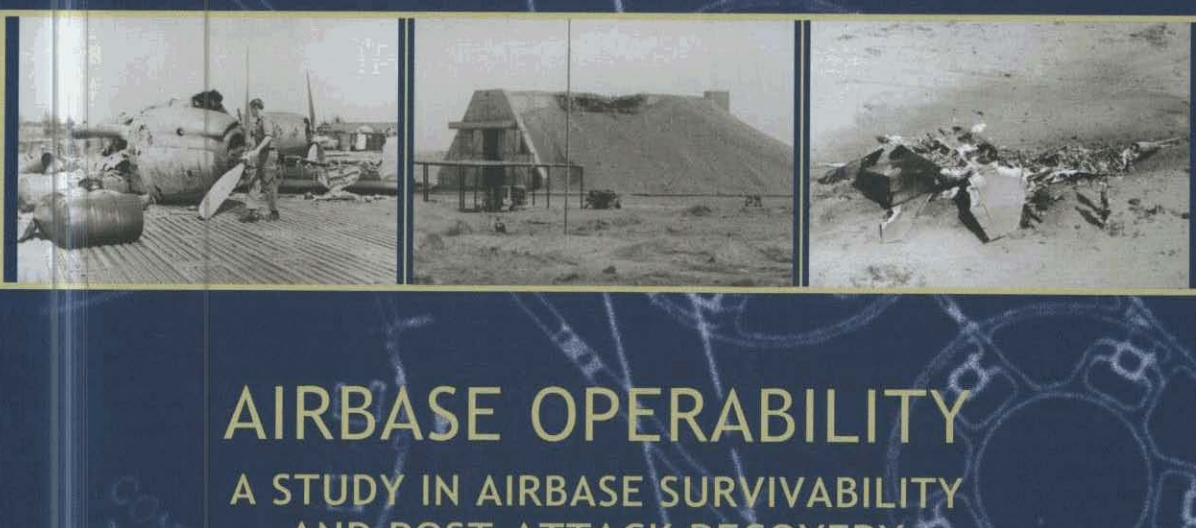

AIRBASE OPERABILITY

A STUDY IN AIRBASE SURVIVABILITY AND POST-ATTACK RECOVERY

2nd Edition

SAL SIDOTI

Aerospace Centre
2001

AIRBASE OPERABILITY

A STUDY IN AIRBASE SURVIVABILITY AND POST-ATTACK RECOVERY

SAL SIDOTI

2ND EDITION

1999 CHIEF OF AIR FORCE AIR POWER FELLOW

AEROSPACE CENTRE
RAAF BASE FAIRBAIRN

DISCLAIMER

The views are those of the author and do not necessarily reflect the official policy or position of the Department of Defence, the Royal Australian Air Force or the Government of Australia.

National Library of Australia
Cataloguing-in-Publication entry

Sidoti, S. J.
Airbase operability: a study in airbase survivability and post-attack recovery

2nd ed.
Bibliography
Includes index
ISBN 0 642 26564 X

1. Air bases – Security measures. 2. Air bases – security measures – History. 3. Air bases – Security measures – Case studies. I. Australia. Royal Australian Air Force. Aerospace Centre. II. Title
358.417

Published and distributed by:

Aerospace Centre
RAAF Base
Fairbairn ACT 2600
Australia

Tel: (02) 62876563
Fax: (02) 62876382
e-mail: publications@aerospacecentre.com

The Aerospace Centre

The Aerospace Centre, formerly known as The Air Power Studies Centre, was established by the Royal Australian Air Force at its Fairbairn Base in August 1989 at the direction of the Chief of Air Force. Its function is to promote a greater understanding of the proper application of air power within the Australian Defence Force and in the wider community. This is being achieved through a variety of methods including development and revision of doctrine, the incorporation of that doctrine into all levels of RAAF training, and increasing the level of air power awareness across the broadest possible spectrum. Comment on this publication or enquiry on any other air power related topic is welcome and should be forwarded to:

The Director
Aerospace Centre
RAAF Base
Fairbairn ACT 2600
Australia

Telephone: (02) 6287 6563
Facsimile: (02) 6287 6382
e-mail: publications@aerospacecentre.com

About The Author

Squadron Leader Sal Sidoti joined the RAAF in January 1987 and after completing his electrical engineering training became an Armament Engineering Officer in 1992. He was posted to No. 1 Central Ammunition Depot, serving in a variety of explosives inspection, engineering and auditing roles. During 1994 he undertook the US Navy Explosive Ordnance Disposal (EOD) course and served until September 1998 as the Officer-in-Charge of the RAAF EOD Flight. He was selected as a Chief of Air Force Air Power Fellow in 1999 to undertake the study which is now the subject of this book. Following his fellowship he was promoted to Squadron Leader and was posted to the Defence Intelligence Organisation.

Squadron Leader Sidoti holds a Bachelor of Electrical Engineering Degree from the University of New South Wales and a Masters Degree in Business Administration from Deakin University.

Other Works By The Author

A History of Attacks on Airbases, Paper No. 80, Air Power Studies Centre, Canberra, 1999

Airbase Operability, Fellowship Paper No. 20, Air Power Studies Centre, Canberra, 2000

ACKNOWLEDGMENTS

A great many people contributed to the original edition of this study, and many more so to the second. There remains too many to list them all, but a few special ones can be included. Firstly, I thank my immediate supervisors for this work, Group Captains Mike Rowntree and Ian MacFarling who provided considerable advice and proofreading. To them I promised to definitely never split my infinitives again. I remain indebted to the staff and fellows of the Aerospace Centre who assisted with the first edition, and must add to this list my editor for the second edition, Summer-Rochelle Blackman, whose dedication and professional skills have contributed so much to this version. I am also indebted to those people who helped me by supplying information, offering advice or proof-reading at various stages. To these I add those who actually read the first edition and provided such valuable feedback and comment. Finally, I again thank my wife Rebecca for her support and encouragement.

PREFACE TO THE 2ND EDITION

I think I began my time at the then Air Power Studies Centre as quite an illiterate 'Gunnie', and despite the best attempts of the staff and fellows my attempts to convert thoughts into quality words often drove me to drink with despair. Not that this statement is likely to surprise many who know me, the illiteracy or the drink.

However, I quite proudly feel I left at worst semi-illiterate and having taken a break from my studies and then returned to my book 'fresh' I was convinced that the first edition could be improved. This was a result of feedback I received from readers and from my own changing thoughts on the subject. I have made little change to the main body of the book, but have revamped some of my conclusions to more strongly emphasise what I believe are the important conclusions that should be drawn.

But, perhaps I could be honest and just admit that it gave me the opportunity to happily split one last little infinitive.

CONTENTS

LIST OF ILLUSTRATIONS

ABBREVIATIONS

AAA	Anti-aircraft Artillery
ABDR	Aircraft Battle Damage Repair
ABO	Airbase Operability
ADF	Australian Defence Force
AE	Airfield Engineering
AEW&C	Airborne Early Warning and Control
AOS	Aircraft Operating Surface
AWAC	Airborne Warning and Control
BDA	Bomb Damage Assessment
CB	Chemical and Biological
CBW	Chemical and Biological Weapon
CCD	Camouflage, Concealment and Deception
CEP	Circular Error of Probability
CI	Counter-Intelligence
C^3I	Command, Control, Communications and Intelligence
EOD	Explosive Ordnance Disposal
EOGB	Electro-Optically Guided Bomb
FAE	Fuel-Air Explosive
FOB	Forward Operating Base
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAS	Hardened Aircraft Shelter
IED	Improvised Explosive Device
IO	Information Operation
IS	Information System
LGB	Laser Guided Bomb
MAOS	Minimum Aircraft Operating Surface
MOB	Main Operating Base
MOS	Minimum Operating Strip
NBC	Nuclear, Biological and Chemical
NGS	Naval Gunfire Support
NVA	North Vietnamese Army
NVNAF	North Vietnamese Air Force
OCA	Offensive Counter Air

PAR	Post-Attack Recovery
PARCC	Post-Attack Recovery Command Cell
PSP	Perforated Steel Planking
RAAF	Royal Australian Air Force
RAOS	Restoration of Aircraft Operating Surfaces
RESF	Restoration of Essential Facilities
RN	Royal Navy
RRF	Rapid Reaction Force
SAM	Surface-to-Air Missile
SAS	Special Air Service
SF	Special Forces
STOVL	Short Take-Off Vertical Landing
TBM	Tactical Ballistic Missile
UAV	Uninhabited Aerial Vehicle
UED	Unattended Explosive Device
USAF	United States Air Force
UXO	Unexploded Explosive Ordnance
VVS	Voyenno-Vozdushnyye Sily (Soviet Army Air Force)

CHAPTER 1

Introduction

While the [Northern] airfields afford the RAAF flexibility, they are vulnerable to attack from the air or by special land forces. Therefore protective measures must be taken if the integrity of the airfields is to be ensured. In terms of manpower and materiel, the cost of defending airfields is considerable; however, the cost of not defending them could undermine the entire northern defence umbrella.[1]

INTRODUCTION

The fixed-wing air power deployed by the Royal Australian Air Force (RAAF) is a vital component of the Australian Defence Force (ADF). The degradation of this capability, even temporarily, could seriously reduce Australia's ability to monitor and defend the air-sea gap to the north and conduct the other roles for which the ADF relies upon fixed-wing air power.

In the Australian strategic context we place a very high reliance upon fixed-wing aircraft operations. The large distances and open spaces in the nation's north require this. Similarly, the large distances between Australia and its neighbours, allies, potential operational areas and ultimately the home bases of potential adversaries increase this dependence.

Doctrinally, RAAF aircraft fulfil all the functions of air power. We use them for transport, both tactical and strategic, reconnaissance and patrol, air defence, maritime and land strike, and in direct support of land combat operations. To have this utility ADF aircraft must be able to contribute to the broader campaign and must be capable of participating wherever the ADF is called upon to serve. Clearly then, the ability to maintain these air operations is not only critical to the RAAF, but to the defence of Australia and its interests in the broadest possible sense. The inability to deploy and utilise fixed-wing air power may have a significant effect upon virtually any campaign the ADF is called upon to undertake.

To ensure that air power remains relevant to the broader goals of the ADF it must possess several abilities. Firstly, it should be technically and doctrinally able to influence campaigns through the employment of the right equipment, techniques, weapons and people. Secondly, it must be able project this influence into the

[1] Treloar, R.B., and Titheridge, A.W., 'Counter Air Operations' in Stephens, A. (Ed), *Defending the Air Sea Gap,* Australian Defence Studies Centre, Canberra, 1992, p 52.

operational area where it is required. Finally, due to the limited resources available it should be survivable. Its ability to influence the broader campaign is directly dependent upon air power's ability to survive in the environment in which it is called to serve. An air power instrument that cannot be deployed into an operational environment because it is unable to survive there is of limited use. In fact it may be worse than useless, because it consumes considerable resources while making little contribution to the broader campaign. In summary, the ultimate utility of air power may be as much about reducing vulnerabilities as it is about increasing capabilities.

AIR POWER'S ACHILLES HEEL

Air power doctrine is quick to emphasise the strengths and capabilities of combat aircraft. However, air power is also acknowledged as having several inherent weaknesses. A significant one is the reliance of fixed-wing combat aircraft upon airbases that possess large runway surfaces of sufficient size and quality, and the required supporting infrastructure.[2] 'In the two years of war in Korea no single factor had so seriously handicapped Fifth Air Force operational capabilities as the lack of adequate air facilities. Operations from short and rough runways damaged and deteriorated combat aircraft, posing inordinate maintenance, supply and attrition burdens upon the combat wings and tactical air force.'[3]

In the north of Australia, and in many areas of the world that are potential candidates for deployed operations, there are few quality airfields. Although these areas boast a vast number of small airstrips they have neither the size nor the pavement quality to support combat jet aircraft operations. Accordingly, during the 1980s the RAAF embarked upon a program of airbase construction across the north of Australia. Given the vital role RAAF aircraft play in the defence of Australia and the few available places to base them, the importance of uninterrupted use of these northern airfields has been recognised in RAAF doctrine. 'Each base represents the vital ground for the ACC [Air Component Commander] and the air component assets. If bases are not available, or their operational capability is impaired, then air power's rapid force projection ability is either degraded or lost completely.'[4]

Noting our reliance upon these few airbases to support such a large component of our northern defences it is possible that, as part of a larger campaign, an aggressor may seek to target them. Indeed, air power theory states the mounting of an air campaign is dependent upon three basic factors — materiel, personnel and position, with position encompassing the location and vulnerabilities of ground based contributors, airbases being principal among them.[5]

---

[2] Royal Australian Air Force, *The Air Power Manual, 3rd Edn*, Air Power Studies Centre, Canberra, 1998, p 30.
[3] Futrell, R.F., *The United States Air Force in Korea*, Duell, Sloan and Pearce, New York, 1961, p 463.
[4] Royal Australian Air Force, AAP 1002, *The Operational Air Doctrine Manual*, p 21.
[5] Warden, J.A., *The Air Campaign*, Pergamon-Brasseys, Washington DC, 1989, p 15.

In attacking air power infrastructure a wide variety of methods may be employed, encompassing attack from the air or ground, a selection of less overt methods, or a combination of these. The principal aims of these attacks are likely to be the destruction of aircraft or to reduce the ability of the airbase itself to support and generate air missions. 'The historical experience has been that it is cheaper by far to destroy aircraft on the ground than in the air.'[6]

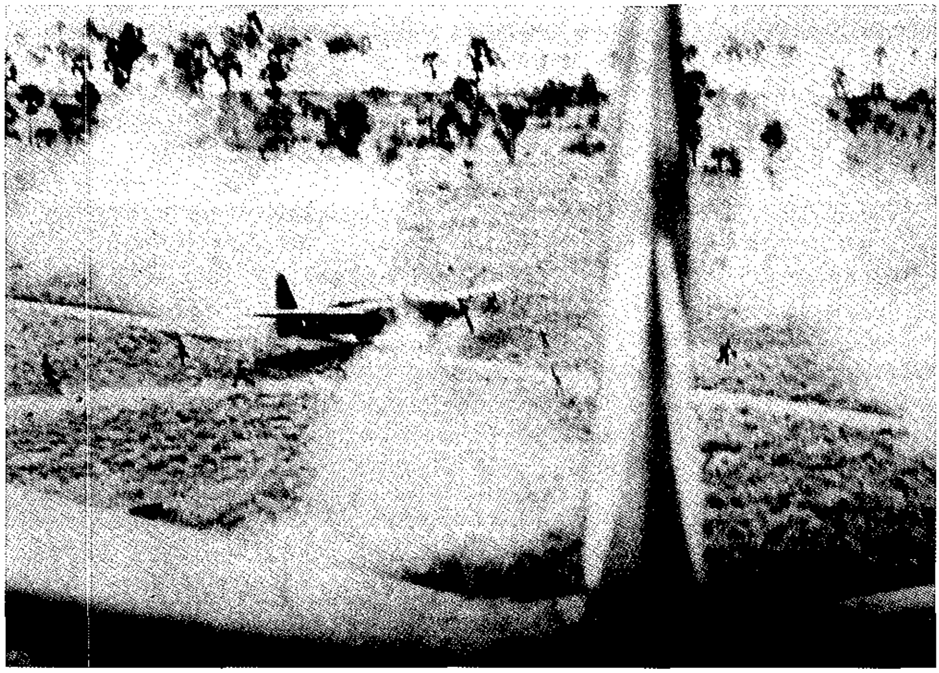

Figure 1.1 Selaroe Strip, Tanimbar Island, Indonesia, 1945. Japanese aircraft being strafed on the Ground. (AWM Photograph SUK13746)

With the coming of the jet age, attacks on airbases began to increase in attractiveness. Aircraft costs and complexity were reducing fleet sizes, commensurately increasing the military value of individual aircraft. Small losses of these aircraft became more significant, and construction times prevented their replacement during campaigns. Tactical combat aircraft could no longer generally be operated from austere dirt strips and became tied to more extensive maintenance organisations. Accordingly, the returns reaped from attacking enemy aircraft on the ground and the vulnerability of their supporting infrastructure increased simultaneously.

[6] *Ibid.*, p 36.

Additionally, airbases are also rarely solely homes for aircraft. As large, notionally secure pieces of defence real estate with established infrastructure and support services they are attractive places for other defence assets to be established, both in peace and wartime. Airbases will typically also function as accommodation centres, logistics depots, transport way stations, command, control and communication nodes, and fuel and ordnance storage sites. The cumulative effect of co-locating all of these assets is to create a 'target rich environment', making the airbase an increasingly lucrative target for attack.

The success, or otherwise of such an attack will depend upon 'surprise, the state of enemy defences and the physical protection given aircraft on the field'.[7] To make these three criteria more applicable in a broader setting they can be replaced by; the level of threat, the survivability and resilience of the airbase and the ability of the airbase to regenerate itself.

This ability of an airbase to defend itself, protect its assigned aircraft and personnel, generate missions and regenerate itself after attack has been termed Airbase Operability (ABO). Formerly termed airbase survivability, ABO is more appropriate, as airbases must remain operational, not just survive. Within the United States Armed Forces a great deal of emphasis is being placed on the operability of their airbases as they are being recognised as corner stones of US power projection around the world. 'Make no mistake, ABO is a fundamental warfighting capability because it will permit aerospace forces to sustain combat operations.'[8] Throughout this book the term ABO will be used to encompass the ability of the airbase to survive degradation and to regenerate itself afterwards.

AIRBASE OPERABILITY

It may not be feasible to build an airbase as an unassailable fortress, immune to any form of attack. This has been shown historically as technically and economically impossible. However, each and every feature added to an airbase to make it survivable will degrade the attacker's ability to inflict lasting damage. Given air superiority, sufficient resources and precision weapons, an attacker could reduce the most resilient airbases to inoperability, as was recently demonstrated during the 1991 Gulf War. However, where the circumstances are not so favourable for the attacker, and their resources more limited, ABO features can prevent much damage. The difference between the crushing success of the Israeli air attacks on the first day of the 1967 war, as compared to their far more limited results during the 1973 war was due in part to the ABO enhancements the Egyptians added to their airbases during the intervening years.[9]

[7] Warden, J.A., *The Air Power Campaign*, Pergamon-Brasseys, Washington DC, 1989, p 36.
[8] Boyles, J.B. and Mittelman, G.K., 'Paradox of the Headless Horseman', *Airpower Journal*, Vol 3, No 1, Spring 1989, p 30.
[9] Centner, C.M., 'Ignorance is Risk', *Airpower Journal*, Vol 6, No 2, p 26.

From the attacker's perspective, airbase defences (both active and passive) reduce the attractiveness of the airbase as a target. Firstly, other factors being equal, for a given expenditure of attack effort a smaller result in terms of damage inflicted would be achieved. Secondly, operability features may force the attacker to use techniques and methods that place his attacking force in greater danger of suffering higher levels of attrition. As an example, aircraft parked in the open can be destroyed using a variety of methods, allowing the attackers to choose the method which best suits the defensive environment and their own strengths, whereas, aircraft parked in hardened shelters may only be destroyed using precision guided penetration weapons. The requirement to use these weapons may force the attacker to employ a specific attack method, perhaps exposing his forces to defensive action. Here, the employment of an ABO feature may have partially removed the initiative from the attacker.

Given the historical examples of airbases that have been completely closed due to enemy action or other causes, it should be apparent that operability enhancements alone will generally not provide total immunity or protection. These enhancements must be viewed and judged in terms of the results that they can be expected to achieve. They may not prevent the disruption of air operations from that base, but what they might do is make this far harder, slower or more costly to achieve.

AIM

The aim of this book is to analyse the factors that contribute to the operability of the airbase. It seeks to consider in a single volume all of the issues that make an airbase resilient and recoverable, and in doing so, is intended to help emphasise the interrelationship of these factors. The study is designed to be sufficiently generic to enable it to be applicable to a broad audience in a very wide range of circumstances and geographic locations. Recent Air Force support to peace-keeping operations, conflicts, and exercises suggests that the RAAF will continue to operate in many parts of the world.

