capability would have to be matched with compatible target identification procedures and rules of engagement.

Threats

1. With StEW tracking, Red strikes can be launched at ranges greater than the air intercept radius of action of JSF from ZZ, which is up to 450 nautical miles (based on 300 nautical miles transit to base, AAR just completed).

2. Without StEW tracking, Red air launched missile can be launched at ranges greater than half the organic sensor detection range (this assumes that the intercept speed of JSF is roughly equivalent to the ingress speed of Red aircraft).

3. Red aircraft approaching in more sectors than there are on-station JSF, with missile release point beyond intercept range of AWD. All Red aircraft approaching in an unprotected sector will be able to penetrate to missile release point. Width of each protected sector is primarily a function of Red missile launch range, detection range of Red aircraft and the engagement range of JSF. Representative sector widths are 35–50 degrees.

4. Number of Red aircraft approaching in a sector is greater than the number of air-to-air missiles available. Assuming Red missile release point is greater than the AWD's intercept range, this equates to the number of JSF missiles available in a particular sector.

5. Red land, surface and/or sub-surface platforms within engagement range of the JTF remain undetected by Blue force ISR until missile launch.

6. Adversary access to fifth generation (low observable) aircraft could reduce favourable kill ratio of JSF over fourth generation aircraft, requiring more on-station aircraft to counter this.

7. Restrictive rules of engagement, identification procedures, and air coordination arrangements could severely degrade the optimum performance of JSF intercepts.

AEW&C

Strengths

1. Provides long-range organic sensor detection of air tracks and shorter-range organic detection of missile tracks, overcoming the severe limitations of the radar horizon experienced by surface-based detection systems.

2. Sometimes allows engagement systems to remain passive during the start of an engagement, providing a greater element of surprise to Red. In the case of cooperative engagement, the engagement system (AWD) may remain passive throughout the engagement.

3. AEW&C information will also provide enhanced early warning of air and missile attacks that will allow potential targets to initiate passive defence measures.

4. Provides dedicated battlespace management function, to assist in complex command and control task.

5. As well as increased radar coverage at low-level, the coverage of UHF/VHF radio communications, including data links, from the AEW&C are likewise improved, making AEW&C an extremely important sensor and communications platform.

Weaknesses

1. Radar horizon at 35,000 feet (approximately 230 nautical miles) is still restrictive in comparison to long-range stand-off threats (with launch ranges of 350 nautical miles), thereby allowing attacking aircraft to reach missile release point before detection. Also, a single aircraft is unlikely to provide the entire Area of Operations (AO) with surveillance coverage.

2. Radar performance against missiles with a small radar cross-section may reduce warning times to surface forces to a point bordering on ineffectiveness.

3. Vulnerability to air and surface launched missiles may restrict positioning. In some cases, the range from an airborne threat at which the AEW&C will have to retrograde may be so great as to render the AEW&C ineffective. If Red possess a passive, anti-radiation missile with stand-off range that is greater than the

AEW&C's detection range, it becomes vulnerable to being destroyed without ever detecting the threat.

4. Must remain active and at high level to be of use, making it relatively easy for an adversary to detect and track—even at long ranges.

Opportunities

1. Cooperative engagement with AWD and/or GBAD provides a synergistic relationship that has the potential to improve the overall performance of the JTF's air defence system significantly.
2. The AEW&C's self-protection capability should reduce vulnerability to air and ground threats, thereby improving its flexibility and effectiveness.
3. A comprehensive, non-cooperating target identification and discrimination capability increases the amount of additional information available from AEW&C in comparison to StEW alone.

Threats

Possession of long-range AEW&C 'killer' missiles by an adversary may require AEW&C to retrograde at ranges beyond which it can provide useful information on targets. In extreme cases, such a missile may be launched from ranges beyond AEW&C's detection range for the launch aircraft and it may remain oblivious to the threat.

AWD

Strengths

1. Highly persistent, providing efficient 24/7 area coverage of the JTF (at least).
2. Only weapons system in the JTF known to possess a good anti-missile capability. Also has an anti-platform (surface, submarine and air) engagement capability making it the most 'comprehensive' weapon system in the JTF.
3. Capable of multiple, simultaneous engagements. Difficult to swamp through a mass attack.
4. Employs an area defence surface-to-air missile, SM-2, with approximately 80 kilometre (43 nautical miles) range.