As this book seeks to show, considerable common ground can be found amongst the factors that impact on the operability of different airbases. The factors that determine the operability of a northern Australian forward operating base, a main operating base, a rear echelon airbase or one overseas may not be totally dissimilar. Only the relative importance of the factors vary. Accordingly, a common recipe for 'The Survivable Airbase' can be produced, which with careful application may be broadly applicable in nearly all circumstances.

Perhaps most importantly however, this book also seeks to provide a basic education on what makes a military 'airbase' different from a civilian 'airport'. Air Forces the world over tend to employ specialists, people who are experts in their own fields, but who often have a limited understanding of broader airpower issues. ABO is a core airpower discipline, in that its successful application is essential if airpower is to achieve the roles assigned it. This book does not seek to tell specialists how to do their own jobs. Rather it seeks to describe to everyone else on the airbase what these jobs are, why they are important and how they may impact upon the base as a whole.

SCOPE AND STRUCTURE

The scope of any study that seeks to analyse and interpret those factors that contribute to the operability of the airbase must be necessarily broad. Two factors interrelate to determine how well the airbase will survive degradation and be able to continue to support air missions — the threat posed and the operability features of the base (itself a combination of its survivability and its ability to recover from damage). The structure of this book will broadly mirror these two aspects. The correlation between threat and operability will determine capability. Figure 1.2 demonstrates the philosophy whereby ABO both supports and protects the capability of the airbase.

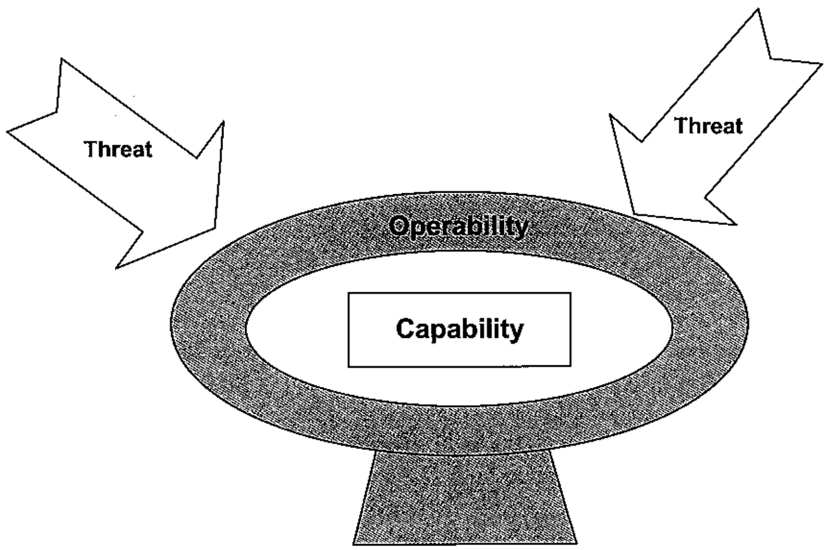

Figure 1.2 Threat, Operability and Capability

Airbase operability is also about more than ground defence or repair of runway surfaces. Once a clear understanding of the scope of the threats facing the modern airbase is obtained it should be apparent that the scope of measures required to deter or defeat them will be equally broad. All airbase personnel are intrinsically involved in ABO generation. The coverage of as many potential ABO issues as possible in a single volume such as this is intended to reinforce the need for a 'total base' multi-disciplinary approach to ABO. Just as every person, facility and piece of equipment on an airbase contributes to its capability, so they must to its operability.

The History of Attacks on Airbases

Before starting the mechanical analysis, a study of the history of attacks on airbases will provide a solid baseline upon which to apply modern theories and strategies. For although technologies and circumstances change, the lessons of previous conflicts can often be related to the present if done with appropriate analysis.

Accordingly, a short history of attacks on airbases has been included in this book. A complete coverage of every attack on an airbase since World War I would certainly fill many volumes. This concise history seeks only to be as representative as possible of the enormous range of such attacks which have occurred in the past eighty years. Therefore, it describes individual case studies and campaigns chosen to contribute a lesson to the understanding of ABO.

What is the Threat?

Following the historical analysis, the first major component of this book will assess the threats faced by modern airbases. Threats have been defined as any force, action or situation that has the potential to degrade the ability of the airbase to fulfil its assigned mission. When defending the capability of the airbase the first step should be to understand thoroughly those forces seeking to degrade it. This threat analysis is subdivided in line with the source of those threats and considers the threat from the air, from the ground, and from other less overt or conventional sources.

Airbase Operability Measures

The second major component of this study will describe and assess those airbase characteristics and features that contribute to survivability and resilience. Again, just as ABO encompasses all aspects within the airbase it is also dependent upon a large number of factors external to the base perimeter. An unusual example of this was the use of military civil affairs officers to perform civic and humanitarian work in the areas surrounding US airbases in Vietnam. By doing so it was hoped to reduce the likelihood that Viet Cong attacks would be launched from these regions, a constant and very real threat throughout the war.

The book also studies the tasks and missions that will be undertaken on the airbase following an attack. It describes the assets and forces required to achieve this task and the likely difficulties that will be faced. Again, a broad range of disciplines is required to complete this demanding task and this book seeks only to identify their roles and flag those issues of critical importance. It does not seek to prescribe the conduct of the recovery operation for this is a task for which qualified experts with in-depth knowledge of local circumstances are employed.

Figure 1.3 Iraqi Hardened Aircraft Shelter

Most of the topics presented in this book are complex issues on which adequate discussion could fill volumes on their own. Air forces employ and train people to be experts in these matters. Accordingly, in many places this work will treat these issues in a sweeping and often seemingly superficial manner, relying on the experts in place to fill in the necessary detail in their own particular circumstances.

The final component of this book is a 'Commander's Checklist' that summarises those important issues the airbase commander and staff need to consider when assessing the survivability of their facility. It seeks to flag those issues of critical importance, which can then be addressed in depth by consultation with the relevant subject matter experts and noting the unique circumstances of each particular airbase.

CHAPTER 2

Historical Perspectives

Thus, [USAF] advanced fighters were virtually ineffective during a crucial phase of the [Korean] war because they depended on longer, harder runways.[1]

INTRODUCTION

The aim of this chapter is to highlight examples of attacks upon airbases by both air and land forces to demonstrate the effect that these attacks have had upon the conflicts in which they were a part. It will consider which attacks succeeded, which attacks failed, and why. This will provide a factual basis upon which to analyse the theory of airbase attack.

Figure 2.1 Russian Il-10 Aircraft in Burnt Out Hangar, Kimpo Airfield, Korea, 1950 (AWM P0716/113/058)

[1] Bahm, P.C. and Polasek, K.W., 'Tactical Aircraft and Airfield Recovery', *Airpower Journal*, Summer 1991, p 44.

Great care must be taken when detailing historical examples of military operations that the conclusions drawn and lessons learnt are relevant to the present. With the pace of development of weapons and tactics that has occurred in the last ten years it is difficult to draw direct parallels between historical examples and current operational scenarios. Dr Alan Stephens, in his paper *High Noon of Air Power*, cautions firmly against the misuse of historical analysis as a means of analysing the potential of air power and consequently its vulnerabilities.[2] However, if considered in the context of a rapidly and often fundamentally changing technological and doctrinal environment, some valid lessons may be drawn.

A broad range of historical examples will be considered — anti-airbase operations during World Wars I and II, the Korean War, operations during the Vietnam War, a selection of incidents during the various Arab–Israeli Wars, the Falkland–Malvinas Islands War, and the American led coalition attacks on Iraqi airfields during the 1991 Gulf War. Other conflicts and isolated airbase attacks are cited where they demonstrate unique features or provide additional insights on airbase attack. This is certainly not an attempt to catalogue exhaustively attacks of this nature for that would require far more space than available here. It merely provides examples selected to highlight a range of scenarios as broad as possible

THE EARLY DAYS — WORLD WAR I

Perhaps the first recorded attack on an airbase occurred during World War I when on 24 August 1914 an aircraft of the Royal Flying Corps observed and then attacked with a single bomb three German aircraft parked on an airfield near Lessines.[3] Although no damage was recorded the event was a foretaste of a new military operation — the air attack on the airbase; a military operation that would be repeated in virtually every major conflict where aircraft were involved, from that point onwards.

Prior to World War II there was initially little attempt made to attack aircraft at their airbases. Two main reasons for this seem apparent. Firstly, military aircraft operations were still in their infancy and combat aircraft had yet to make a decisive impact on the results of wider land or sea campaigns. Secondly, airbases were usually any flat piece of unobstructed ground. They were rarely improved and base support facilities were often simple tents. 'The aerodrome just by the village of Bethouart was occupied by a herd of cows, and that no-one took the least notice of them, each pilot taking off or landing in whatever direction seemed to be most suitable to avoid the animals.'[4]

However, when aircraft were based for any period of time they did draw enemy attacks. During 1917 the German Air Service began to expand their ground attack and interdiction operations aggressively with great effect. Despite improvements in control and coordination British pilots had great difficulty in effectively intercepting these

[2] Stephens, A., *High Noon of Air Power*, Air Power Studies Centre, Canberra, 1999, p 26.
[3] Kreis, J.F., *Air Warfare and Airbase Air Defence*, Office of Air Force History, Washington DC, 1988, p 5.
[4] Kennett, L., *The First Air War 1914-1918*, The Free Press, New York, 1991, p 136.

attacks. In an effort to control them, the British Royal Flying Corps, in turn, attacked German airfields. Following this first large-scale attempt at airbase attacks several important countermeasures were taken by both sides. The policy of attacking airfields and concomitant airbase defence was refined by Major Harold Hartney, commander of the US 1st Pursuit Group. He believed that counter air operations could be used to force the enemy to relocate their airfields so far to the rear that they could no longer influence the tactical situation on the ground.[5] He also pioneered ideas of fortifying hangers and maintenance facilities and their placement underground. He extensively protected his airbases with anti-aircraft guns and routinely used dummy and auxiliary airfields.

Active airbase defences were improved, with the use of anti-aircraft artillery, searchlights and machine guns. The Germans also used camouflage — painting the tops of their aircraft to hide them from aerial observation and by constructing dummy airfields near real ones.

The Australians too pioneered the use of air attacks on airbases as a means of gaining control of the skies. 80 Wing, which included the Australian No. 2 and No. 4 Squadrons, 'was to take to the air in full force, scare all the German machines to the ground, and then go down after them and bomb them in their hangars'.[6]

The first major target was Haurbourdin aerodrome on 16 August 1918. Camels of No. 4 Squadron attacked the airfield first whilst S.E.5s of No. 2 Squadron and RAF units provided top-cover. They dropped 25 pound high explosive bombs, 40 pound phosphorus bombs and strafed exposed aircraft and hangers. Nearby trains, horse-drawn wagons and staff cars were all attacked as targets of opportunity as the aircraft waited their turns to strike at the airbase. The attack was a great success and was followed by a similar mission to Lomme the following day. The attacks prompted a strong aerial response from the Germans, however, by the end of the month the success of these two attacks combined with ongoing heavy German air losses forced them to move the majority of their aerodromes east of Lille, reducing their ability to contribute to the ground battle.[7]

AIRBASE ATTACKS DURING WORLD WAR II

Poland

From the opening moments of the European war the Luftwaffe actively pursued the destruction of their opponents' air forces. Their doctrine was to include aggressive attacks against airfields as an integral part of the *Blitzkrieg* strategy.[8]

[5] Kreis, *Air Warfare and Airbase Air Defence,* p 219.
[6] Cutlack, F.M., *The Australian Flying Corps in the Western and Eastern Theatres of War 1914-1918,* 10th Edition, Angus and Robertson, Sydney, 1940, p 345.
[7] *Ibid.,* pp 344-351.
[8] *Kreis, Air Warfare and Airbase Air Defence* p 54.

It became rapidly apparent during these early attacks that German aircraft were able to attack airbases almost unhindered by the anti-aircraft defences in place — a good example of doctrinal and performance surprise. During the inter-war years there had been great advances in aircraft design and tactics but little, if any, improvement in anti-aircraft gun system technology. Guns were still aimed visually and could rarely hit moving targets and radar had generally not been deployed.

Accordingly, when German aircraft attacked nine of the 12 main Polish operating airbases on 1 September 1939 they were able to destroy those aircraft and facilities they could find. However, the Poles had undertaken a comprehensive program of dispersal and camouflage of their aircraft. Very few operational Polish aircraft were destroyed in the opening attacks. This enabled the Polish air force to continue operations for that month and put up a credible defence effort, destroying 126 German aircraft in air-to-air fighting during the campaign. Given the advances in attacking aircraft and the inability of extant defences to counter them, dispersal and camouflage alone may have temporarily saved the Polish air force.

Norway, The Netherlands and Belgium

In Norway, Germany utilised airborne and aircraft-inserted forces entirely to capture the heart of the country. Having failed to insert an invasion force by sea, a small force of paratroopers captured Oslo airport on 7 April 1940 and the Luftwaffe began a massive operation of flying in fuel, munitions, ground forces and combat aircraft. Later that day airborne forces were again used to capture Sola airfield and by evening 180 German aircraft had been flown into there. The next day the Germans captured other airfields. 'The speed with which the Germans had seized the airfields and then turned them into operational bases, capable of supporting significant air operations, was one of the nastiest surprises of the campaign.'[9] Accordingly, given the difficulties experienced by the Germans in inserting forces into Norway using other means, the failure to defend its airfields adequately may have cost Norway the war.

The Luftwaffe then turned its attention to the Netherlands and Belgium. These attacks saw the first large-scale use of air and glider borne troops. Bombers attacked Waalhaven airbase at dawn on 10 May 1940 from both medium and low altitudes. Despite suffering relatively high losses from the Dutch anti-aircraft defences and fighters these attacks paved the way for the paratroops who were able to capture the airbase. Germany further used airborne forces to capture other airbases. Ju52 troop transport aircraft were used to land infantry at Ypenburg. Again heavy anti-aircraft gun defences made this a costly operation, shooting down several of the 13 Ju52 transports comprising the first wave. Others wrecked themselves on obstacles placed on the airfield. The heavy anti-aircraft defences and the lack of tactical allowed the Dutch anti-aircraft defences to shoot down as many as 315 German aircraft, making the operation an expensive one for the Luftwaffe.[10]

[9] Cooling, B.F., *Case Studies in the Achievement of Air Superiority,* Center for Air Force History, Washington DC, 1994, p 79.
[10] Kreis, *Air Warfare and Airbase Air Defence,* p 67.

When the Germans turned their attention to Belgium they had a far easier time. The Belgian Air Force was neither dispersed nor well defended on the ground. German air attacks on the morning of 10 May destroyed virtually all of the Belgian aircraft. Those that survived were flown to France, where they were of little use because of their age and obsolescence.

German Air Attacks on France

The foremost aim of the Luftwaffe during the invasion of France was to 'achieve air superiority over the battlefield by attacking Allied airbases and aircraft'.[11] In this goal they were quite successful, and those allied aircraft that were not destroyed in the initial attacks were kept on the defensive throughout the entire campaign. For example, all 18 aircraft of No. 114 Squadron Royal Air Force were destroyed or rendered unserviceable during a Luftwaffe attack on Conde Vraux airfield.[12] A similar fate awaited the bombers of No. 142 Squadron as they were destroyed in neatly parked, unprotected rows preparing for a mission.[13]

Of those few French and British aircraft that could compete with the German fighters in the air, most continued to suffer heavy casualties whilst on the ground. A group of new Dewoitine 520 fighters that fought quite well in the air suffered over 50 per cent losses on the ground through German attacks on their airbases.[14]

The Battle of Britain

The Battle of Britain is the name given to the August–September 1940 campaign, whereby the Luftwaffe attempted to destroy the RAF in preparation for an amphibious invasion of the UK. The battle was a major strategic defeat for Germany in that the failure to subdue the RAF led them to cancel their plans for the invasion. This left England in the hands of the Allies and allowed the build-up of forces that eventually led to the combined bomber offensive and the Normandy invasion.

Perhaps the earliest loss for the Germans during this campaign was the information war. Their preliminary intelligence estimates of the RAF, in particular the capability of its fighter defences, were highly inaccurate. These misled the Luftwaffe into believing they had a far greater superiority than they actually had. A July intelligence report prepared by the Luftwaffe Head of Intelligence, Colonel Joseph Schmid, denigrated the RAF's ability to fight the Luftwaffe to the extent that combat between the two would allow the Luftwaffe to 'achieve a decisive effect' allowing further operations to be prosecuted against England.[15] Operational estimates forecast that four days of major air attacks on England would break Fighter Command. A further four

[11] Cooling, *Case Studies in the Achievement of Air Superiority*, p 81.
[12] *Ibid.*, p 81.
[13] Kreis, *Air Warfare and Airbase Air Defence*, p 71.
[14] Cooling, *Case Studies in the Achievement of Air Superiority*, p 84.
[15] *Ibid.*, p 92.

weeks of operations would then eliminate the remainder of the RAF and allow the destruction by bombing of the factories that could replace the RAF aircraft.

The other major knowledge-edge loss by the Luftwaffe was the failure to realise the significance of the British radar system. Initially promising attacks by the Luftwaffe on radar installations during mid-August were questioned by Goering and ceased forthwith.[16] Radar allowed the RAF to respond effectively to Luftwaffe raids and protect their own airbases and cities.

Early German planning for the Battle of Britain called for an aggressive offensive counter air campaign. The foremost task was to gain air superiority through attacks on the RAF. This was to be achieved by attacking their bases and aircraft production facilities and attacking RAF fighter aircraft wherever they could be found. In attacking the British airfields the Germans were quite successful, although ultimately not decisive, perhaps for the following reasons:

- the light bomb loads of the available German aircraft;
- the effectiveness of the British air defences;
- the number of small airfields and satellite strips employed by the RAF; and
- the simplicity of the British fields, usually being just sod runways and a few scattered buildings.

Attacks on RAF airfields began in earnest on 12 August. Mainly by daylight, attacking from both high and low-level, virtually every major aerodrome was visited at least once in the first few days.[17] Those airfields defended with a large number of guns were better able to weather the attacks and were often able to inflict heavy casualties on the attackers. 'These attacks brought out the importance of having an abundance of anti-aircraft guns for airfield defence, for it is the guns which protect the aircraft during the vulnerable moments when they are approaching or leaving the ground.'[18]

Despite these strong defences many airfields were badly damaged. A combined low and medium level attack on Manston rendered the field 'temporarily unusable'.[19] However, events had conspired to ensure that Fighter Command's airfield system was very resilient. Both the Hurricane and the Spitfire were grass-airfield machines and a very large number of airfields had been spread throughout the English country-side before the war.[20] Following the initial raids Fighter Command instituted a wide-spread program of dispersal. This reduced RAF casualties on the ground; however, a lack of

[16] Murray, W., *Luftwaffe,* George Allen and Unwin, London, 1985, p 52.
[17] Pile, F., *Ack-Ack: Britain's Defence Against Air Attack During the Second World War,* George Harrap & Co., London, 1949, p 137.
[18] *Ibid.*, p 136.
[19] *Ibid.*, p 137.
[20] Cooling, *Case Studies in the Achievement of Air Superiority,* p 155.

support equipment such as telephones and motor vehicles made operations in this decentralised manner very difficult.[21]

The Germans also dropped large numbers of empty parachutes, designed to convince the British population that spies were being deployed by this method. This was a psychological warfare technique designed to unsettle Allied military and civilian personnel alike.

The 24 August saw the concentration of Luftwaffe activity on the airfields of No. 11 Group, RAF. Raids were conducted both during day and at night with night-time raids being used to sap the will of the people. One of the largest airfields, Biggin Hill, was raided twice on the night of 29 August and four more times the following day.[22] Despite the casualties being inflicted on the Germans, the situation was desperate for the RAF.