Weaknesses

1. Small area of influence—particularly in SM-2 configuration, where it is restricted by its own sensor horizon.
2. Magazine capacity is large but no ability to reload, or change a load-out, while at sea imposes limits on how many engagements can be undertaken. Adversary tactics may be aimed at 'sapping its strength' through the use of decoys and probes.
3. The SM-2 missile needs terminal illumination by a fire control radar and therefore the system is radar horizon limited.
4. In SM-2 configuration, the ability to engage targets over land will be restricted to 'high-flyers' only, due to the radar horizon.

Opportunities

Cooperative engagement with AEW&C, coupled with an active missile (eg. SM-6), significantly improves the area of influence—possibly extending it much further into overland areas.

Threats

1. The number of Red targets penetrating to release point is greater than the AWD's surface-to-air missile load-out.
2. The number of Red missiles in a salvo is greater than the capacity of the targeting and guidance system to engage.
3. Supersonic, sea-skimming threats reduce the area of influence of the AWD in SM-2 configuration still further and to a degree that threatens the AWD's effectiveness as a second layer area defence system. Note, however, that the increased threat is offset to a degree by supersonic missiles being larger and having a greater radar cross-section. This will allow the missiles to be detected and engaged at extended ranges.
4. Cannot consider the AWD to be capable of area air defence by itself. Must be supplemented by other assets.

STRATEGIC EARLY WARNING (StEW) TRACKING

Strengths

1. Provides added confidence about the nature and position of major air and maritime surface threats.
2. Provides Blue increased reaction time to counter major air and maritime surface threats.
3. Pushes JSF intercept ranges out to the limits of its range.

Weaknesses

1. Poor discrimination of raid size—a weakness that may be exploited by an intelligent adversary to deceive Blue.
2. Will not detect all threat platforms or missiles.
3. Predictable diurnal variations in JORN performance could be exploited by an intelligent adversary.
4. JORN coverage restricted to region—not global.

Opportunities

1. Access to space-based radar would provide global coverage and potentially better accuracy and discrimination than JORN.
2. May replace the need for AEW&C in some cases—particularly when used in conjunction with JSF.

Threats

1. Over-reliance may lead to false sense of security.
2. Coverage will be of specific areas and not the entire AO and surrounding areas.

GBAD

Strengths

1. Provides second layer anti-missile defence to land forces.
2. May be the only reliable way of engaging some types of tactical UAVs and attack helicopters.
3. Provides the means of quickly adapting the size and shape of the inner layer air defence envelope, to keep pace with land movements.

Weaknesses

1. As it is ground based, the system is radar line of sight limited unless a missile with an active seeker head and receptive to third party targeting is purchased.
2. Restricted mobility may limit its deployability, movement and positioning, resulting in reduced performance.
3. May incur heavy logistic support penalty.
4. Capability against missiles may be problematic, particularly without an active missile system with a beyond visual range capability.

Opportunities

1. Could work in combination with AWD to protect shore end of ship-shore link, giving AWD more freedom of manoeuvre and more comprehensive protection to utility landing crafts (LCUs) and other vessels that have to venture close to shore.
2. Can assist with vital area protection tasks—Forward Operating Bases, Sea Points of Disembarkation, Airports of Disembarkation, etc (static assets).

Threats

1. Even a relatively short stand off range will enable Red aircraft to remain outside the engagement range of many GBAD systems.
2. Adversary could exploit terrain masking in complex terrain to negate the GBAD’s effectiveness.

MOBILE REGIONAL OPERATIONS CENTRE

Strengths

1. Persistent presence, providing economical 24/7 surveillance coverage.
2. Flexible configuration can be task orientated.
3. Provides 24/7 command and control support of air operations and planning.

Weaknesses

1. Land-based and therefore very limited detection range against low flying targets, which may be further compromised by terrain masking.
2. Limited mobility in complex terrain, preventing ideal placement.

Opportunities

1. May provide a good complimentary system to GBAD engagement layer.
2. May be a good system to provide second layer ISR support to fixed surface target areas (eg. beachheads).