This counter air policy was proving to be very effective, but the Germans began changing goals and plans too quickly and lost sight of the initial aim. Royal Air Force Bomber Command raids on Berlin between 25 August and 4 September infuriated Hitler and he ordered the Luftwaffe to concentrate their attacks on the British urban areas. By this stage of the campaign Luftwaffe losses during raids on RAF facilities had become untenable and the plans to invade England by sea, which had depended upon the neutralisation of RAF air power, were postponed indefinitely. The importance of the counter air campaign is illustrated in the following description of the final day of the Battle of Britain on 31 October 1940. 'The great Battle fizzles out damply, the Germans having exhausted every tactical alternative after being deprived of their best chance of victory by the inept decision of their Supreme Command to attack London rather than continue with the direct offensive against Fighter Command and its ground installations.'[23]

British Ground Attacks on Axis Airbases — North Africa 1940–43

The battle for North Africa during 1940–43 was characterised by fluid frontlines, long distances across relatively featureless deserts and tenuous supply lines. During this period British forces proposed that a motorised unit be formed to conduct long range reconnaissance throughout the extensive rear areas and to raid vulnerable facilities such as airbases and supply dumps. General Wavell, Commander of Commonwealth Forces in the theatre, was attracted to this idea and authorised the formation of such a force to be called the Long Range Patrols (LRP). The strategic aim of the patrols was to help offset the numerical superiority of the mainly Italian Axis forces by forcing them to divert resources to provide expanded rear area security.

[21] *Ibid.*, p 140.
[22] Pile, *Ack-Ack: Britain's Defence Against Air Attack During the Second World War*, p 143.
[23] Hough, R. and Richards, D., *The Battle of Britain*, Norton & Company, New York, 1989, p 370.

Initially operating from a base on the western edge of the Egyptian Sand Sea the LRP conducted its first raids against Italian airstrips north of Kufra during September 1940, destroying fuel dumps and pumping facilities.[24] Further patrols during late 1940 destroyed the first Axis aircraft, an unguarded Savoia S.79 bomber.

Wavell was impressed with the results obtained by the modest resources allocated to LRP and at the end of 1940 increased their number to five independent patrols and renamed them the Long Range Desert Group (LRDG). During 1941 the LRDG continued operations raiding airbases, harassing Axis supply lines and providing much needed reconnaissance information.

Following on from the success of the LRDG, L Detachment of the Special Air Service (SAS) Regiment was formed in November 1941 with the primary purpose of raiding airfields.[25] Combined SAS-LRDG raids continued throughout 1941 until the final successful African raid in September 1942. Utilising parachute insertion or long range desert vehicles to reach the vicinity of the target airfield they would then use either stealth to plant explosive charges on aircraft during the night, or simply drive their vehicles onto the airstrip at high speed and use machine-gun fire to destroy aircraft. In total 367 Axis aircraft were destroyed by British Special Forces in North Africa and the Mediterranean during the period October 1940 to July 1943.[26]

In countering the SAS-LRDG threat the Axis forces employed two main measures, one active and one passive. By sending out aircraft on the morning following a raid they were often able to find and severely damage the retreating raiding parties. They also improved the airfield passive defences, installing strong ground defences and instituting aggressive patrolling. These measures made the SAS-LRDG task more difficult and reduced Axis losses. One analysis proposed the use of further passive defence measures such as dispersing aircraft in revetments, the employment of minefields, dog patrols and selective lighting as being potentially the most successful measures which could have been used to minimise losses to these raids.[27] Attempting to capitalise on the ease with which SAS-LRDG parties were able to destroy Axis aircraft in North Africa, a similar Special Boat Squadron (SBS) group was assigned to raid Maleme airfield on the island of Crete but was turned back 'by impressive defences that included many machine gun posts, dogs, and searchlights'.[28]

Malta

The seemingly unending contest between the Axis forces and British defenders in the sky over Malta illustrate the ability of airfields to recover following attack. Several times British air power and airbases at Malta were destroyed, but because of Hitler's decision not to seize the island with land forces, defences were rebuilt, air operations

[24] Vick, A., *Snakes in the Eagle's Nest*, RAND Corporation, Santa Monica, 1995, p 68.
[25] *Ibid.*, p 44.
[26] Vick, *Snakes in the Eagle's Nest*, p 57.
[27] *Ibid.*, p 63.
[28] *Ibid.*, p 49.

restored and Malta remained a base for British air operations throughout the war.[29] During April 1942 an average of 170 bombers were raiding the island every day.[30] On 20 April a new batch of 47 Spitfires arrived at the island off the American carrier USS *Wasp*. The Luftwaffe tried desperately to destroy these new aircraft and within three days of their arrival dropped 985 tons of bombs on Takali airfield and 485 tons on Luqa. Both airfields were ruined and 30 of the new Spitfires destroyed.[31] During this month a greater weight of bombs was dropped on Malta that had fallen on London during the worst three months of the Blitz.[32] Many more aircraft were damaged or destroyed on the ground during these and later raids.

Constant repairs to the airfields enabled them to remain operational. 'The aerodromes were in such a frightful state that rollers had to be used continuously for twenty-four hours on end.'[33] However, the build up of defensive fighters, arrival of trained ground staff and improvements to the island's early warning radar soon enabled unsustainable losses to be inflicted on the Luftwaffe. By the war's end 707 RAF aircraft had been destroyed at Malta, 160 of them on the ground.[34]

During this battle the Germans and Italians also employed area denial weapons. These were small anti-personnel bombs that did not detonate on impact but after a random time delay or when disturbed. When dropped onto the airfields they caused considerable disruption, slowing repair work and airbase recovery. These weapons, the German SD2 Butterfly bomb and the Italian 4AR Thermos bomb, took considerable effort to clear and caused many casualties.[35]

Pearl Harbor — 7 December 1941

The attack by Japanese aircraft on US naval assets and airbases in Hawaii is highly significant because of the number of parallels that may be drawn between the conditions that existed then and those which could conceivably involve Australia in the future. The attack on Pearl Harbor is usually referred to as being a surprise attack, a 'bolt from the blue' that the Americans could not have predicted. This may not be correct, and the success of the Japanese raid demonstrated how important the accurate analysis and dissemination of intelligence is to avoiding highly destructive attacks on airbases. The potential vulnerability of the Hawaiian airfields to air attack had been identified as early as 1924, when the then Brigadier-General William Mitchell stated that Oahu formed 'an easy, compact and convenient object for air attack'.[36]

[29] Kreis, *Air Warfare and Airbase Air Defence*, p 344.
[30] Hamlin, J.F., *Military Aviation in Malta G.C. 1915-1993*, GMS Enterprises, Peterborough, 1994, p 24.
[31] Hamlin, *Military Aviation in Malta G.C. 1915-1993*, p 25.
[32] Hogben, A., *Designed to Kill*, Patrick Stephens Ltd, Wellingborough, 1987, p 92.
[33] Hamlin, *Military Aviation in Malta G.C. 1915-1993*, p 26.
[34] Hamlin, *Military Aviation in Malta G.C. 1915-1993*, p 34.
[35] Hogben, *Designed to Kill*, pp 99-101.
[36] Bateson, C., *The War with Japan – A Concise History*, Ure Smith, Sydney, 1968, p 24.

The attack on Pearl Harbor evolved from a long running political stalemate between the United States and Japan. The Americans were taking a steadfast stance and refusing to grant Japan concessions in the hope that it would deter the Japanese from war. American cultural myopia at the time allowed them to assume that this would not in fact provoke the Japanese, and that the Japanese would not be 'irrational' in attacking before negotiations had ceased. Accordingly, the Americans were not expecting war because they believed the political climate was not yet ripe for it. Yet, despite this, many general warnings had been provided to US forces in Hawaii previously, possibly producing a numbness that comes from long term exposure to warnings.

American intelligence sources also had a great deal of evidence that a surprise attack on Hawaii was imminent. Highly accurate reports from their ambassador in Tokyo and many classified message intercepts provided (in hindsight) a precise picture of when and where the Japanese would strike.[37] Due to poor US intelligence analysis and dissemination procedures these warnings were provided to Hawaii either too late or in too general terms to be of any great utility. In return, Washington did not have a full understanding of the situation in Hawaii and assumed that because of the previous warnings the fleet would have put to sea.[38]

The US, believing Japanese military attention would be focused westward towards Russia and Manchuria, mainly implemented the warnings by instituting anti-sabotage measures. The aircraft warning systems in Hawaii were never fully activated, search aircraft were not activated around-the-clock, and there was no recognised commander for these forms of operations.

Consequently, Japanese tactical surprise was virtually complete. Both Wheeler and Hickam fields were bombed and strafed. The aircraft at these fields were parked close together in rows; an anti-sabotage precaution rather than being dispersed in anticipation of air raids. 'The destruction of defending air power on the ground was almost total.'[39] At the Marine airbase at Ewa, 49 aircraft were shot up on the ground. Of the 231 Army aircraft on Oahu, 97 were destroyed and 88 severely damaged. 41,000 kilograms of ordnance was dropped on the airfields, nearly one-third of the total for the whole attack.[40] Later that morning as American aircraft either arrived from carriers nearby or went in search of the Japanese fleet, many were shot down by the US anti-aircraft defences.

Pearl Harbor demonstrated several enduring lessons on airbase operability. Firstly, intelligence needs to be disseminated, timely, and acted upon. Secondly, it demonstrated the paradox that protective measures for one form of threat could make assets more vulnerable to a different threat. Thirdly, it demonstrated the degree of

---

[37] Betts, R.K., *Surprise Attack,* The Brookings Institution, Washington DC, 1982, p 43.
[38] *Ibid.*, p 44.
[39] Campbell, C., *Air War Pacific,* Hamlyn, London, 1991, p 31.
[40] Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987, p 12.

caution that should be applied when ground based anti-aircraft defences are placed near airfields.

Darwin — February 1942

No history of attacks on airbases published in Australia would be complete without reference to the Japanese air attack on the airfield and city of Darwin on 19 February 1942.

For two months Japanese land, air and naval forces had been advancing with uprecedented speed into South-East Asia and the South-West Pacific. Australia was struggling to mobilise in the face of what seemed like an inevitable Japanese attack on the Australian mainland, as Australia's largest settlement on the north coast Darwin was likely to bear the brunt of the initial attack.

This occurred on 19 February in two waves at 10 am and 12 noon that day. The attackers, a mixture of level and dive bombers with fighter escort, flew in from Ambon and Kendari in what is now Indonesia.

The Darwin airbase was caught completely unprepared. An early warning radar shipped to the city two weeks before the attack had not yet been installed because the base staff were completely unconvinced that such a miraculous invention could really work as promised. Further, warning of the attack from distant observers went unheeded and defence of the base was correspondingly ineffective. Considerable damage was done to the civil and military airbase facilities in the first raid by dive bombers and straffing fighters. Communications links, hangars, oil and explosives stores, workshops and the power plant were all damaged.

The second raid, conducted by 27 level bombers was aimed soley at the RAAF base. This raid was more severe than the first and further damaged the aerodrome facilities until 'the very surface of the aerodrome itself had also been almost destroyed'.[41] Married quarters, messes, the RAAF hospital, the equipment store and vehicle workshops were destroyed.

The Darwin raid was a timely wake up call to the Australian Defence Force, government and people. A thorough inquiry into the raid was immediately conducted by Royal Commision and many reasons why the base had been caught so badly by surprise were listed. The Commision found that the deficiencies at Darwin had been well known to the RAAF hierarchy long before the raid and little had been done to rectify them. The base facilities were concentrated in one small area, their gun and fighter defences were inadequate and they lacked any form of passive defences. Command authorities were confused and procedures for warnings and conducting pre and post-attack drills were *ad-hoc* at best. This was made all the more regrettable by the fact that a RAAF Reserve Officer who had served as air adviser to the Chinese

[41] Garrison, A.D., 'Darwin 1942', *Australian Defence Force Journal,* No 122, January/February, 1997, p 63.

Government had briefed all station commanders on the measures for protecting aerodromes that had been successfully adopted against the Japanese in the war in China. None of this advice was apparently utilised.[42]

The Solomons and Guadalcanal

The Pacific War was characterised by desperate naval battles and island hopping advances and retreats. Firstly, by Japanese forces vigorously expanding their empire, and then by the US and Allied forces driving them back again. Sea and air power played a significant part in this campaign and the unusual nature of the battle space provided a unique perspective on airbase operations. The limited number of carriers that could be deployed by both sides, and their potential vulnerability, meant that land based air power was essential to support combat operations. 'Not until Luzon in 1945 would the United States have enough carriers and the Japanese air force be weak enough, for these precious ships to remain in combat for more than a few days at a time'.[43]

The limited number of potential airfield sites that could be established in the mountainous island theatre meant they were strongly fought for. 'The survival of American air power on Guadalcanal, in the final analysis, depended upon the survival of the airfield.'[44] During October and November 1942 the Japanese made their ultimate efforts to remove US forces from Guadalcanal. Approximately 90 US aircraft were operating from Henderson Field and were coming under constant attack from large numbers of Japanese aircraft based at Rabaul on the island of New Britain in New Guinea. Peaking in mid-October, Henderson came under heavy air attack combined with night bombardment from naval ships, including 14 inch shells from battleships. On the night of 13 October, 53 shells and bombs hit the runway, 13 of which were repaired by US engineers whilst their own planes were waiting to land. Confusion between the local US Army defence battalion and the fighter controllers resulted in some friendly aircraft being fired upon by their own anti-aircraft defences.[45]

The constant defence and repair of Henderson enabled US land based air power to contribute to the broader campaign in the region, with eventual Allied naval victories bringing an end to Japanese attempts to reinforce Guadalcanal.

As at Henderson, Allied operations in New Guinea were vulnerable to Japanese aircraft based at Rabaul. The Japanese had also established an airfield at Munda, the next large island up the Solomons chain from Guadalcanal. Extensive use of camouflage and concealment had prevented allied forces from discovering this base until it was ready for operations. Once it was discovered the Americans attacked it constantly. Fighters and bombers from Guadalcanal and heavy bombers from

---

[42] *Ibid.*, pp 41-77.
[43] Cooling, *Case Studies in the Achievement of Air Superiority*, p 334.
[44] *Ibid.*, p 334.
[45] Kreis, *Air Warfare and Airbase Air Defence*, p 230.

Australia attacked throughout the end of 1942 and early 1943. Japanese anti-aircraft defences were generally ineffective; the runways were constantly cratered and many aircraft were destroyed on the ground. The cratering was repaired hastily, but daily raids prevented the base from being used effectively to support fighter operations. Logistic isolation was also beginning to effect Japanese airbase operability, and the interdiction of Japanese transport shipping was having a severe impact on aircraft serviceability and sortie generation.[46]

In summary, the Pacific campaign was a string of airbase operability battles. The side that could capture airbases and keep them operational most effectively would eventually carry the day. The Americans had demonstrated how tenacious defence and repair of an airbase could make a significant strategic difference.

> The importance of recovery efforts to operation of an airbase and the base's continued use by a flying force was soon emphasised. After devastating raids during the Battle of Britain, the RAF restored several of its bases to operation only through the most exemplary efforts of leadership and diligence. Fighters could operate largely because of the repeated efforts of military and civilian crews who repaired bomb damage. Elsewhere, American and Japanese commanders in the Solomon Islands went to great lengths to repair bomb damage and keep airfields serviceable. The Americans succeeded at Guadalcanal; the Japanese lost at Munda and had to abandon their important airfield there.[47]

The survivability of early airfields, when provided with dedicated and tenacious repair crews was again to be demonstrated later in the war during the American invasion of Iwo Jima.

Milne Bay

Milne Bay, located on the east coast of Papua New Guinea, was developed as an airstrip in June 1942. It allowed Allied air power control over the eastern sea and land approaches to Port Moresby and placed Allied aircraft within striking distance of Japanese airbases on the island of New Britain. Three airstrips were built at the site which was occupied by 75 and 76 Squadron Kittyhawks, a flight of 32 Squadron Hudsons, an Operational Base Unit, 7,500 Australian Army troops organised in two brigades, and approximately 1,340 American servicemen.[48]

---

[46] *Ibid.*, p 257.
[47] Kreis, *Air Warfare and Airbase Air Defence,* p 347.
[48] Mordike, J., 'Turning the Japanese Tide: Air Power at Milne Bay August-September 1942', in Stephens, A., (Ed), *The RAAF in the Southwest Pacific Area 1942-1945,* Air Power Studies Centre, Canberra, 1993,.p 80.

Command and control of the forces at Milne Bay was always a difficult issue and is dealt with in detail in Dr John Mordike's paper on the battle presented at the 1996 RAAF History Conference. On several occasions it may have jeopardised the defence of the airbase. Before the initial attacks there was reluctance on the part of some American servicemen to prepare defensive works at the order of the Australian Commander. Accordingly, when the first Japanese air raids occurred they had no protective slit trenches to occupy and overcrowded the positions dug by Australians. This prevented the Australian troops from manning their weapons as planned and potentially affected the ability of the airbase to defend itself.[49]

Figure 2.2 Gurney Airfield Milne Bay (AWM Photograph OG1471)

On 21 August 1942, the main Japanese landing force was sighted in Milne Bay and Major General Clowes assumed active command of all Allied land and air forces in the area. A misplaced landing by the main Japanese force and the destruction of part of their invasion force at sea delayed the initial assault with the first attack on the airfields occurring on the morning of 27 August. Eight dive-bombers and 12 escorting Zeros raided the No. 1 strip in an offensive counter air operation. None of the bombs

[49] *Ibid.*, p 82.

dropped actually struck the runway. Strafing by the Zeros set fire to a Liberator bomber that was parked on the strip, having crash-landed there earlier.[50]

The next attack on the airfield occurred at 0300 hours on the morning of 31 August. Sentries heard noise in the vicinity of the strip and flares were fired. An advancing force of Japanese infantry were engaged with machine gun fire as they advanced in tight packed groups across the flat ground of the No. 3 strip. The attack was repeated twice more, each time the Japanese suffering heavy casualties because of the massed defensive fire and open ground. Eventually, the attackers withdrew.

The final air attack on the Milne Bay airbase was on the last day of the battle after the Japanese ground forces had withdrawn. Nine enemy bombers attacked the No. 1 strip, causing little damage.

During the battles one of the most debilitating aspects of life at Milne Bay was sickness, particularly from diseases borne by mosquitos. At one point one-third of 76 Squadron personnel had been admitted to sick camp with the most prevalent disease being malaria.[51] This was due to the geography of the site, but also to lack of preparation. Mosquito nets, suitable clothing, mosquito repellent and medicine had either been supplied in insufficient quantities, or not at all.[52] Ignorance of environmental factors compromised the operability of the airbase.

The Marianas and Iwo Jima

The Allied seizure of the Mariana Island group in the summer of 1944 provided a base from which American very heavy bombers could attack the Japanese home islands. The Japanese could not retake the islands nor did they have a bomber capable of reaching Saipan, Tinian or Guam from their mainland. Their only option was to attack the American bombers from their remaining Pacific bases, Iwo Jima being principal amongst them. From 2 November 1944 until 2 January 1945 they attacked the American airfields and aircraft on Saipan, destroying several B-29s and damaging many more. Most of the Japanese bombers flew from bases on the home islands, staging through Iwo Jima.[53]

In return, American aircraft pounded the airfields on Iwo Jima but could not keep them inoperative. A newly developed microwave early warning radar was ordered for Saipan but did not arrive until after the Japanese raids petered out. Two radar-equipped destroyers were eventually posted to the north-west of Saipan to provide some air defence early warning. However, the raiders were frequently able to slip under the radar screen and on the night of 27 November attacked Saipan's Isley Field,

[50] Gillison, D., *Royal Australian Air Force 1939-1945,* Australian War Memorial, Canberra, 1962, p 611.
[51] Mordike, 'Turning the Japanese Tide: Air Power at Milne Bay August-September 1942', p 79.
[52] Wilson, D., *The Decisive Factor,* Banner Books, Melbourne, 1991, p 104.
[53] Craven, W.F. and Cate, J.L., (Eds), *The Army Air Forces in World War II – Vol V,* Office of Air Force History, Washington DC, 1953, p 583.

its construction lights still lit.[54] The debilitated state of Japanese air power and the continued high rate of losses are more likely to have stopped the raids than the damage done to the Iwo Jima airfields.