Threats

Usefulness may be compromised by Red possessing missiles with even a moderate stand-off capability, allowing the launch platforms to reach weapon release points undetected.

HARPOON 3 SIMULATION RESULTS

Run	Escort kills	CAP kills	Striker kills	ASM launched/hit AWD		FFH		LPH		SAMs used	Launch window	SAMs per ASM	% ASM launched	% ASM hit	% Esc killed	% CAP killed	% Strike killed	
4 axis Harpoonski (4 x CAP 8 x strike 8 x escort)																		
1	4	0	3			8	0	12	0						50.00%	0.00%	37.50%	
2	3	0	2	24	0					36		1.50	75.00%	0.00%	37.50%	0.00%	25.00%	
3	2	0	3			20	0			46		2.30	62.50%	0.00%	25.00%	0.00%	37.50%	
4	4	0	1			28	0			44		1.57	87.50%	0.00%	50.00%	0.00%	12.50%	
5	6	0	0			24	0	8	0	67	265	2.09	100.00%	0.00%	75.00%	0.00%	0.00%	
6	5	0	0	32	0					59	240	1.84	100.00%	0.00%	62.50%	0.00%	0.00%	
Ave	4	0	1.5							50.4	252.5	1.86	85.00%	0.00%	50.00%	0.00%	18.75%	
1 axis Harpoonski (4 CAP 8 x strike 8 x escort)																		
1	3	0	0	32	1					66	60	2.06	100.00%	3.13%	37.50%	0.00%	0.00%	
2	6	0	0	32	1					61	70	1.91	100.00%	3.13%	75.00%	0.00%	0.00%	
3	8	0	0					32	1	67	50	2.09	100.00%	3.13%	100.00%	0.00%	0.00%	
4	7	0	0	32	0					53	30	1.66	100.00%	0.00%	87.50%	0.00%	0.00%	
5	5	0	1					28	3	46	35	1.64	87.50%	9.38%	62.50%	0.00%	12.50%	
6	6	1	0					32	3	55	55	1.72	100.00%	9.38%	75.00%	25.00%	0.00%	JSF caught trying to flank escorts
Ave	5.83	0.17	0.17							58.00	50.00	1.85	97.92%	4.69%	72.92%	4.17%	2.08%	
4 axis AS-17 (4 CAP x 4 strike 8 x escort)																		
1	8	0	1	12	0					21	360	1.75	75.00%	0.00%	100.00%	0.00%	25.00%	
2	5	0		16	0					31	350	1.94	100.00%	0.00%	62.50%	0.00%	0.00%	
3	6	0	1	12	0					22	70	1.83	75.00%	0.00%	75.00%	0.00%	25.00%	
4	4	0		12	1			4	1	35	120	2.19	100.00%	12.50%	50.00%	0.00%	0.00%	
5	5	0	2	4	0			4	2	30	240	3.75	50.00%	12.50%	62.50%	0.00%	50.00%	
6	5	0	2					8	2	28	165	3.50	50.00%	12.50%	62.50%	0.00%	50.00%	
Ave	5.5	0	1							27.83	217.50	2.49	75.00%	6.25%	68.75%	0.00%	25.00%	
1 axis AS-17 (4 CAP 4 strike 8 x escort)																		
1	6	0	0	16	0					34	25	2.13	100.00%	0.00%	75.00%	0.00%	0.00%	Launched over land - 6 ASM hit ground
2	4	0	0	16	3					27	30	1.69	100.00%	18.75%	50.00%	0.00%	0.00%	
3	7	0	0	16	5					23	30	1.44	100.00%	31.25%	87.50%	0.00%	0.00%	
4	5	0	0					16	4	31	25	1.94	100.00%	25.00%	62.50%	0.00%	0.00%	
5	6	0	0			16	3			26	25	1.63	100.00%	18.75%	75.00%	0.00%	0.00%	
6	3	1	2					8	1	20	25	2.50	50.00%	6.25%	37.50%	25.00%	50.00%	JSF caught trying to flank escorts
Ave	5.17	0.17	0.33							26.83	26.67	1.89	91.67%	16.67%	64.58%	4.17%	8.33%	

Run	Escort kills	CAP kills	Striker kills	ASM launched/hit AWD		FFH		LPH		SAMs used	Launch window	SAMs per ASM	% ASM launched	% ASM hit	% Esc killed	% CAP killed	% Strike killed	
4 axis Harpoon F18 (4 x CAP 8 x strike 8 x escort)																		
	3	4	0			32	0			47	90	1.47	100.00%	0.00%	37.50%	100.00%	0.00%	
1 axis Harpoon F18 (4 x CAP 8 x strike 8 x escort)																		
	4	4	0					32	3	51	40	1.59	100.00%	18.75%	50.00%	100.00%	0.00%	
4 axis AS-17 F18 (4 x CAP 4 x strike 8 x escort)																		
	5	3	1	8	0			4	0	24	245	2.00	75.00%	0.00%	62.50%	75.00%	25.00%	
1 axis AS-17 F18 (4 x CAP 4 x strike 8 x escort)																		
	3	4	0	16	2					28	30	1.75	100.00%	12.50%	37.50%	100.00%	0.00%	
													93.75%	7.81%	46.88%	93.75%	6.25%	
4 axis Harpoonski 6 x JSF (6 x CAP 8 x strike 8 x escort)																		
1	7	0	1			28	0			55	255	1.96	87.50%	0.00%	87.50%	0.00%	12.50%	
2	6	0	1					28	0	46	140	1.64	87.50%	0.00%	75.00%	0.00%	12.50%	
3	7	0	3			12	0	8	0	43	310	2.15	62.50%	0.00%	87.50%	0.00%	37.50%	
													79.17%	0.00%	83.33%	0.00%	20.83%	
4 axis Harpoonski 4 x JSF ea x 8 AMRAAM (4 x CAP 8 x strike 8 x escort)																		
1	7	0	3	20	0					31	95	1.55	62.50%	0.00%	87.50%	0.00%	37.50%	
2	8	0	6					8	0	13	110	1.63	25.00%	0.00%	100.00%	0.00%	75.00%	
3	8	0	4			16	0			25	185	1.56	50.00%	0.00%	100.00%	0.00%	50.00%	
													45.83%	0.00%	95.83%	0.00%	54.17%	
4 axis Harpoonski no Wedgetail (4 x CAP 8 x strike 8 x escort)																		
	5	0	1					28	0	49	285	1.75	87.50%	0.00%	62.50%	0.00%	12.50%	
4 axis Harpoonski no CAP (0 x CAP 8 x strike 8 x escort)																		
	0	0	0			0	1	32	0	51	80	1.59	100.00%	3.13%	0.00%	0.00%	0.00%	Harpoon hit FFH not targeted
1 axis AS-17 4 x JSF ea x 8 AMRAAM (4 x CAP 4 x strike 8 x escort)																		
1	6	0	3	4	0					7	35	1.75	25.00%	0.00%	75.00%	0.00%	75.00%	
2	8	0	4										0.00%	0.00%	100.00%	0.00%	100.00%	
3	7	0	4										0.00%	0.00%	87.50%	0.00%	100.00%	
													8.33%	0.00%	87.50%	0.00%	91.67%	

CONCLUSION

Since at least the time of Alexander the Great, and probably for much longer, experimentation has provided the tool that has allowed military professionals to develop their armed forces in the most effective manner. Professional judgment alone has not always developed a correct appreciation of the capabilities required to successfully conduct military operations. Field Marshal Haig in World War I and the USAAF bomber commanders prior to World War II adhered to concepts that ultimately proved unworkable in actual combat. The German leadership in World War II also decided to develop two capability options, the V-1 and V-2, that held great promise but proved to be failures due to the immaturity of their technology, the exorbitant cost of their production and the negative impact they had on overall force structure. To avoid mistakes such as these, military experimentation has been given greater attention by the world's military decision-makers of our time.

The environment in which we live today is one of continual technological change and development. In the field of aerospace technology, constant modification and growth is a characteristic that stands out in any review of its history. This persistent characteristic presents problems to those who must decide on what capabilities are to be acquired for future use. Capability decisions made now may be threatened by the appearance of a new technology or concept that could alter the training, structure, organisation, equipment or employment of our own forces or those of an adversary. To help reduce the uncertainty of the future, and to help identify the most appropriate military concepts of operation for Australia's unique circumstances, the ADO has implemented a process of CD&E throughout Defence. The aim of CD&E is to better inform decision-makers by learning about the future through experimental activities that allow us to employ future capabilities, and gain experience of them, before they are created. This process not only provides greater insight into the future but also reduces the costs and risks that would otherwise be incurred by acquiring this same knowledge after the capability is actually created.