The decision to capture Iwo Jima was made in October 1944 to provide Twentieth Air Force a base closer to the Japanese mainland.[55] The American pre-invasion bombardment of the Japanese-held island of Iwo Jima is another good example of the ability of these early airfields to be recovered quickly following severe bombardment. An island of only seven kilometres long and four kilometres wide it was subjected to the heaviest air and naval bombardment yet seen during the war. In the ten weeks prior to 16 February 1945 the island was deluged by 6,800 tons of bombs, 203 rounds of 16 inch, 6,472 rounds of 8 inch and 15,251 rounds of 5 inch projectiles.[56] As heavy as this attack was it never kept the island's airfields inoperable for more than a few hours at a time.

After Iwo Jima was captured the airfields were repaired and extended for use by US aircraft. Considering the island secure, airbase ground defence was a low priority. However, once the facility was declared operational Japanese troops who had hidden in caves in Mount Suribachi emerged at night and attacked the airbase killing 44 and wounded twice that number.[57] This should have been an enduring lesson in security for rear area airbases.

The European Eastern Front — Poltava

During the first day of the German offensive against the Soviet Union the Luftwaffe undertook a massive offensive counter air campaign. By midday 800 Russian aircraft had been destroyed on the ground, for a loss of only 10 Luftwaffe planes.[58] Later, another good example of the vulnerability of aircraft parked undispersed and unprotected occurred at Poltava airbase in the Southern USSR on 21 June 1944.

Poltava, like several other Russian airbases, was to be used by American B-17 bombers to enable them to attack German targets normally out of range from England or Italy. The aircraft would fly from their normal bases, bomb German targets and continue on to land at Russian bases. They would then refuel, rearm and reverse the process.

The second of these missions landed in Russia on the afternoon of 21 June 1944, the bombers landing at Poltava and Mirgorod, their escorting P-51 fighters at Piryatin. The Luftwaffe had shadowed the bombers and knew where they had landed, a photo

[54] *Ibid.*, p 582.
[55] *Ibid.*, p 586.
[56] Bateson, *The War with Japan – A Concise History*, p 372.
[57] Cooling, *Case Studies in the Achievement of Air Superiority*, p 613.
[58] Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, p 11.

reconnaissance mission confirming this. The 79 B-17s at Poltava were lined up in open un-revetted parking areas.

Luftwaffe bombers attacked after dusk that evening dropping 110 tons of mixed large high explosive and smaller fragmentation bombs.[59] Every B-17 at Poltava was damaged, 50 being completely destroyed and the other 29 requiring considerable repair. The Russian Air Force lost a further 26 aircraft. 'Blast shields and revetments were not common on the VVS's airstrips and were not built at Poltava. Had they been, the damage could have been reduced considerably.'[60] Also, no attempt had been made to camouflage the aircraft and their silver finishes made them an obvious target in the reflected light of the air dropped flares. None of the German bombers was shot down in the raid, the VVS lacking effective night-time AA or fighter control. 'The VVS lacked the doctrine, command structure, and the equipment to defend the base.'[61]

Similar attacks on Mirgorod and Piryatin failed due to navigational errors by the Luftwaffe.

Of interest, during the fire fighting, rescue and subsequent repair and recovery operations following the attack unexploded ordnance posed a major hazard to personnel. At least 30 Russians were killed during the bomb disposal operations and many more injured — more than during the actual attack.[62]

Meiktila, Burma

The Allied airfield at Meiktila, Burma, is an interesting example due to the desperation and nature of its defence. In the last months of the war desperate Japanese ground forces were attempting to seize this important airfield. Each night during March 1945 Japanese troops would assault the airbase, and each night, the RAF Regiment and other Commonwealth troops would pull the aircraft into a tight inner perimeter to defend them. Each morning, the airfield would be cleared of remaining Japanese forces and flight operations would resume.[63]

The Allied defenders were able to use this method as the tightly parked aircraft were safe at night from air attack. During this campaign the Japanese air force had been reduced to virtual impotence and accurate tactical bombing at night was still an unknown.

---

[59] Kreis, *Air Warfare and Airbase Air Defence,* p 208.
[60] *Ibid.*, p 211.
[61] *Ibid.*, p 211.
[62] *Ibid.*, p 208.
[63] Shlapak, D.A. and Vick, A., *Check Six Begins on the Ground,* RAND Corporation, Santa Monica, 1995, p 28.

World War II Conclusions

World War II was arguably the first major conflict in which air power proved decisive in the outcome of wider campaigns. The aircraft themselves matured into potent fighting machines with order of magnitude improvements in firepower, accuracy, range and reliability. Accordingly, the airbase took on a far greater relevance as a target, and airbase attacks were prosecuted with vigour in all theatres.

Defence of the airbase also matured. The principles of layered and mixed defence took over from one based solely on the use of active defences such as guns and airborne fighters. The vulnerability of airbases to ground and air attack was evident for the first time as bomber aircraft and penetration style Special Forces tactics were developed and improved. It quickly became apparent that airbases could be neutralised by attack. Radar was developed and the importance of early warning in providing air defence was established.

However, if the attention of the attacker was diverted elsewhere, the integral ability of the airbase to recover would enable it to do so. A combination of active defences, passive defences and a recovery capability could ultimately keep the airfields operational whilst inflicting often unacceptable casualties on the attacker.

KOREA

Availability of Airstrips for UN Jet Aircraft

Unlike earlier propeller driven aircraft, which were operated quite successfully from unimproved dirt strips of moderate length, jet aircraft require long runways capable of withstanding severe impact forces from high aircraft ground pressures. The expanded requirement of modern tactical aircraft for quality pavement surfaces was first encountered during the initial USAF operations in the Korean War. The F-80 Shooting Star was fielded by the USAF as a superior machine to the propeller driven fighters it had replaced; however, it required longer, wider runways which were capable of withstanding the increased ground pressures of the new jets.[64]

High speed jet aircraft with their smaller wheels increased tyre pressures from the World War II maximum of 80 psi to 200 psi. They also landed at generally higher speeds and in some cases had greater all-up weights. Furthermore, their jet engines could be vulnerable to damage caused by ingesting foreign material lying on the movement surfaces. Construction of airfields to these new specifications required three times the construction effort of the typical airfields of World War II.[65]

---

[64] Bahm, P.C. and Polasek K.W., 'Tactical Aircraft and Airfield Recovery', *Airpower Journal*, Vol 5, No 2, Summer 1991, p 43.

[65] Stewart, J.T. (Ed), *Airpower the Decisive Force in Korea*, D. Van Nostrand, Princeton, 1957, p 232.

When the few airfields on the peninsula capable of handling these aircraft were overrun by the 1950 North Korean initial offensive, the F-80 squadrons were required to operate from airfields in Japan. This significant increase in staging range impacted upon the ability of these high performance aircraft to influence the war. Even in Japan, there were only four runways capable of supporting combat-loaded jet fighters.

Of the six airfields in South Korea earmarked for improvement to jet standard, the North Koreans captured three and one was subsequently assessed as being unable to be immediately improved.[66] This left US Engineers with two potential airbases — Pohang and Taegu. Although Perforated Steel Planking (PSP) matting strips were quickly laid at both fields, the short time frames allocated to the engineers and the unsuitable nature of the sub soil at both sites meant that 'it became evident to General Partridge [Commander, US Fifth Air Force] that the only aircraft which he could base in Korea during the immediate future would be Mustang fighters'.[67] Accordingly, the UN forces were denied the land based air power which was theoretically available to them, by a combination of enemy action and the under-developed infrastructure of the region; an enduring lesson for future joint force commanders planning air operations in an under-developed region.

Figure 2.3 The Korean Peninsula Showing some of the Major Airbases

[66] Futrell, R.F., *The United States Air Force in Korea,* Duell, Sloan and Pearce, New York, 1961, p 103.
[67] *Ibid.*, p 104.

Basic environmental health problems also affected the ability of the UN air forces to operate. During the second half of 1950 the UN forces suffered from poor housing, poor field hygiene resulting in infection and disease, scarce potable water and frequent occurrences of spoilt or contaminated food.[68] Maintenance facilities and other base infrastructure were also slow to be improved and this directly affected mission generation and operability rates.

UN Counter Air Operations against the North Korean Air Force

Early in the air war, the North Korean Air Force and its major airbases were quickly destroyed by UN air power. North Korean Yak piston engined fighters were all destroyed in the first few weeks.[69] In fact, UN air superiority was quickly established over the whole theatre and 'the Reds came to appreciate the fact that they could not repair airfields and reconstitute an air force in an area dominated by United Nations Air Forces'.[70]

As a result, the majority of the North Korean and Chinese 'volunteer' aircraft operated from airbases within China itself. Located just north of the Yalu River these aircraft were able to mount 'hit and run' raids into North Korea throughout the area south of the Yalu known as 'MiG Alley', a roughly triangular area bounded by Chosan, Sinuiji and Chonju. These Manchurian bases were denied to the UN forces as targets by the political decision not to allow air strikes into Chinese territory. In early 1951 'there were 445 MiGs operating from the political sanctuary of airbases beyond the Yalu'.[71] 'For two years F-86 pilots patrolling MiG Alley stared across the Yalu at four major Communist airfields, Tapao, Antung, Tatungkou and Takishan, where hundreds of gleaming MiG-15s presented a magnificent target — but on the other side of the river.'[72]

By 1953 the odds were further stacked against the US. In January 1953 the Americans still only had 176 F-86s facing almost 700 MiGs operating from Chinese airfields. The situation worsened yet further when intelligence reported Il-28 bombers, exported from the Soviet Union, had been stationed in Manchuria. These formidable aircraft posed a unique threat to US airbases in the theatre and could even strike directly at Japanese and Okinawan airbases from Chinese territory. The new US president Eisenhower was aware of this threat and one of the first concerns he brought to the National Security Council was the need for for better dispersal of UN aircraft in Korea. Allied aircraft were concentrated on painfully few airfields, none of which had the space or engineering capacity to expand. Accordingly, requests were again placed to strike at the Chinese airfields, the Joint Chiefs still reluctant to grant it.[73]

---

[68] Cooling, *Case Studies in the Achievement of Air Superiority,* p 457.
[69] Hastings, M., *The Korean War,* Michael Joseph Ltd, London, 1987, p 307.
[70] Futrell, *The United States Air Force in Korea,* p 636.
[71] Hastings, *The Korean War,* p 310.
[72] Stewart, *Airpower the Decisive Force in Korea,* p 41.
[73] Crane, C.C., 'To Avert Impending Disaster: American Military Plans to use Atomic Weapons During the Korean War', *Journal of Strategic Studies,* Vol 23, No 2, June, 2000, pp79-82.

However, this enormous advantage did not stop the North Koreans from trying to establish airbases within North Korea itself. During a routine reconnaissance mission of enemy air facilities on 25 September 1951, it was discovered that the North Koreans were well advanced in building a major airbase near Saamcham. Further investigation revealed it was merely a single component of a group of three fighter-capable fields all within 20 miles of each other. These bases posed a major threat to UN air operations in the region. If the airfields could be completed and utilised by MiG fighters they would extend 'MiG Alley' further south to Pyongyang. 'If MiGs were dispersed within the revetments being built at the [airfields], rooting them out would be a bloody, costly business.'[74] Accordingly, the UN forces targeted the airfields immediately for day and night time B-29 attacks. Given the ability of the UN aircraft to revisit these smashed bases, the North Koreans realised the hopelessness of the situation and limited their repair efforts to a few key bases.

However, before the near-truce of June 1953 the North Koreans devoted considerable effort to repairing airfields that had, since 1951, been rendered unusable by heavy damage. Since the movement into theatre of additional forces was to be prohibited during the truce, their intention was to repair the airfields and then in the last hours before the truce was signed, fly in as many aircraft as possible. Understanding the communist plan, the UN forces undertook the Joint Airfield Neutralisation Program (JANP) which aimed to keep unserviceable 35 critical North Korean airfields. The objective was to keep runway surfaces shorter than the 3,000 feet required to land a MiG-15. By 23 June all but one of the targeted airfields had been neutralised despite bad weather delaying the operation. [75]

Airbases are not only vulnerable to the direct effects of the guns and bombs of attacking aircraft. Unique regional or local features can complicate the vulnerability assessment of an airbase. This concept was illustrated during the JANP with attempts by UN forces to destroy two of the airfields by flooding them with water. The water was to be released by bombing nearby irrigation dams at Toksang and Kusong. However, the North Koreans were able to gradually release water from the dams as damage was done, thus preventing the catastrophic release of water required to flood the airbases. This attack methodology illustrated the concept that airbases should never be viewed as island bastions and their defence/vulnerability assessment should always encompass their surroundings.

Following the failure of the truce negotiations, UN air forces were directed to continue attacks on North Korean airbases ensuring that each could be fully neutralised in four to five days, if the need arose. As the winter weather set in throughout July 1953, only Bomber Command could continue regular operations against the North Korean airbases. Discovering through photo-reconnaissance that the North Koreans were quickly able to repair damage done by 100 pound bombs, the Bomber Command B-29 shifted to using heavier 500 pound bombs. The logic being that 'the heavier bombs

[74] Futrell, *The United States Air Force in Korea,* p 376.
[75] *Ibid.*, p 637.

would penetrate deeper into soggy earth and explode a crater which the Reds would find hard to repair'.[76]

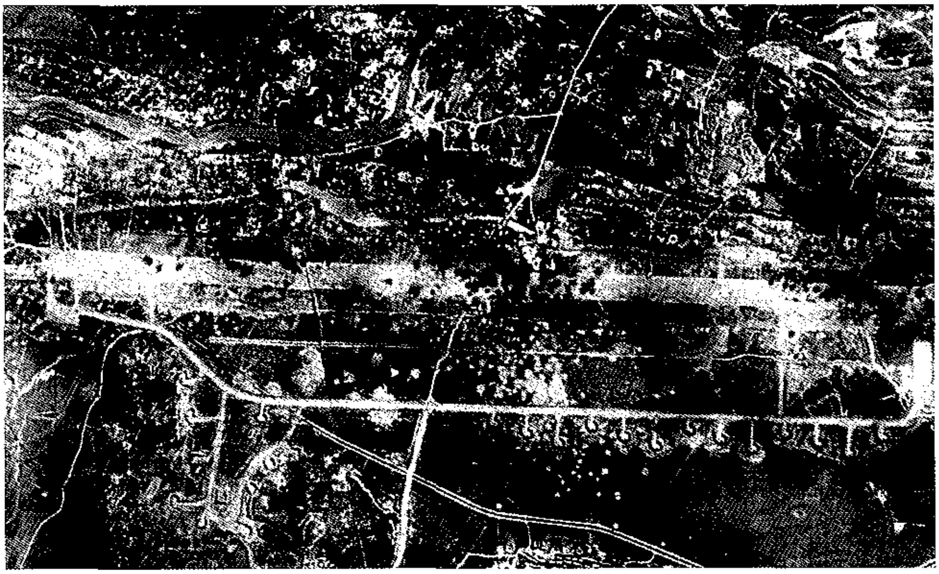

Figure 2.4 Sunan Airfield Showing Severe Damage (USAF Photograph)

Unfortunately, when clearer weather permitted more aerial photo reconnaissance to be undertaken it was found that the North Koreans had made considerable progress in repairing critical airfields. The concrete strip at Namsi and up to five other airfields had all been repaired. Forty-three MiGs had been flown into Uiji and were parked in revetments, whilst 21 other aircraft were parked in the dispersal areas at Sinuiju. The considerable rough field capabilities of the MiG aircraft assisted the North Koreans, Uiji for example having a sod runway.

Following news on 19 July than an armistice may again be imminent UN aircraft launched another wave of attacks on North Korean airfields. Both fighter and bomber aircraft attacked the aircraft operating surfaces and parked aircraft, destroying many of them. By 27 July it was clear that all the North Korean airfields were again closed to jet aircraft. Sabre fighter-bomber strikes were used against the MiGs in revetments at Uiji with no less than 21 being destroyed. This perhaps demonstrated that revetments, although providing some degree of protection, could not protect parked aircraft indefinitely against a determined attack by a well armed foe with air superiority.

[76] Futrell, *The United States Air Force in Korea,* p 638.

However (as was also to be demonstrated in Vietnam), keeping the enemy airbases closed required repeated strikes and frequent photo-reconnaissance.

Following the armistice on 27 July it was revealed that during the inclement weather in early July the Communists had flown approximately 200 aircraft into Uiji and towed most of these planes up the hard surfaced highway between Uiji and Sinuiji.[77] Although many were damaged, these aircraft were parked in dispersal points in the fields and hills surrounding the highway where they survived as an initial North Korean air order of battle going into the armistice.

Korea Conclusions

Korea was the first major conflict fought with relatively high performance aircraft with unforgiving airfield support requirements. Accordingly, the ability to operate these aircraft from the limited number of suitable strips available to either side was crucial to their ability to influence the war. Had the North Koreans and Chinese continued to operate aircraft of World War II vintage they may have been able to build and utilise improvised strips. This could have significantly complicated the UN offensive counter air attempts, although potentially at the cost of rendering them near ineffective in the air.

Korea also demonstrated some new techniques and options that would be used in many subsequent conflicts where a lesser developed or equipped nation would be at war with an advanced air power. The use of political sanctuaries contributed significantly to the Communist ability to maintain an aircraft presence over the battlefield. The Koreans mastered the art of deception, with considerable effort being devoted to confusing UN attempts to ascertain how successful their campaign had been. They effectively employed dispersal, ensuring that despite heavy Allied bombing of all North Korean airbases actual aircraft losses on the ground were quite low.

Despite being fought with weapons and tactics similar or identical to those at the end of World War II Korea demonstrated the way ahead for airfield attack. Using modern aircraft, airfields could be bombed into temporary uselessness when required. However, these airfields could also be repaired just as quickly. Airfields can be shut down but to keep them shut requires constant revisiting. The continuous counter air campaign of the Allies prevented the North Korean Air Force from having an impact on the ground war. Destruction of their airbases and the need to intercept the Allied bombers limited them to air-to-air operations only. In this way the two year long 'Battle of the Airfields' contributed significantly to the broader Korean Campaign.[78]

[77] *Ibid.*, p 640.
[78] Stewart, *Airpower the Decisive Force in Korea*, p 59.

THE ARAB–ISRAELI WARS

The Arab–Israeli series of wars began in 1948 and are effectively still continuing with current Israeli operations in Lebanon. These wars have been punctuated regularly with a broad spectrum of air operations, including a large number of attacks on airbases during Offensive Counter Air (OCA) operations.

The first such conflict was the Israeli War of Independence — fought during 1948. Air forces during this period, on both sides, were very limited and no accounts of significant attacks on enemy airbases can be found.

1956 — The Sinai Campaign/The Suez Affair

During 1956, Egypt, in a show of nationalism and strength against Britain and France, nationalised the Suez Canal, which had been previously controlled by its former colonial rulers. Combined with an Israeli move into the Sinai and the supposed threat both belligerents posed to commerce through the Suez Canal, this caused France and Britain to issue both sides with an ultimatum to withdraw. Egypt refused and the French and British began attacking Egypt by air on 31 October 1956.

By October 1956 the EAF had built up a sizeable air force including 80 MiG-15s, 45 Il-28s, 82 Meteors and Vampires and 200 other aircraft. Although Israel had also developed a sizeable air force, the 1956 air war was dominated by French and British aircraft and their attacks on Egypt.

The first attacks were night air strikes against Egyptian Air Force (EAF) airfields. Using high altitude bombing meant the accuracy was quite poor and many of the EAF aircraft survived, despite having no protective revetments. British and French fighter-bombers followed up these initial attacks with daytime raids on 1 and 2 November. 'By morning of November 2 the EAF had largely been destroyed on the ground, never having struck inside Israel.'[79] British and French authorities were claiming that 105 EAF aircraft had been destroyed on the ground by noon on 1 November.[80] Of the remaining aircraft, only 20 Il-28 bombers did not flee to neutral countries. These were based at Luxor and were subsequently destroyed by a French F-84F strike on 4 November. The EAF airfields, despite many of them being of considerable size with redundant runways, were heavily bombed and in most cases closed.

An attack by Royal Navy aircraft on MiG-17s stationed at Almaza demonstrated the usefulness of camouflage. Of the MiGs stationed at the airfield, eight were placed under camouflage netting near some hangers and were missed in the first round of attacks. These aircraft were destroyed in later raids, but they would have survived had they been moved after the first attack. This demonstrated the short-term protection even the simplest deception measures can provide.

[79] Kreis, *Air Warfare and Airbase Air Defence*, p 302.
[80] Cooling, *Case Studies in the Achievement of Air Superiority*, p 572.

The attacks demonstrated the success that can be achieved against air forces on the ground. The combination of Anglo-French air superiority (which was never contested by the EAF) and a total lack of protection for parked aircraft ensured their destruction. Observing the success of these attacks, IAF planners would ensure their own plans for pre-emptive strikes on Arab air power were well developed and kept current should the need arise.

The Anglo-French air operations had been launched from aircraft carriers in the Mediterranean Sea, airbases in Cyprus and Malta, and from IAF bases in Israel. The vulnerability of the coalition aircraft, particularly at Nicosia and Akrotiri in Cyprus, was noted, but little appears to have been done about it on the ground, despite photo reconnaissance sorties showing Egyptian bomber and fighter aircraft deployed to nearby Syrian airbases. General Sir Charles Knightley, Allied Commander-in-Chief, emphasised the vulnerability of the allied aircraft on the ground by pointing out 'the effect of even a couple of MiGs, flown perhaps by Russians, flying over Nicosia with a load of rockets' could have.[81] Photo-reconnaissance missions were continued, but aerial photos of the Cyprus fields show lines of British and French aircraft parked in the open with no attempt made to protect them. Ultimately, no Arab air attacks on these airfields were mounted. However, on 10 November 1956 EOKA terrorists infiltrated the Nicosia airbase and placed a 'time bomb' on a 1 Squadron Hunter fighter. This aircraft was damaged beyond repair.[82]

During this campaign the Egyptian El Gamil airfield was the target for an airborne assault by paratroopers of the British 3rd Parachute Battalion. The airfield had been comprehensively blocked by sand-filled oil drums to prevent unauthorised aircraft from landing, however, these obstacles provided handy cover for the paratroops.[83] After a thorough pre-assault attack by carrier aircraft, 600 paratroops jumped into the airfield after dawn on 5 November, followed by heavy equipment including anti-tank guns. The airfield was cleared of all substantial opposition within thirty minutes and the airfield was clear to accept aircraft by midday.

At the end of this conflict, although Egypt had been militarily defeated, the UN ordered a British, French and Israeli withdrawal from the disputed territories. Egypt began rebuilding its armed forces and repairing its damaged facilities. Over 40 EAF aircraft which had been flown out of the country (mainly to Syria and Saudi Arabia) during the attacks returned.[84] This is an example of the effective use of political sanctuaries to protect aircraft from attack by a superior air power that would be also seen in Korea and Vietnam, and also during the 1991 Gulf War, though not so effectively. The principal conclusion that can be drawn from this conflict is again that aircraft parked in the open can be destroyed easily with modest resources.

[81] Cull, B., *Wings over Suez,* Grub Street, London, 1996, pp 237.
[82] *Ibid.*, p 341.
[83] Barker, A.J. *Suez: The Seven Day War,* Faber and Faber, London, 1964, p 117.
[84] Cull, *Wings over Suez,* pp 356-358.

1967 — The Six Day War

During the early 1960s, the Soviet Union supplied the Arab states bordering Israel with a large amount of military hardware and training support. The EAF had benefited the most from this patronage and had built up a substantial air force, consisting of approximately 450 aircraft and 25 bases.[85] April and May 1967 saw a deterioration in the already unfriendly diplomatic relationship between Israel and the Arab states. Provocative Egyptian troop movements and their closure of the Gulf of Aqaba to Israeli shipping on 22 May ensured that war would result. President Nasser of Egypt fully expected war would start no later than 5 June 1967 and was advised that in the event of an Israeli pre-emptive air strike Egypt would suffer only 10 per cent attrition.[86]

The Six Day War began on the morning of 6 June 1967 with Israeli Air Force strikes on EAF airbases. The Israelis had carefully studied the British and French attacks on Egypt during the earlier Suez campaign and had noted the unsuccessful use of medium altitude night bombing. Therefore they determined to undertake their attacks during daylight and at low-level. The low-level flight profiles flown by the Israelis required high fuel consumption rates and accordingly light ordnance loads. Bombs were used to close the runways temporarily, keeping the Egyptian aircraft on the ground and making them easy strafing targets.[87]

Once again the EAF was totally unprepared for such an attack and no precautionary measures had been taken to defend airfields or protect aircraft. In the first wave of attacks 200 EAF aircraft were destroyed, with follow up sorties undertaken to strike at EAF bases in the west and south of the country.[88] Three hundred Egyptian aircraft were destroyed on that first day. The effective destruction of the EAF was then exploited by the IAF who attained immediate air superiority and were able to prosecute vigorous close air support and interdiction missions in support of Israeli ground forces. In total 451 Arab aircraft were destroyed in the first two days, of which only 58 were lost in aerial combat.[89] Several EAF aircraft which did manage to get airborne during the initial attacks and survive the ensuing air-to-air combat were destroyed after crashing whilst attempting to land on damaged runways.[90]

Defence of the EAF bases was inadequate, and virtually all the EAF aircraft were lined up in neat rows. One step that had been taken by the Egyptians was the placement of many aircraft dummies on the airfields to confuse attacking pilots. These dummies were generally ineffective because of their lack of realistic deployment and advances in Israeli aerial photography techniques. They were parked in unlikely

[85] Kreis, *Air Warfare and Airbase Air Defence*, p 307.
[86] *Ibid.*, p 311.
[87] Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, p 12.
[88] Mason, R.A., 'Air Power as a National Instrument: The Arab Israeli Wars' in Stephens, A., (Ed), *The War in the Air 1914-1994*, Air Power Studies Centre, Canberra, 1994, p 187.
[89] Kreis, *Air Warfare and Airbase Air Defence*, p 317.
[90] Cooling, *Case Studies in the Achievement of Air Superiority*, p 578.

locations and the ground under them did not bear the characteristic fuel and exhaust stains of a working jet tarmac.[91]

This campaign was also the first in which dedicated runway attack munitions were used. A bomb was used that employed retro-rockets and a parachute to slow itself after a low-level high speed deployment. The parachute orientated the weapon so it faced the ground at a high impact angle and a rocket motor in the tail propelled the warhead through the runway surface. The warhead then detonated under the runway surface causing the maximum sized crater possible. Delay fusing was also utilised to prevent runway repair crews from approaching impact sites safely.[92] Despite this, most runways were repaired quickly by dedicated crews, although the initial aircraft losses on the ground could not be overcome.

Ultimately, doctrinal and performance surprise contributed greatly to the Arab defeat in this conflict. The Egyptians knew an attack was coming but failed to anticipate how destructive it would be. When the attacks started the Egyptian high command was isolated from its units and subordinates failed to take the initiative and respond accordingly.

1973 — The October War (The Ramadan or Yom Kippur War)

On 5 October 1973, following months of tension and skirmishing, Egyptian and Syrian aircraft attacked Israel as a prelude to a major ground offensive. One of the initial offensive actions by the IAF was to attack the forward EAF airfields from which they were mounting ground support attacks in support of the Suez Canal crossing.

However, the EAF had learnt the lessons of 1967 and dramatically improved the resilience of its airbases. Hundreds of concrete hangers had been built and additional runways added to provide redundancy.[93] Egypt had built over 1,000 hardened aircraft shelters and complemented these with underground fuel storage and hardened command and control and anti-aircraft installations. During the war the IAF only managed to destroy a single Egyptian hardened aircraft shelter. These facilities gave excellent protection and could not be destroyed with the 500 pound unguided bombs or Maverick missiles available to the Israelis. The Arabs also improved their taxiways and nearby roadways to serve as additional runways. Only 21 Arab aircraft were destroyed on the ground in this conflict, an amazing contrast to 1967.[94] Comparative figures from another source are presented at Table 2.1.

[91] Kreis, *Air Warfare and Airbase Air Defence,* p 316.
[92] Cooling, *Case Studies in the Achievement of Air Superiority,* p 578.
[93] Cohen, E., *Israel's Best Defence,* Airlife Publishing Ltd, Shrewsbury, 1994, p 350.
[94] Kreis, *Air Warfare and Airbase Air Defence,* p 341.

	1967	1973
IAF sorties against airfields	490	468+
Arab aircraft destroyed on the ground	370	22
IAF losses in airbase attacks	19	7
IAF Kill-to-loss ration	19:1	3:1

Table 2.1 Comparison between Israeli Airbase Attacks in 1967 and 1973[95]

These improvements, combined with the lack of surprise and improved Egyptian anti-aircraft defences, reduced the success of the IAF attacks during 1973. Kotmiya airfield was shut down for two days following repeated attacks, and Mansura airfield was closed for six days, seven MiG-21 aircraft also destroyed on the ground. Despite the low number of Arab aircraft destroyed, the Israeli attacks were successful in greatly limiting the number of sorties the Egyptians could generate.[96]

The initial Egyptian attacks on IAF airbases also caused considerable damage. Bir Gifgafa airfield had five craters blown in its main runway, which took over four hours to repair. The control tower was also destroyed. Israeli aircraft landing at Ras Nasrani had to dodge craters and debris with the landing gear of one F-4 aircraft being damaged.[97]

Arab–Israeli Wars Summary

The Arab–Israeli Wars were important in the history of air-to-ground warfare as they demonstrated the potential use of aircraft in the future — fast jets attacking at low-level deploying a variety of specialist weapons using accurate aiming systems. Aircraft parked on airfields were shown to be even more vulnerable targets than they had been during World War II. The frantic building of hardened aircraft shelters in Europe on both sides of the Iron Curtain was a direct result of the Israeli successes during that campaign. The results of this operability enhancement program are directly visible in the widely differing number of Arab aircraft destroyed on the airfields. Air forces that did not improve the defences and survivability of their airfields could not expect the aircraft based there to survive the first days of conflict.

INDIA–PAKISTAN WAR OF 1965

The 1947 partitioning of India to form primarily Muslim Pakistan and Hindu India resulted in ongoing religious tension that finally erupted into a short war in 1965. Air forces made a considerable contribution to this conflict and both sides undertook

[95] Cordesman, A.H., and Wagner, A.R., *The Lessons of Modern War Volume I: The Arab-Israeli Conflicts, 1973-1989*, Westview Press, London, 1990, p 96.
[96] Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, p 45.
[97] Kreis, *Air Warfare and Airbase Air Defence*, p 327.

aggressive offensive counter air campaigns as part of a broader strategy to obtain air superiority.

Offensive Counter Air Operations

As with the Arab–Israeli Wars, attacks on airfields began on 6 September 1965, the very first day of the conflict, with Pakistani aircraft attacking Indian airbases at dusk. This was followed by night raids by Canberra bombers of both sides. The highly limited avionics and navigation systems of all the aircraft in this war ensured that night attacks were never executed with any great success. In fact, Air Vice Marshal Yusaf, at the Pakistani Air Headquarters recalled that 'the biggest hazard of the night war was the traffic hurtling around the roads without lights in the total blackout'.[98]

Before full-scale conflict started on 6 September the Pakistani Air Force had pre-planned to open hostilities with a coordinated series of airbase attacks designed to neutralise the forward enemy airbases. Low-flying aircraft had conducted reconnaissance, but the limited resources available seriously compromised the strikes. Only three airfields were targeted in the initial strikes and only one, Pathankot, was actually struck, with Indian fighters, poor visibility and lack of available Pakistani aircraft preventing the others from being successfully attacked.

However, daytime fighter-bomber strikes were to become a commonplace occurrence during this short war. Regular raids by both sides were mounted in an attempt to destroy aircraft and facilities and to hole runways. Very limited success was achieved in the latter aim, due to the use of instantaneous fusing on the bombs causing them to detonate on the runway surface rather than penetrating first.

Much use was made by both sides of camouflaged revetments to protect aircraft. In many cases these revetments provided a great deal of protection and it was the aircraft parked in the open, particularly on ready alert pads, which suffered the most from these attacks. Anti-aircraft defences were generally very light and in most cases ineffective allowing the raiding fighters opportunity to strafe and bomb at leisure, dependent mainly on the limited fuel reserves of the short range aircraft used.[99]

Airborne Operations

Bombing missions were only one component of Pakistani airbase attack plans. Air assault using either airborne (parachute) forces or actually landing Hercules transports full of commandos on enemy airfields were considered. It was decided though that a night-time airborne operation against three Indian airfields stood the greater chance of success.

The mission appears to have suffered greatly from lack of resources and an almost total lack of planning. Sixty commandos were to be dropped at night over each of three Indian airfields, Adampur, Helwara and Pathankot with the intention of killing

[98] Fricker, J., *Battle for Pakistan: The Air War of 1965*, Ian Allen Ltd, London, 1979, p 138.
[99] *Ibid.*, pp 93-100.

or destroying any enemy personnel or vital equipment they could encounter. Once they had achieved their mission they were to make their way, using whatever means that could be found, back to the India-Pakistan border.

Not surprisingly the missions were a total failure. Dropped on the night of 6/7 September approximately three kilometres from their target airfields the vast majority of the commandos never reached their objectives. Only one or two small groups found targets worth attacking, the rest of them being engaged by airfield defences or nearby Indian Army troops. Of the 180 paratroops used in this operation only 13 were able to return to Pakistani lines, the remainder being killed or captured.

Following this debacle, the Pakistanis were very alert to the possibility of Indian forces attempting a similar action. Tension built up until the night of 8 September when rumours culminated in a general alert being issued at all Pakistani airbases near the border. At Sargodha airbase, the base commander reported to Air Headquarters that his facility was under attack and a Hercules load of Pakistani Army troops were immediately despatched to provide reinforcements. The aircraft landed at Sargodha without lights, disgorged its load of troops onto the runway and immediately took off again. Poor communication appears to have been the norm and these reinforcements were then engaged by an airfield sentry resulting in a three hour long fire-fight. When dawn arrived it was discovered with considerable embarrassment that not a single Indian paratrooper had existed.[100]

VIETNAM

Vulnerability of US Airbases to North Vietnamese Air Attack

During the Vietnam Conflict the US deployed a large number of aircraft into the theatre. The lack of quality airfields forced the US forces to begin extensive construction programs. The airfield at Tuy Hoa was expanded by contractors who initially built a 9,000 foot aluminium matting runway and then a 9,500 foot concrete one. During this time various support facilities such as taxiways, fuel and ammunition storage and communications facilities were also built. Despite having a 1,300 strong work force the task took nearly 12 months to complete.[101]

Given the lack of offensive capability possessed by the North Vietnamese Air Force (NVNAF) the principal form of attack used against these US targets was by land forces. The rapid growth of US air power in the region quickly stretched the capability of the limited number of suitable airbases to accommodate them. In 1965, one of the principal US airbases, Da Nang, would have presented the North Vietnamese a very tempting target. Large numbers of aircraft were parked together on unprotected hard

[100] Fricker, *Battle for Pakistan: The Air War of 1965*, pp 105-108.
[101] Bingham, P.T., 'Operational Art and Aircraft Runway Requirements', http://www.airpower.maxwell.af.mil/airchronicles/apj/apj88/bongham.html accessed 21 January 1999, p 4.

stands, fuel tanks were exposed, the ordnance storage area was packed very much in excess of its safe limit, plus the normal collection of support facilities.[102] To defend this, the Americans emplaced Hawk missile batteries and interceptor aircraft. Although these defences would have taken a heavy toll of any North Vietnamese air attack, US planners remained concerned by the threat.[103] However, no NVNAF air attack on US airbases was ever attempted.

North Vietnamese Army and Viet Cong Ground Attacks on US Airbases

During the period 1964–73 Viet Cong (VC) and North Vietnamese Army (NVA) forces attacked USAF Main Operating Bases (MOBs) 475 times destroying 99 US and South Vietnamese aircraft and damaging a further 1,170. More ground attacks on airbases were recorded during this conflict than in any other. Attacks against smaller bases and forward operating locations raised the total number of US and allied aircraft destroyed to 375.[104]

At the beginning of the conflict airbase security and defence was notoriously lax. Most main operating bases were unfenced and very lightly defended. Local South Vietnamese security procedures and access control was similarly poor. This made these bases, which rapidly began to swell with large numbers of expensive advanced US aircraft, tempting targets. Given the strategic objective of the North Vietnamese to wear down the American support for the war through constant attrition and adversity, small-scale attacks on airbases were appropriate.

An early attack on Bien Hoa airbase demonstrated the destructive effect a small party with good infiltration skills and intelligence can have. Shortly after midnight on 1 November 1964 a small party infiltrated to within 400 metres of the base perimeter fence with six 81 millimetre mortars. They fired 83 rounds onto the airfield, directing the fire at B-57 bombers parked wing-tip to wing-tip. Five B-57s were destroyed, eight received major damage and seven received light damage. An entire B-57 squadron was taken out of action and the attacking party was able to escape without loss.

Attacks using standoff weapons such as rockets and mortars accounted for 96 per cent of ground attacks on main operating bases in Vietnam.[105] Eventually, from 1968 onwards, the success rates for these attacks began to fall as more effective countermeasures were employed. Subsequently, following 1970, the success rates again climbed as the NVA and Viet Cong forces learnt from their mistakes and adopted better tactics. Figure 2.5 shows the percentage of ground attacks by year that actually succeeded in destroying or damaging aircraft.

[102] Kreis, *Air Warfare and Airbase Air Defence*, p 279.
[103] *Ibid.*, p 279.
[104] Vick, *Snakes in the Eagle's Nest*, p 68.
[105] *Ibid.*, p 68.

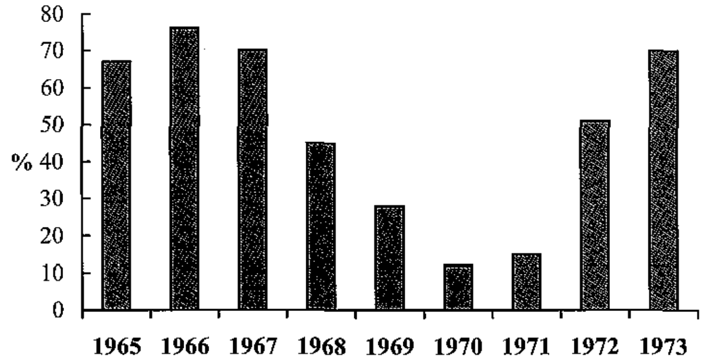

Figure 2.5 Attack Success Rate Against Main Operating Bases, 1965–1973[106]

Ground Attacks on RAAF Aircraft

During the Australian involvement in Vietnam, RAAF aircraft came under fire on several occasions. During the 1968 Tet offensive a 35 Squadron Caribou came under mortar fire at Kontum, one round landing less than 70 metres from the aircraft. The following day at Ben Het the same aircraft was fired upon by a recoilless rifle. On 23 April 1968 Australian and US aircraft at Vung Tau came under attack from enemy rocket and recoilless rifle fire. One of these rounds skimmed the roof of the RAAF working area and destroyed an American Caribou which was parked 60 metres from the nearest RAAF office block.[107] Stand-off attacks against Vung Tau were repeated at irregular intervals with casualties (although no Australians) inflicted each time.

During 1969 RAAF aircraft were again attacked, with Caribou A4-208 being bombarded by mortar fire at Katum. The aircraft was damaged by several near misses and both crew members were slightly wounded. The aircraft made an emergency evacuation and was able to land at Bien Hoa without further incident. Aircraft A4-191 was also attacked by mortar fire at the same base in May of that year.