The Romans, Napoleon and especially the German Army of the inter-war period used this process to completely change their armed forces into superior war fighting systems that dominated armed conflict in their respective eras. The Germans in particular provide a good example as they used the analysis of historical and future factors to alter completely the training, organisation, equipment and tactics that they used. Significantly, all this work began at a time when the German forces did not possess a single tank or combat aircraft.

Even though they were successful in devising such a radical new method of warfighting, the Germans were less successful in describing the technique in a set of conceptual documents that described the underlying principles of 'Blitzkrieg'. The lesson for the

RAAF is that we must develop the initial thoughts, ideas and reasoning behind a new capability into a set of conceptual documents that can be used as the basis of discussion, debate and testing through experimental activities. By fully documenting the military problem and the characteristics of the suggested solution we can more completely test and validate the concept. When concepts are validated in this manner they provide a clearer understanding as to how the capability described fits into the overall capabilities of a FEG, the RAAF and the ADF. The connection between the capability and other related capabilities will be more apparent and a cohesive vision of how the whole force conducts operations will be available in a hierarchy of documented operational concepts. With the ADO's involvement in experimentation at the multinational, joint, single Service and individual system levels, the concepts at every rung in the hierarchy will be rigorously examined and experimented with before they are validated.

In the CD&E process, concepts are thoroughly analysed and tested through the use of experimentation. In this book experiments have been defined as procedures that allow us to discover something unknown (but useful) about the armed forces, test a principle or hypothesis, or illustrate a known law. This definition embraces a range of activities such as war games, rehearsals, studies, trials, exercises, and makes use of modelling and simulation techniques. The different abilities of each of these techniques can be combined in a campaign of experimental events to examine and define a capability in great detail. The benefit of conducting these campaigns is that they produce robust concepts, which in turn allow defensible capability decisions to be made.

The results of an experiment will provide an outline of the way in which a tested capability was employed. The manner of its operation will have been developed in conjunction with the subject matter experts in the related area and will represent a 'staff solution' to the military problem that has been explored. It should always be remembered, however, that military experimentation deals with a highly complex human activity and that alternative methods of operation are possible, even if they are not likely. The Byzantine practice of arming their heavy cavalry with a bow and the German use of armoured formations early in World War II (particularly by Rommel) was completely contrary to the 'staff solutions' devised by their adversaries' experts in the same specialisations. For this reason validated concepts should be regularly revised and updated to ensure their currency in an ever-changing world.

In the RAAF, the Air Power Development Centre has been given the responsibility of conducting futures analysis, concept development and experimentation in support of the RAAF's capability development. These processes have been considered to be so important that the entire structure of the APDC has been altered to support this work most effectively .

The AFEC that is being developed by the RAAF will provide the tools, processes and expertise that will allow the RAAF to realise the benefits of CD&E in the development of the RAAF's capabilities. The shortfalls in capability that are identified by this process will begin the process of identifying solutions that are feasible and viable. The concepts and experimental results produced by the AFEC will be used to better inform senior Defence decision-makers about current and future Air Force capabilities. The essence of this work will be distilled into the OCD set that will govern the acquisition of the capability. The OCD will, in turn, influence the writing of CONOPS and TACPROCS that will guide the employment of the capability throughout its in-service employment. But of course the major result of CD&E activities conducted by the AFEC will be the fielding of improved capabilities suited to the future environment and capable of delivering the effects that the RAAF will have to produce in the future.

Although capability development is definitely the central reason and purpose of developing the AFEC, additional benefits will also be derived from it. Through distributed experimental activities and the network enabled availability of the AFEC's capabilities, the RAAF can benefit from improved training methods, enhanced operational planning, and increased understanding by more RAAF members about the reasons governing RAAF capability decisions. These additional uses of the AFEC's abilities may also generate new ideas and concepts that can be used to feed the CD&E process. All of these elements will, in turn, help the RAAF to develop the professional mastery of its people, which is the real source of the RAAF's capabilities.

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