During March 1970, Caribou A4-193 was unloading fuel drums at That Son when it came under 'an intensive and very accurate mortar attack from the hills overlooking the base'.[108] The aircraft received a direct hit and was set on fire. The crew abandoned the aircraft taking cover in a ditch before moving to a bunker. The barrage continued for three hours and began again early the next morning. Further hits destroyed the aircraft. The base itself was also substantially damaged with the fuel dump being destroyed.

[106] Vick, *Snakes in the Eagle's Nest*, p 71.
[107] Coultard-Clark, C.D., *The RAAF in Vietnam*, Allen & Unwin, St Leonards, 1995, p 122.
[108] *Ibid*., p 124.

Mortar fire was again targeted at a 35 Squadron Caribou whilst taxiing at Tra Vinh on 19 May 1970. In this case the aircraft was able to quickly embark the waiting passengers and leave the airfield before it could be hit.

Vietnam also demonstrated the difficulties of operating aircraft from poor quality airstrips, even for aircraft specifically designed for these tasks. In October 1968, near Da Lat, Caribou A4-210 was extensively damaged when a ditch edge collapsed. Although repairs were carried out in country, the aircraft never flew satisfactorily after the incident and had to be returned to Australia for repairs.[109]

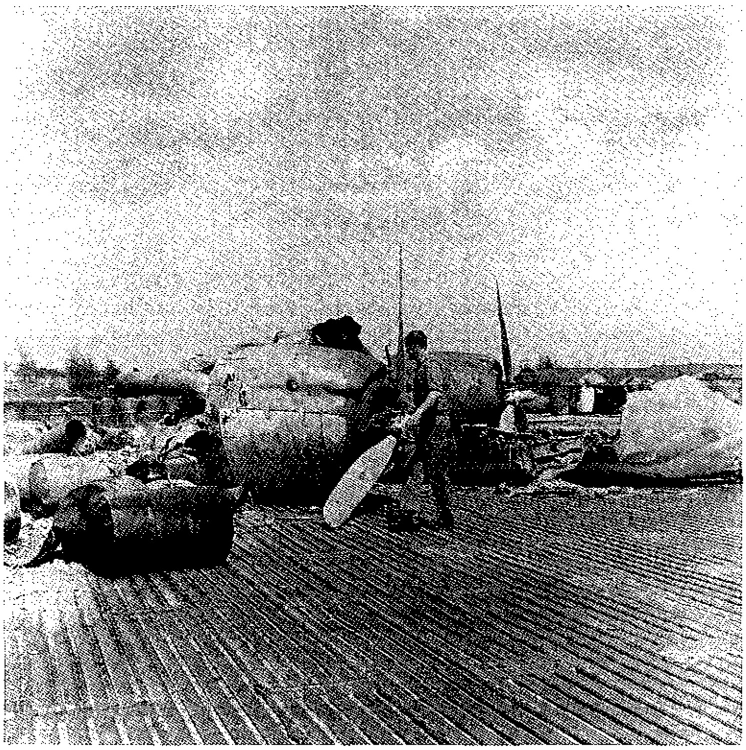

Figure 2.6 The Remains of a RAAF Caribou Aircraft following the That Son Mortar Attack (AWM Photograph VN/70/18/6)

US Offensive Counter Air Operations Against the North Vietnamese Air Force

Prior to the Gulf of Tonkin incident, the NVNAF had no combat aircraft, possessing only training and transport aircraft. However, in August 1964, MiG-15 and MiG-17 aircraft began appearing on North Vietnamese airfields, having been supplied by China.

[109] Strugnell, T., 'Wallaby Airlines – First Squadron in, Last Squadron Out', *Air Force Today*, 2 September 1999, p 5.

Between 1962 and 1964 the North Vietnamese, with Soviet and Chinese assistance, developed their Air Force. Four airfields in North Vietnam were developed to handle combat jet aircraft; these were Phuc Yen, Gia Lam, Kep and Kien An. Nine other airfields were capable of handling propeller driven aircraft. Until mid-1965 the USAF assessed the aerial threat posed by the North Vietnamese Air Force as tolerable and it was not until late 1966 that they were considered as having had an 'appreciable success in harassing our aircraft'.[110] Some of the smaller NVNAF bases had been attacked and closed by American and South Vietnamese air attacks in 1965 but these had little effect on the primary threat — MiG jet fighters. Throughout the war Phuc Yen and Kep remained the primary bases for the NVNAF MiGs with the other bases used mainly for dispersal and to provide greater operating flexibility.

In March 1965 the USAF and USN began Operation *Rolling Thunder*. This program lasted over three years and consisted of a series of intermittent incremental attacks against North Vietnamese targets, including many NVNAF airbases. Despite the weight of US firepower brought to bear during these attacks, they were assessed as being largely ineffective in preventing NVNAF air operations.

NVNAF aircraft were frequently evacuated to political sanctuaries in China or other dispersal areas. Because of the intermittent nature of the *Rolling Thunder* raids, any substantial damage that was inflicted on the airfields could be repaired during the lulls in bombing. The US forces during this period also lacked the ability to bomb effectively during periods of bad weather and cloud cover, which were frequent in the region.[111]

The North Vietnamese used extensive passive defences to protect their airfields and parked aircraft. Some of the measures used included revetted parking apron located away from the airfields, buried fuel tanks, and extensive dispersal and camouflage on anti-air defences and support facilities. Many of the NVNAF's biggest bases were for large periods of the war off limits to American bombers due to their proximity to major population centres.

Beginning in April 1967 the Americans increased the pressure on the North Vietnamese government and increased the tempo of their bombing. OCA attacks on NVNAF airbases were increased and many of the restrictions placed on airbases in residential areas were removed. US anti-aircraft defence suppression weapons and techniques also improved. By the end of March 1968, virtually all of the NVNAF bases were bombed into disuse and virtually all the NVNAF aircraft were evacuated into China. It was at this stage that President Johnson called a temporary halt to bombing above the 19th parallel. The damaged airfields were then quickly repaired.

Following the North Vietnamese offensive of March 1972, a far wider ranging bombing campaign, Operation *Linebacker*, was authorised. Again the primary targets were the communist supply and transportation systems; however, far fewer targets were protected from attack by political decree. US forces had access to better weapons

[110] Kreis, *Air Warfare and Airbase Air Defence*, p 279.
[111] *Ibid.*, p 286.

in the form of laser-guided bombs and better anti-radiation missiles and electronic countermeasures.

Four main bases in the north housed the NVNAF MiG-15, 17 and 21 aircraft. These were Phuc Yen, Yen Bai, Kep and Gia Lam. Kien An, Dong Suong, Hoa Loc and Bai Thuong served as dispersal sites. During April 1972 US aircraft attacked the NVNAF bases close to the coast and in the southern areas extensively. Laser guided unitary bombs were used against runways for the first time cratering those runways targeted.[112] The ease of access to these bases by USAF and USN aircraft kept them generally unserviceable to jet traffic.

During December 1972 the Linebacker II raids continuously targeted the NVNAF bases in the north. B-52s and F-111s were used in large-scale night attacks against all of the major bases. The F-111s were particularly effective in precision night low-level bombing. However, despite the weight of firepower deployed, NVNAF operations were not shut down at any bases except Bac Mai and Yen Bai, which were only closed for a single day. Despite this, the aerial bombardment did cause heavy damage and forced the North Vietnamese to once again remove the MiG fighters to China.

Unexploded Explosive Ordnance Encountered During Aircraft Battle Damage Repair

Aircraft returning from combat operations may have sustained damage and require repair upon return to the airbase. All ammunition and ordnance when fired can be expected to produce a percentage of hits that fail to detonate or function as designed, resulting in a piece of Unexploded Explosive Ordnance (UXO). Accordingly, it has been found that some projectiles and missiles fired at aircraft have struck the target, but failed to function. The aircraft may then return to the airbase with the UXO remaining lodged within the airframe.

Vietnam was the first conflict that featured the large-scale use of Surface-to-Air Missiles (SAM). In June 1966 a US F-105 Thunderchief was struck by an air-to-air missile that failed to explode and remained lodged in the rear section of the fuselage.[113] The aircraft was able to land safely and the dangerous cargo was removed and made safe. The unstable nature of unexploded munitions can endanger the crew tasked to repair or service returning aircraft.

Vietnam Summary

US attacks against NVNAF airfields were normally successful, but rarely fully effective. Usually the most that was achieved was the destruction of supporting facilities and stores and the forced evacuation of aircraft out of the theatre. The main reasons for this included:

---

[112] Kreis, *Air Warfare and Airbase Air Defence*, p 293.
[113] USAF, *Air War Vietnam*, Arms and Armour Press, London, 1978, p 16.

- The considerable rough field capability of the MiG aircraft and their modest airstrip requirements.
- The political limitations placed on US bomb targeting.
- The dense and effective anti-aircraft defences of North Vietnam.
- The large pool of labour available to repair bomb damage.
- The proximity of sanctuary in China for fleeing NVNAF aircraft.
- The extensive use of underground facilities and widely dispersed off-base aircraft parking.

VC and NVA attacks on US and South Vietnamese airbases achieved mixed results. In terms of actual damage done, the results were quite modest compared to the ability of the USAF to replace losses. Ground attacks are credited with destroying 99 US and South Vietnamese aircraft and damaging a further 1,170.[114] As a comparison, only 92 US aircraft were lost in air-to-air action during the conflict.[115] However, consistent with North Vietnam's strategic aims, the ground attacks kept constant pressure on the US forces, inflicted casualties and ensured that American service personnel and equipment were not safe, no matter where they were in the theatre.

The Vietnam War demonstrated the potential danger posed to heavily defended airfields by standoff attacks. Despite base defences being able to generally prevent penetration attacks, standoff attacks using mortar or rocket fire were often successful, with only the limited accuracy of these attacks preventing greater damage. This demonstrated the need for hardening of airbase facilities and aircraft parking to thwart these kinds of weapons and friendly patrolling and control of the standoff weapons footprint outside the base perimeter.

ENTEBBE — JULY 1976

On 27 June 1976, West German and Palestinian terrorists hijacked an Air France 707 aircraft and directed that it be flown to Entebbe airport in Uganda. Following the release of the non-Jewish passengers from the aircraft, the Israeli Defence Force decided to undertake a long range rescue mission. A group of Israeli commandos were flown to Entebbe in four C-130 transports using two Boeing 707s as support. They landed at Entebbe airport at approximately 2300 hours on 3 July and using a variety of deception techniques were able to kill the terrorists and rescue the hostages. Several Ugandan Air Force MiG-17 aircraft were also disabled before the rescue team left.[116]

[114] Vick, *Snakes in the Eagle's Nest*, p 68.
[115] USAF, *Air War Vietnam*, p 290.
[116] Darman, P., *Surprise Attack*, Brown Books, London, 1993, pp 149-151.

The Entebbe raid is significant in the way it represents a daring and imaginative operation to attack an airbase. During the operation the Israeli forces secured the airfield and had the objective been to seize it, more forces could then have been flown in easily. The use of transport aircraft to land assault forces was pioneered by the Germans in World War II and continues to be a threat to all airbases, particularly during low-level contingencies with restrictive rules of engagement and potential confusion over security responsibilities.

THE IRAN–IRAQ WAR

OCA attacks conducted during the 1980 Iran–Iraq War are an interesting example of this form of conflict between two regional nations. Unfortunately, little of technical merit has been published in the West detailing these operations.

Both sides conducted attacks on their opponent's airbases, although the motives for both sides may have differed considerably. Iraq was supplied mostly with older Soviet supplied aircraft, and it was aware these did not have the capability to inflict serious damage on the Western supplied Iranian Air Force. The Iraqi aircraft were short-ranged and the Iranian aircraft were well protected in hardened shelters, with many of their airbases out of range from Iraq.

However, despite this the Iraqis believed that offensive air strikes would deliver a strong political message, and on the afternoon of the 22 September 1980 struck 10 Iranian airfields. Damage was light due to the small scale of the attacks, their inaccuracy and that many of the weapons failed to detonate on impact. Others hit the runway surfaces with an insufficient impact angle and did not penetrate causing shallow, easily repaired scab craters.

On following days the Iraqis concentrated their efforts and fewer airfields were attacked, with proportionately greater effect. However, the campaign ceased after less than one week with only Dezful being successfully neutralised.

In return the Iranian struck back at two Iraqi airbases on the 22 September and conducted further OCA missions for four more days. The Iranian concept of operations was based on US doctrine and directed the use of large mixed strike packages, including fighter cover and supression of enemy air defences. However, the Iraqi air defences took a considerable toll of these large attacks, partially due to poor Iranian pre-strike intelligence. Like the Iraqi campaign, these high cost missions were ceased when sufficient political mileage was seen to be obtained.[117]

[117] Berquist, R.E., *The Role of Airpower in the Iran-Iraq War,* Air University Press, Maxwell AFB, 1988, pp 56-59.

THE FALKLANDS WAR

The Falkland Islands, located in the southern Atlantic Ocean, were British sovereign territory when occupied by Argentine forces in April 1982. Responding quickly, the British dispatched a task force to recapture the islands. Following an intense battle involving air, land and sea forces the islands were recaptured, with Argentine forces surrendering on 14 June 1982.

There was only one major airfield on the Falklands Islands, located near the capital Port Stanley. It was composed of a single 4,100 foot solid bed-rock runway and some rudimentary support facilities.[118] This runway could be used by C-130 transports, and light aircraft but was assessed by the Argentines as being too short and wet for combat jets. They also considered lengthening the runway, but this option was ruled out as the existing runway was always wet, and given how heavily it was being used, time was inadequate.[119] A ship-load of airfield matting was delivered from Argentina for this purpose, but was not accompanied by the heavy equipment required to prepare the ground for its use. The extension of the runway and its use by British F-4 Phantoms immediately after the war, until the construction of the new Mount Pleasant airfield, indicate that the task was certainly technically feasible.[120] Also scattered around the islands were many grass strips suitable for use by Argentine ground attack aircraft and C-130s.

During this war there were several notable attacks on airbases — three attacks by lone Vulcan bombers on the airfield at Port Stanley, many attacks by RAF and RN Harriers against Stanley and other minor airfields, and the attack by an SAS force on Argentine aircraft parked on Pebble Island.

Vulcan Attacks on Port Stanley Airfield

At 0423 hours on the morning of 1 May 1982, a lone RAF Vulcan bomber of 101 Squadron callsign 'Black Buck 1' attacked Port Stanley airfield. The bomber, which made 17 air-to-air refuelling operations during the mission, approached at low-level before pulling up to 10,000 feet and releasing twenty-one 1,000 pound Mk83 bombs three miles from the coast.[121] One bomb struck the runway at Port Stanley, one struck the runway edge and the others landed beyond it. Some damage was done to the airfield facilities. An electronic counter-measures pod was used to defeat the Argentine air defence radar, anti-aircraft guns not opening fire until the Vulcan had

[118] Armitage, M.J., Mason, R.A., *Air Power in the Nuclear Age,* Macmillan Press, London, 1985, p 226.
[119] *Proceedings*, Naval Review, 1983, p 109.
[120] Train, H.D., 'An Analysis of the Falklands/Malvinas Islands Campaign', *Naval War College Review,* Winter, 1988, pp 38-39.
[121] Burden R.A., Draper M.I., Rough D.A., Smith C.R. and Wilton, D.L., *Falklands The Air War,* Arms and Armour Press, London, 1986, p 363.

long departed.[122] Later that morning Harriers from the Task Force also raided the airfield, the first of many such missions.

The Vulcan mission forced several changes to the Argentine deployment of air assets. Firstly, some mainland based air defence assets were relocated northwards to protect Buenos Aires from possible British attack, removing them from the battle. Secondly, it compelled the Argentines to disperse their lighter aircraft (Pucaras etc.) to smaller satellite fields that had neither sufficient air nor ground defence. This may have contributed to the success of the forthcoming SAS raid on Pebble Island. Bomb damage assessment was performed by photo-reconnaissance Harriers and showed that, despite the single crater, the strip was still available to Hercules and Pucara aircraft.[123]

The single Vulcan bomber raid was repeated at 0430 hours on the morning of 4 May, with no bombs this time striking the airstrip. All 21 of 'Black Buck 2's' 1,000 pound bombs fell to the west of the runway threshold causing no further significant damage.

In addition to the direct attacks on the airbase, another pre-dawn Vulcan mission was flown on 1 June using AGM-45 Shrike anti-radiation missiles to attack the TPS-43 air defence radar near Port Stanley.[124] The radar, which had been used to locate the British fleet by tracking Harrier flight paths, was hit but quickly repaired.[125] This mission was repeated on 3 June destroying a Skyguard fire control radar.[126]

A final Vulcan strike mission was flown against Stanley airfield on the night of 11 June. This mission used unguided airburst fused bombs and was aimed at parked aircraft and airfield facilities rather than the aircraft operating surfaces themselves.[127] The results of this raid, although not specified in detail, were assessed as being 'successful'.[128] Another account claims that there was confusion in the Vulcan over the bomb-release system and the bombs had actually detonated on impact rather than in the air as designed.[129]

Other information sources claim that there was little actual damage done to the solid bedrock runway, by either Vulcan or Harrier attacks. Argentine sources claim the attacks were mainly ineffective and that the apparent bomb damage was a deception achieved by painting craters and throwing some dirt around.[130] Another report claims the one true crater was repaired quickly and the two mock craters had been manufactured from mounds of earth. These were removed at night to allow Hercules

[122] Ethell, J. and Price, A., *Air War South Atlantic,* Sidgwick and Jackson, London, 1983, pp 52-53.
[123] Eddy, P., Linklater, M. and Gillman, P., *The Falklands War,* Andre Deutsch, 1982, p 155.
[124] Armitage, M.J., Mason, R.A., *Air Power in the Nuclear Age,* Macmillan Press, London, 1985, p 235.
[125] Braybrook, R., *Battle for the Falklands – Air Forces,* Osprey Publishing, London, 1982.
[126] Ethell and Price, *Air War South Atlantic,* pp 173-174.
[127] Armitage, M.J., Mason, R.A., *Air Power in the Nuclear Age,* Macmillan Press, London, 1985, p 238.
[128] Burden et al., *Falklands The Air War,* p 367.
[129] Middlebrook, M., *The Fight for the 'Malvinas',* Viking, London, 1989, p 246.
[130] Copley, G.R., 'How Argentina's Air Force Fought in the South Atlantic', *Defense & Foreign Affairs,* October, 1982, p 11.

transports to land.[131] Irrespective of the actual level of damage inflicted it is apparent that the strip was in regular use by C-130 transports and light aircraft throughout the conflict.

Harrier Attacks on Parked Argentine Helicopters

As a result of the Vulcan raids on Stanley the Argentines began moving their helicopter fleet to a landing field just North of Mount Kent each evening. By day they would return to Stanley and the protection of the air defences there. An SAS observation team had been watching this process and advised that an attack at first light could catch the helicopters before they were moved. On 21 May two RAF Harrier GR3s attacked the Mount Kent site with cluster weapons and 30 millimetre cannon fire. Of the 14 helicopters present, only three were damaged in the attack. According to one source, it was the camouflage applied to the Argentine aircraft that saved them. 'Greater damage would have been caused if the colour schemes of the helicopters had not merged so well with the terrain; the Harrier pilots did not see most of the helicopters.'[132]

Ground Attacks against Aircraft on Pebble Island

Before the main British landings at San Carlos there was concern over the impact that Argentine ground attack aircraft may have on the beachhead once established.[133] A substantial number of these aircraft were believed to be based on a small airstrip on Pebble Island, just north of the main island of West Falkland. The waterlogged condition of the grass airfield had prevented aircraft departures from the strip for several days. On the night of 14 May a small detachment of British SAS troops, with a Naval Gunfire Support (NGS) team, attacked these aircraft using a combination of demolition charges and NGS. Demolition charges were also used to make the airfield unusable, three craters carefully placed at the intersection of the two runways.[134] Argentine defence of the aircraft was almost non-existent with the garrison sheltering from the cold night winds in a group of sheds nearly a kilometre from the airfield.

The Argentine defenders finally responded to the SAS incursion, but only after the British had begun to withdraw. After stopping a feeble enemy counter attack, the high-level of mobility provided by Royal Navy Sea King helicopters enabled the raiding party to withdraw without further contact with the enemy. Interestingly, static defence of the aircraft had not been totally ignored as the Argentines were able to detonate an emplaced explosive charge, which had been pre-positioned on the airfield perimeter, as the exfiltrating SAS party passed by it. No casualties were caused to the British force. Eleven Pucara, Mentor and Skyvan aircraft were destroyed in the raid, a

---

[131] Freedman, L., 'Intelligence Operations in the Falklands', *Intelligence and National Security,* Vol 1, No 3, September, 1986, p 324.

[132] Middlebrook, *The Fight for the 'Malvinas',* p 149.

[133] Hastings, M., and Jenkins S., *The Battle for the Falklands,* Michael Joseph Ltd, London, 1983, p 186.

[134] Ethell and Price, *Air War South Atlantic,* photograph 22.

significant blow to the ability of the Argentine forces to threaten British ground forces and helicopters.

Falklands Conclusions

The Falklands War was important in because it was a modern conflict employing reasonably advanced weapons. However, unlike the Gulf War of 1991, the scale of forces involved was far more representative of what may be seen in typical regional conflicts. In these instances it is likely that there will be relatively modest numbers of aircraft and other forces operating in a region of large distances and hostile climate and terrain. The ability of the Royal Navy and RAF carrier based aircraft to defend the amphibious operation and support the ground forces was crucial to British victory. Had they not been available the British would have been unlikely to contest the Argentine occupation.

Perhaps the principal limitation of the Argentine Air Force's ability to attack the British force was the distance they had to fly from combat aircraft capable airfields on the Argentine mainland. They were always operating at the edge of their endurance, which reduced their flexibility in employment and their ability to conduct sustained strikes. Had the airfield at Port Stanley been modified and used to operate combat jet aircraft as a priority after the Argentine landing, the outcome of the conflict may have been very different.

The use of the Vulcan bombers to attack the Port Stanley airfield demonstrates firstly the vulnerability of the airbase, but also the limited utility of 'half-hearted' attacks. (Noting the aim of those attacks was perhaps more political than simply to close Stanley airfield.) If air operations from Stanley were interrupted, this was only for a very limited period of time. However, it achieved several broader aims and substantially contributed to the success of the British forces.

GRENADA — OPERATION *URGENT FURY* — OCTOBER 1983

During October 1983 US forces headed a Caribbean coalition to capture the island of Grenada, which had been taken over in a Marxist coup. Both principal initial assaults on the island were on and through the island's two main airfields.

One of the initial objectives of the assault was the airstrip at Point Salines. The airfield was defended by local and Cuban troops and anti-aircraft guns. The runway was blocked by large oil drums, trucks, bulldozers, tankers, and stakes driven into the ground with wire between them. Five hundred and fifty Rangers made a low altitude parachute drop over Point Salines and secured the airfield. They cleared the runways, which allowed reinforcements to be flown in and landed directly at the field. A captured Cuban bulldozer was used to flatten stakes and push aside drums.[135] Eventually over 5,000 US troops would be landed there.

The other major airfield on the island was called Pearls Airport and was located near the town of Grenville. US Marines took this in a heliborne assault, simultaneously with the airborne assault on Point Salines. Two Cuban aircraft and their crew were captured during this operation. However, after the marines had secured the airfield local militia forces were able to begin a small bombardment of the terminal area with a single mortar tube from the hills west of the airfield. Fortunately for the marines the ninth round misfired in the tube and the militia abandoned the weapon, the attack causing no casualties.[136]

Operation *Urgent Fury* demonstrated the pre-eminent importance of airfields as potential insertion points for assaulting troops. Although the weight of US forces made defence of the airfield practically impossible, had it been better defended (both actively and passively) it may have made the operation considerably more difficult.

LIBYA — OPERATION *EL DORADO CANYON* — APRIL 1986

US President Reagan decided on 7 April 1986 to use air strikes on military targets in and around Tripoli to demonstrate American resolve following alleged Libyan sponsorship of terrorism. Two of the targets chosen for the 14 April night raid were airbases — the Benina military airfield and the military portion of the Tripoli international airport. Benina airfield housed MiG-23 interceptors and Tripoli was home to Libya's fleet of Il-76 transport aircraft.

The Libyans were unprepared for the attacks and none of the aircraft parked at these two locations were dispersed or afforded any form of protection. Runway lighting at the military airports was still illuminated during the attack.[137] F-111 aircraft attacked the transport aircraft parked at Tripoli airport, using laser-guided bombs, and caused very heavy losses. Three Ilyushin Il-76 transports, a Boeing 727 and a Fiat G.222 were all destroyed, with a further three Ilyushin Il-76 damaged.[138]

US Navy A-6 bombers attacked the Benina airfield using unguided unitary and cluster bombs. Damage at both airfields was heavy — two transport aircraft destroyed and 12 damaged, two helicopters destroyed and 10 to 15 damaged, and as many as 14 MiG-23s destroyed.[139] The runways were also heavily cratered. The strict rules of engagement imposed upon the attackers to reduce collateral damage also reduced the effect that was achieved.

---

[135] Adkin, M., *Urgent Fury: The Battle for Grenada*, Lexington Books, Lexington, 1989, p 214.
[136] *Ibid.*, p 241.
[137] Drew, D.M., 'Air Power in Peripheral Conflict: From the Past, the Future?' in Stephens, A., (Ed), *The War in the Air 1914-1994*, Air Power Studies Centre, Canberra, 1994, p 259.
[138] Boyne, W.J., 'El Dorado Canyon', *Air Force Magazine*, March 1999, p 61.
[139] Drew, 'Air Power in Peripheral Conflict: From the Past, the Future?', p 260.

Tripoli Conclusions

This raid demonstrated that modest numbers of attacking aircraft operating at long range from their land bases could now inflict considerable damage on unprepared airbases. Aircraft parked in rows on unprotected hardstands are still as vulnerable as they have always been. It represented an evolution of the tactics demonstrated during the Arab–Israeli wars. It also demonstrated that airbases could now be effectively attacked at night and precision guided weapons were further increasing the vulnerability of airbase features.

PANAMA — OPERATION *JUST CAUSE* — DECEMBER 1989

During December 1989, US forces undertook an invasion of the Central American nation of Panama to capture the ruler, Manuel Noriega, and restore a democratically elected government to power. During this operation a number of assaults upon airbases were significant.

Many of the primary targets on the first day of operations were airfields. Parachute assaults were used to capture Tocuman, Rio Hato and Torrijos airfields. The capture of these airfields was vital for the insertion and resupply of US forces in the theatre. 'The reliance on air lines of communication was total.'[140]

One of the most important of these operations was conducted by US Navy Special Forces to deny the use of Paitilla Airfield and to destroy Noriega's personal aircraft. Starting at 0100 hours on 20 December 1989, Task Force White (Golf Platoon, SEAL Team Four)[141] conducted an over-the-beach assault on Patilla airfield.[142]

One source states that the deployment of a few armoured cars at Paitilla airport was the principal reason for the high casualty count amongst the assaulting special forces.[143] Special forces, by necessity of their requirement to deploy by unusual means, will normally be lightly equipped, and accordingly have little organic capability to deal with armoured vehicles. Four SEALs were killed in this operation, and a further nine wounded.[144] The plan preferred by the SEALs to deny Noriega use of the airport was to position sniper teams in buildings overlooking the airport. Anti-materiel sniper rifles would then be used to disable any aircraft attempting movement. This option was ruled out due to the potential for collateral damage to civilians outside the airfield.[145] Of note, is how easily this preferred plan might have effectively denied the use of the airfield to Noriega or his forces.

---

[140] Jackson, J.T. in US Army War College, *Case Study – Operation Just Cause Panama 1989,* p 91.
[141] Kelly, O., *Brave Men Dark Waters – The Untold Story of the Navy SEALs,* Pocket Books, New York, 1993, p 1.
[142] US Army War College, *Case Study – Operation Just Cause Panama 1989,* p 10.
[143] *Ibid.*, pp 39-40.
[144] Kelly, *Brave Men Dark Waters – The Untold Story of the Navy SEALs*, p 2.
[145] *Ibid.*, p 255.

THE 1991 GULF WAR

The Gulf War is notable in that it represents one of the most recent large-scale conflicts that pitted conventional armed forces against one another in a theatre-wide series of operations. The Iraqi airbase network was one of the strongest aspects of the Iraqi military machine, airbase hardening making Iraq's airfields 'the strongest component of its air force'.[146] Acknowledging this strength, commensurately strong coalition forces were allocated to its suppression.

Despite the weight of air power devoted to the task of attacking Iraqi airfields 'the fact that many of Iraq's frontline fighters were able to escape to Iran clearly indicates that many runways remained accessible and useable, despite the coalition's best efforts'.[147] Of the 16 primary Iraqi Air Force bases and 28 dispersal airbases targeted only nine were placed irreparably out of action.[148] These figures attest to the operability of these airbases; however, these results must be considered in the context of the goals of the coalition offensive counter air campaign. 'We never had any intention to render all of the airfields inoperable,' General Schwarzkopf explained, 'our intention is to render the [Iraqi] *Air Force* [emphasis in original] ineffective'.[149]

During the second week of the air war, fully 60 per cent of F-111F and 26 per cent of the F-117 sorties attacked airfield targets, mostly aircraft shelters. During the third week, F-111F aircraft conducted more than 200 strikes against airfield targets (representing 18 per cent of their strikes for that week).[150] Royal Air Force Tornado strike aircraft attacked runways with their specialised JP233 weapon. B-52G strategic bombers were used to attack airfield targets using low altitude high-speed attacks. They attacked runways with unguided unitary bombs and laid fields of area denial sub-munitions.[151] In the two weeks 1,300 sorties were flown against Iraqi airfields by US and allied aircraft.[152]

Each major Iraqi airfield possessed trained runway repair teams, specialised equipment and stockpiles of material to use during repairs. At no stage was it apparent that the coalition attacked these airbase repair assets as part of their airfield attack strategy.[153] Accordingly, where meaningful damage was inflicted it was usually repaired quickly. Craters were painted on operational runways to make them appear damaged and real craters were papered over to attract further wasted attacks.[154]

[146] Centner, C.M., 'Ignorance is Risk', *Airpower Journal*, Vol 6, No 4, p 27
[147] *Ibid.*, p 32.
[148] Canan, J.W., 'Airpower Opens the Fight', *Air Force Magazine*, Vol 74, No 3, March 1991, p 18.
[149] *Ibid.*, p 18.
[150] Murray, W., *Air War in the Persian Gulf*, Nautical and Aviation Publishing, Baltimore, 1996, p 185.
[151] Coyne, J.P., *Airpower in the Gulf*, Aerospace Education Foundation, Arlington, 1992, p 50.
[152] Canan, p 18.
[153] Centner, p 29.
[154] Asia-Pacific Defence Reporter – Random Intelligence, Vol XVII, No 9, March 1991, p 23.

Figure 2.7 Damaged Iraqi Hardened Aircraft Shelter (Photograph courtesy Mr Owen Hammond)

During the second week of the air war, fully 60 per cent of F-111F and 26 per cent of the F-117 sorties attacked airfield targets, mostly aircraft shelters. During the third week, F-111F aircraft conducted more than 200 strikes against airfield targets (representing 18 per cent of their strikes for that week).[155] Royal Air Force Tornado strike aircraft attacked runways with their specialised JP233 weapon. B-52G strategic bombers were used to attack airfield targets using low altitude high-speed attacks. They attacked runways with unguided unitary bombs and laid fields of area denial sub-munitions.[156] In the two weeks 1,300 sorties were flown against Iraqi airfields by US and allied aircraft.[157]

Each major Iraqi airfield possessed trained runway repair teams, specialised equipment and stockpiles of material to use during repairs. At no stage was it apparent that the coalition attacked these airbase repair assets as part of their airfield attack strategy.[158] Accordingly, where meaningful damage was inflicted it was usually

[155] Murray, W., *Air War in the Persian Gulf*, Nautical and Aviation Publishing, Baltimore, 1996, p 185.
[156] Coyne, J.P., *Airpower in the Gulf*, Aerospace Education Foundation, Arlington, 1992, p 50.
[157] Canan, p 18.
[158] Centner, p 29.

repaired quickly. Craters were painted on operational runways to make them appear damaged and real craters were papered over to attract further wasted attacks.[159]

1991 Gulf War Conclusions

In summary, the Gulf War pitted one of the world's most resilient airbase systems against perhaps the strongest air campaign ever conducted. 'Fully one-third of the US tactical air forces went to *Desert Storm,* including 90 per cent of the F-111s, F-117s and F-15E strike aircraft. Over half of the tankers and command and control aircraft deployed, and almost half of the reconnaissance and electronic warfare aircraft.'[160] It demonstrated the finite, yet very tangible benefits that airbase operability features provide. Had the Iraqi airbase network not possessed such a suite of operability features it may have been neutralised far more easily than it was. Because of the highly resilient nature of the Iraqi airbase network the aim of the coalition offensive counter air attacks was to 'disrupt operations and to reduce sortie rates, rather than to close the airfields altogether which, given their size, was beyond the capability of the resources available'.[161] The dispersed and hardened bases, combined with an active deception and repair capability, ensured that despite the coalition's weight of precision fire power, Iraqi aircraft were potentially available for combat tasking (had it been desired) right up until the end of the war.

SERBIA — OPERATION *ALLIED FORCE* — MAY/JUNE 1999

The most recent international conflict in which airbases have been attacked was Operation *Allied Force*, the NATO action against Serbia from April to June of 1999. Military and infrastructure targets in Serbia were attacked by NATO aircraft to drive Serbian forces out of the disputed province of Kosovo.

During this campaign many Yugoslavian Air Force bases and dual-use airports were attacked, principally as part of a comprehensive defence suppression campaign. NATO reconnaissance imagery shows damage to airfields at Sjenica, Obvra, Batajnica, Ponikve, Nis, Somber, Podgorica and Pristina. In most cases the runway pavements have been primary targets attacked either by massed sticks of bombs or precision strikes at critical junction points. Aircraft parking, fuel and airfield facilities have also been targeted in some instances.

Allied Force also saw the first wide spread use of satellite or Global Positioning System (GPS) guided munitions. GPS-guided US Joint Direct Attack Munitions (JDAM) were used to cut runways and destroy airfield facilities on many airbases. One report states that JDAMs deployed from USAF B-2A bombers were used to put

---

[159] Asia-Pacific Defence Reporter – Random Intelligence, Vol XVII, No 9, March 1991, p 23.

[160] Story, W.C., *Third World Traps and Pitfalls – Ballistic Missiles, Cruise Missiles, and Land Based Airpower,* Air University Press, Maxwell AFB, 1995, p 41.

[161] Hine, P., 'Air Operations in the Gulf War' in Stephens, A., (Ed), *The War in the Air 1914-1994,* Air Power Studies Centre, Canberra, 1994, p 310.

Obvra Airport out of action. A single B-2A sortie hit two runways with three bombs on each one, spread evenly along their length.[162] The principal advantage of GPS guided munitions is that they can be used to attack small fixed targets precisely in all weathers, overcoming a major deficiency of laser guided bombs.

Figure 2.8 Serbia's Sjenica Airfield Post-Attack (NATO Photograph)

NATO reconnaissance imagery also shows a diversity of methods used by Serbian forces to counter the air attacks, and also reveals instances where little had been attempted to ameliorate or repair damage. Extensive use was made of aircraft decoys, camouflage and concealment. Overhead photographs of commercial transport aircraft parked at Belgrade Airfield reveal a fighter aircraft parked under the tail of one of the larger transports.[163] Low angle sunlight has formed long shadows from both aircraft revealing the presence of the hidden fighter. Post strike images of Ponikve airfield show bomb damage across the main runway. A path has been cleared through the resulting debris, but no attempt to repair the bomb damage is apparent.[164] Although, given the overwhelming firepower deployed by the NATO airforces and their demonstrated reconnaissance and restrike capability, any repair attempts would have

[162] Seigle, G., 'B-2A Spirit is No Prima Donna on the Ground', *Jane's Defence Weekly*, 7 July 1999, http://defweb.cbr.defence.gov.au/jrl/janes/jdw99/jdw02394.htm accessed 2 September 1999.
[163] http://www.nato.int/pictures/1999/990419/b990419c.jpg accessed 20 August 1999.
[164] http://www.nato.int/pictures/1999/990419/b990530i.jpg accessed 20 August 1999.

been unlikely to be worthwhile anyway. The US Air Force's senior officer in Europe, General John Jumper was quoted as saying 'one of the myths that was dispelled in this conflict was that you can't close airfields [with bombing]. We closed almost all the airfields so there was no air activity off of them'.[165] Noting the number of airfields which historically have been closed by bombing, this conception should certainly have been only a myth long before *Allied Force*, but the quote highlights the effectiveness of the new generation of air-to-surface weapons.

Despite the increased accuracy of the new weapon systems considerable quantities of unexploded ordnance were left after the campaign. Much of this ordnance was left in Kosovo to be cleared by NATO Explosive Ordnance Disposal teams. Another example was a 2,000 pound unexploded bomb found at Pristina Airport. This bomb was destroyed in place by Russian troops using a 'controlled explosion' over a month after the cessation of the air campaign.[166]

Operation *Allied Force* also saw the first offensive use of computer or information warfare to attack air defence systems. Used in support of air attacks, US computer experts were able to introduce false radar images onto air defence systems to protect attacking aircraft. Less sophisticated brute force methods such as the overloading of systems with extraneous data were also employed as had been undertaken in the 1991 Gulf War.[167]

CONCLUSIONS

> In theory, a major war should confer benefits on the armed forces of the victor. New lessons have been learned, new technologies developed and new confidence found. Thus equipped, they should have a head start on preparations for the next war. In practice the reverse seems to be the case, and this was never more so than after the First World War.[168]

The defence of the airbase can be seen as an attempt to make the best of a bad situation. Airbases are attractive targets, combining high strategic and monetary value with a large number of vulnerabilities. In few other fields of military endeavour would one be expected to defend such a seemingly indefensible target at all costs. Particularly since OCA operations have become a seemingly almost mandatory method of starting military campaigns.

In many of the examples provided in this chapter, the airbase targets seemed to be just that, indefensible. Where the attacker possessed air superiority and precision weapons, and the defender's only earthbound anti-aircraft weapons, all the airbase resiliency features in the world did not prevent severe asset losses. However, where the attacker

---

165 Fulghum, D.A., 'Kosovo Conflict Spurred New Airborne Technology Use', *Aviation Week and Space Technology*, 23 August 1999, p 30.

166 NATO briefing, http://www.nato.int/kosovo/press/1999/k990811a.htm accessed 13 September 1999.

167 Fulghum, D.A., 'Yugoslavia Successfully Attacked by Computers', *Aviation Week and Space Technology*, 23 August 1999, p 31.

168 Dixon, N.F., *On the Psychology of Military Incompetence*, Pimlico, London, 1994, p 110.

had only a finite capability, the implementation of protective measures on the ground made a significant difference — 'since 1940 airbases have been difficult to defend, but they have also proven to be very hard to destroy'.[169]

The study of previous military undertakings and attempts to draw lessons from them is often stymied by the inconsistencies and conflicting results that are found. Also, as previously stated, care must be taken in ensuring that lessons drawn are still valid as 'one era's truisms can be another's falsehoods'.[170] The study of attacks against airbases shows that some simple conclusions can be readily drawn and that despite considerable changes in technology some basic truths have held true over the last 80 years. The most consistent lessons learnt from this study of past airbase attacks are:

- The extreme vulnerability of aircraft and essential facilities unless protected by an operability plan and appropriate passive defences.
- The vulnerability of airbase operations to ground attack and the extent to which an aggressive and well managed ground defence capability can offset this threat.
- The importance and potential effectiveness of a comprehensive airfield recovery capability.

Aircraft parked in the open undispersed are sitting ducks and will be destroyed quickly and cheaply. Dispersal and protection from near misses is normally the most cost-effective solution to protect parked aircraft.

In almost every example presented in this chapter, describing both air and ground attack against airbases, aircraft parked in the open without protection were easily destroyed or damaged. Israeli attacks on Egyptian aircraft in 1967 demonstrated that this was not only feasible, but could be done with considerable economy. Placing aircraft in protected positions such as revetments and Hardened Aircraft Shelters (HAS) has always provided them with a degree of protection and made the attackers' task of destroying them commensurately harder. Although, in later conflicts hardened aircraft parking was also shown to be vulnerable, they were still more difficult to destroy than unprotected aircraft. The soft nature and necessarily light construction of aircraft makes them vulnerable to serious damage from relatively light overpressures or small impacts.

The development of a family of precision guided penetration weapons has ensured that all parked aircraft may be vulnerable, regardless of the physical protection afforded them. Accordingly, the construction of expensive HAS may no longer be economically justifiable, except in unusual cases. However, there are large gains to be made by protecting aircraft from the effects of near misses, ground fired weapons, area weapons and other non-precision attacks. The combination of this limited physical protection with an effective dispersal plan, to minimise the damage caused by a limited number of attack weapons, may often provide the most cost-effective

[169] Kreis, *Air Warfare and Airbase Air Defence*, p 352.
[170] Stephens, A., *High Noon of Air Power*, Air Power Studies Centre, Canberra, 1999, p 26.

protection for parked aircraft. It is also effective against ground attack, protecting against normal weapons and complicating the task of penetrating 'sapper' style attacks. The construction of dispersed and hardened aircraft parking following the 1967 Arab–Israeli War and during the Vietnam War was undertaken in response to these diverse requirements.

A determined special or irregular forces unit can employ stand-off weapons or penetrate inadequate ground defences to destroy aircraft. Well designed and aggressively employed ground defence in depth can prevent these attacks.

Airbases must be adequately defended against ground attack. Where airbase ground defences are perceived to be inadequate ground forces may be tasked to attack the assets at the airbase. In many campaigns aircraft capable of conducting air strikes on defended ground targets are usually in high demand with more targets available than platforms to attack them. Accordingly, where it is feasible to use ground forces to attack an enemy facility they may be employed. This was well demonstrated during SAS-LRDG operations in North Africa during World War II and by the North Vietnamese and VC during the Vietnam War.

Some USAF bases in Vietnam were excellent examples of fortress airbases incorporating well established perimeter defences and mobile defenders with heavy firepower. Against these defences penetrating style attacks were largely unsuccessful. Although generally impossible to quantify, the deterrent effect of these defences was probably of even greater usefulness. Potential attackers were forced to use stand-off tactics that were normally less accurate or selective, and accordingly were often less effective.

Airfields are easy to attack and easy to damage, however, keeping them closed requires repeated attacks on a continuous basis. A strong airfield recovery capability, including the ability to neutralise unexploded explosive ordnance is essential.

Historical examples have shown that unless active defences are particularly strong it is relatively easy to damage airfield surfaces and facilities. In many cases this was shown to be capable of stopping airbase operations. However, it was also demonstrated that this damage could normally be repaired quite quickly and repeated attacks were required to keep airbases inoperable. The possession of even a rudimentary repair and recovery capability enabled operations to be recommenced quite quickly.

This phenomenon was again demonstrated during the 1991 Gulf War, when well developed resiliency features and an effective runway repair capability enabled many Iraqi airbases to be kept operational, despite the weight of coalition firepower thrown at them.

It has been demonstrated that the presence of UXO following an attack can greatly hinder the recovery process. Airbases must have an appropriate capability to deal with this threat. Poltava and Grimsby (refer Chapter 11) are early examples of the disruption and casualties that UXO can inflict upon recovery operations. There is a wide variety of advanced and effective pavement and facility repair options presently available that can quickly repair the damage caused by air base attack. The use of area denial munitions (particularly if a variety of different forms is used simultaneously) has the potential to greatly increase the time required to restore a base's operational capability, and inflict substantial casualties whilst doing so.

Surprise is a consistent factor in airbase attacks.

Historical analysis demonstrates that surprise has been a consistent factor in attacks on airbases. In nearly all the conflicts where air power played a major part, attacks on airbases were part of the opening actions. Air power could be so crucial to a campaign that efforts to negate it must be made at the outset of a conflict and it has consistently proven easier to destroy aircraft on the ground than in the air. Surprise is normally required to achieve this before the enemy can disperse or scramble. Airbases can also be defended quite effectively if prepared, making surprise essential to reduce attackers attrition.

The surprise employed was not necessarily the traditional strategic or tactical where surprise merely consisted of an attack occurring when it was not expected. Surprise was often achieved despite the expectation an attack was imminent through the use of unconventional strategies or technologies. There is little evidence to suggest that surprise will cease as a vital enabling factor in airbase attacks. Therefore, the airbase commander must be constantly vigilant against surprise in all its forms, tactical and strategic, doctrinal and technical.

CHAPTER 3

The Threat — Attack From the Air

Secure airfields are a key factor in Australia's ability to sustain control in the air/sea gap. They are essential for air defence, maritime strike and the high degree of mobility needed to deploy forces throughout the area. As ADF centres of gravity, airfields would attract close attention from an adversary. [1]

BACKGROUND

The first objective of any air force when involved in a military campaign is often to achieve a relative degree of air superiority or control of the air space. Indeed, Australian air doctrine states 'some degree of control of the air is the precondition for most operations'.[2] Accordingly, counter air operations may be undertaken by any aggressor at the commencement of military operations against a nation state or its deployed forces. 'Elimination or reduction of the capabilities of the enemy's air defenses always must be the first priority of an air campaign.'[3]

The potential impact of air attacks on ground operations cannot be ignored. In earlier conflicts, when air power was not so well developed, the ability of aircraft to influence the broader campaign could be limited. By taking basic countermeasures ground operations could continue despite enemy air activity. By moving at night, dispersing forces or placing critical elements in hardened facilities the impact of enemy air control could be reduced. With the advent of all weather day-night aircraft, longer ranges, precision weapons, high lethality warheads and improved targeting, together with sophisticated command and control systems, air power can dramatically change the ground war very quickly. Iraqi President Saddam Hussein did not believe coalition air power could impact upon his operations (airbase operations included) as severely as it did. He is quoted as saying 'The United States relies on the Air Force and the Air Force has never been the decisive factor in the history of wars'.[4] *Desert Storm*

---

[1] Schubert, D.J., 'Maritime Strike' in Stephens A. (Ed), *Defending the Air Sea Gap,* Australian Defence Studies Centre, Canberra, 1992, p 85.

[2] Royal Australian Air Force, *The Air Power Manual 3rd Edn,* Air Power Studies Centre, Canberra, 1998, p 43.

[3] Szafranski, R., 'Parallel War and Hyperwar: Is every Want a Weakness' in Schneider, B.R. and Grinter, L.E., (Eds), *Battlefield of the Future,* Air University Press, Maxwell AFB, 1998, p 134.

[4] Hallion, R.P., *Storm Over Iraq: Air Power and the Gulf War,* Smithsonian Institute Press, Washington DC, 1992, p 162.

demonstrated the offensive potential of the aircraft and the significant impact it can have on ground operations. More so than ever, modern air power poses a very real and powerful threat to all ground operations — airbase operations certainly included.

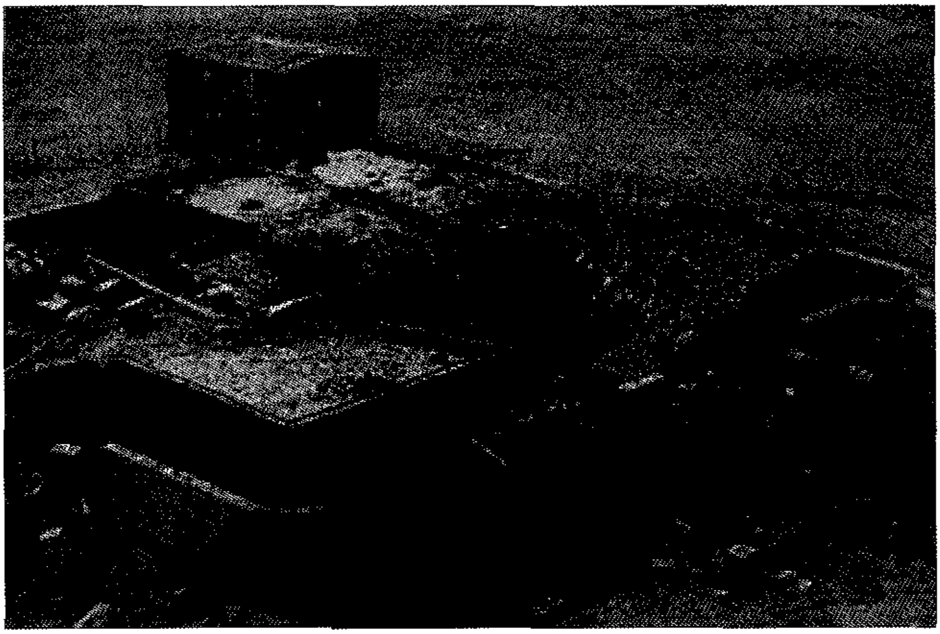

Figure 3.1 An Iraqi Military Facility Demonstrating the Mass Effect of Modern Precision Guided Weapons (Photo courtesy Owen Hammond)

OFFENSIVE COUNTER AIR OPERATIONS

Two basic forms of anti-air warfare may be undertaken during conflict — the offensive and the defensive. In defensive counter air warfare, surface or airborne defences destroy enemy aircraft as they attack. During offensive counter air missions friendly forces aggressively seek out enemy air power attacking it either in the air or on the ground. Most modern air power doctrine recommends that wherever possible the offensive counter air mission should be selected. 'Whenever possible, the offensive course should be selected — if for no other reason than that it is a positive measure that will lead to positive results.'[5] 'Conquering the command of the air implies positive action — that is, offensive and not defensive action, the very action best suited to air power.'[6]

[5] Warden, J.A., *The Air Campaign,* Pergamon-Brasseys, Washington DC, 1989, p 23.
[6] Douhet, G., *Command of the Air,* Coward-McCann, New York, 1942, p 19.

Defensive counter air campaigns have the following broad disadvantages:

- Defensive counter air campaigns pass the initiative to the enemy.

- Aircraft awaiting enemy attack are generally not accomplishing anything and make little contribution to the campaign unless enemy aircraft present themselves.

- Concentration of force is usually difficult to achieve when on the defensive, unless extremely good intelligence and/or threat warnings are available.

The most difficult place to attack enemy combat aircraft is generally in the air. This is the environment in which they were designed to fight and unless one side holds great numerical, technical or tactical mastery a costly battle of attrition may result. Accordingly, it is often far more profitable to attack these aircraft before they become airborne, either at their airfields or in the production chain before they arrive. During World War II the Allies devoted much of their strategic bombing campaign to the destruction of all stages of Germany's aircraft production process. With modern wars being shorter and modern aircraft being too complex to produce quickly on demand attacking aircraft production is unlikely to be a viable option in future conflicts.

Therefore, the offensive counter air operation most likely to succeed is the direct attack of the enemy's aircraft and supporting assets on the ground. This form of operation is attractive to an aggressor as it has the potential of destroying large numbers of enemy aircraft without having to engage them in aerial combat. It allows potentially larger numbers of enemy aircraft to be destroyed for a given number of friendly aircraft. Air Marshall Sir Patrick Hine, former Commander-in-Chief of the RAF in Germany is quoted as saying: 'We could not, however, gain a favourable air situation by remaining on the defensive alone. We would have to take him by the throat and, as soon as we got political clearance, pin him down on his airfields through our own offensive counter air attacks.'[7]

> THE MORE VULNERABLE THE DEFENDER'S AIRCRAFT ARE ON THE GROUND, AND THE MORE POTENT THEY ARE IN THE AIR, THE MORE ATTRACTIVE THEY WILL BE TO AN OFFENSIVE COUNTER AIR ATTACK.

Offensive counter air campaigns can also produce returns in addition to the destruction of enemy aircraft. Suppression of enemy air defences (other than their aircraft) will normally precede or form part of an offensive counter air campaign. This

[7] Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987, p 45.

will allow, and may have been a prerequisite for, unrelated interdiction or strategic strike missions. There is also the potential for damage to collateral facilities that may have been targets themselves for later strike missions.

Air Attacks on Airbases

The choice of which weapon to use in a military engagement is determined by a wide number of factors. These same choices apply to the weapons that could be utilised during air attacks on airbases. Some of the specific characteristics of airbases that could influence the choice of weapons used against them include:

- The fact that airbases are geographically fixed and their location usually well known by potential adversaries.
- The diverse and often soft nature of the targets which can be found there.
- The range from the enemy bases or launch platforms to the airbases.
- The high strategic value of the targets on an airbase.
- The weapons available, or potentially available, to the attacking force.
- The ability (perceived or otherwise) of the airbase's active defences to prevent the application of certain attacks.

Accordingly, the combination of the above factors will define the potential air threat against an airbase. The following weapon groups can be employed in this role.

- Direct attack from aircraft using unguided weapons. (Israel v Egypt, 1967)
- Direct attack from aircraft using guided weapons. (US v Libya, 1986)
- Surface to surface Tactical Ballistic Missiles (TBMs). (Iraq v Coalition, 1991)
- Cruise missiles. (NATO v Serbia, 1999)
- Cluster or area weapons, utilising sub-munitions. (Britain v Argentina, 1982)
- Chemical or biological weapons. (Iraq v Iran, 1980-88)
- Fuel-air explosives (FAE).
- Area denial weapons. (Coalition v Iraq, 1990)
- Dedicated runway attack weapons. (Coalition v Iraq, 1990)
- Soft kill or non-lethal weapons (NATO v Serbia, 1999).

Obviously, this division is arbitrary and certainly not exclusive. Many weapons can be considered as belonging in several categories. For example, a TBM could be used to deliver a persistent chemical agent warhead that would have both an area and an area denial effect.

WEAPONS AVAILABLE FOR AIR ATTACKS ON AIRBASES

Direct Attack Using Unguided Weapons

Despite the proliferation of precision guided weapons the unguided or 'dumb' bomb continues to be the mainstay of many of the world's air forces. Unguided direct attack weapons take a variety of forms including cluster or area weapons, which dispense sub-munitions, chemical bombs, fire bombs, fuel-air bombs or simple unitary bombs which strike their targets in the same form as they are launched. With unitary high explosive bombs, it is also possible to detonate them in the air above their targets, showering the ground with metal fragments. This technique, or the use of area weapons, is an effective method of attacking aircraft in open revetments without the use of precision guided weapons. Strafing attacks using forward firing small calibre automatic cannon is another potential attack option in this category.

The primary disadvantage of unguided weapons is obviously their lack of terminal accuracy. An unguided bomb will miss a target for a variety of reasons. Some of the largest contributors include incorrect aim point selection by the pilot, inaccuracies in the bomb aiming system (whether manual or computerised), target movement, variations in the bomb ballistics and wind effects.

During the Gulf War aircraft with modern computerised air-to-ground aiming systems were able to exhibit accuracy to within 10 metres of most targets from low altitude.[8] This was sufficient to ensure destruction of most targets; however, low altitude bombing was not always prudent in an environment rich with shoulder fired surface-to-air missiles and automatic guns (the type of anti-aircraft threat environment which may be expected on a defended military airbase). Bombing from medium altitude produces much larger errors. One source cites that with the Mk84 2,000 pound unguided bomb dropped from a modern fighter-bomber from 15,000 feet, the minimum average miss distance that could be expected was 50 metres.[9] This represents the inherent variation in the ballistic performance of individual bombs and the ability to discriminate point targets within a fixed width target pipper in the aiming system. This degree of inaccuracy will ensure the survival of a resilient target and make destruction of even fragile targets uncertain.

[8] Hallion, R.P., *Precision Guided Munitions and the New Era of Warfare,* Air Power Studies Centre, Canberra, 1997, p 4.
[9] *Ibid.*, p 5.

Another disadvantage of these weapons is their inability to penetrate hard targets when dropped from very low-level. Penetration is dependent upon the bomb having sufficient kinetic energy and striking at an appropriate angle. These two conditions are difficult to achieve simultaneously with an unpowered munition released at low-level. The limitations that this can impose on attack profiles are discussed in more detail later in this chapter.

Despite the above, unguided weapons will remain in the inventories of most nations for many years to come, mainly due to the cost factor. Notwithstanding their cost effectiveness, precision guided weapons are still more expensive to procure and maintain. Accordingly, many nations will continue to find it difficult to acquire these weapons in quantity.

Direct Attack Using Guided Weapons

To overcome the limitations of unguided ordnance the first direct attack air launched guided weapons were utilised during World War II. These were short-range rocket powered glide bombs that were guided to their target by a director in the launch aircraft via signals transmitted by wire or radio link. The first operational successes of these weapons were the sinking of the sloop HMS *Egret* and the Italian battleship *Roma* during August and September 1943.[10] Significant advances in the use of these weapons occurred during the Vietnam War, with the introduction of the Bullpup command guided missiles and the first Laser Guided Bombs (LGBs).

Many direct attack guided weapons are unpowered, such as laser guided free fall bombs. These weapons have an additional disadvantage of requiring fairly stringent release parameters. Unlike unguided free fall bombs, guided bombs use considerable energy as they manoeuvre onto the target. Accordingly, unless they have sufficient kinetic energy to overcome this loss the bomb will fall short of the target. Later versions of the LGB, such as the Paveway III series have larger aerodynamic surfaces and more intelligent guidance systems to increase the size of the delivery envelope.

The ability of guided direct attack weapons to strike with very high levels of accuracy and steep impact angles have led to them being traditionally employed to attack hardened or buried facilities. The 2,000 pound BLU-109, fitted with a laser-guidance kit, was used often during the 1991 Gulf War to attack these forms of targets. A 5,000 pound class weapon, later designated the BLU-113, it was designed to provide greater penetration capability for deeply buried targets.

Current research is aiming to develop much lighter warheads capable of penetrating hardened targets. The 112.5 kilogram class Miniaturised Munition Technology Demonstration (MMTD) is expected to be capable of attacking 85 per cent of targets now penetrated by 900 kilogram bombs. Utilising a newly designed Motorola smart fuse, this weapon is designed to penetrate 1.8 metres of reinforced concrete with 22.5

[10] Gunston, B., *Illustrated Encyclopedia of the Worlds Rockets and Missiles,* Salamander Books, London, 1979.

kilograms of explosive and have an accuracy of a three metre Circular Error of Probability (CEP).[11] The CEP of a weapon is a measure of its accuracy and refers to the radius of a circle around the desired point of impact within which 50 per cent of the weapons will theoretically land.

The biggest impact of these miniaturised precision penetrators on airbases is the significant increase in destructive potential that can be brought to bear on an airbase by a limited number of attacking aircraft — the defensive environment allowing. A relatively small number of attacking aircraft can attack a large number of hardened facilities in a single sortie. The lighter weight of these weapons can also increase the effective range of strike aircraft allowing them to fly longer distances. This is a result of lighter all up weights or the ability to carry additional fuel in place of the previously heavier weapon loads.

THE DEVELOPMENT OF LIGHT WEIGHT PRECISION GUIDED WEAPONS HAS THE POTENTIAL TO THREATEN TARGETS PREVIOUSLY PROTECTED BY THEIR DISTANCE FROM THE ADVERSARY'S AIR POWER BASE.

Although there are a number of guidance options available for direct attack munitions in use today they can be divided into five principal categories. These are laser guidance, electro-optical guidance, spatial guidance, active homing and passive homing.

Laser Guided Weapons

Laser guided munitions operate passively, that is, they home in on a laser spot reflected from the target which is shone there by another platform. The illuminating platform may be the aircraft that launched the weapon, another aircraft or a ground party. If the target moves the laser can be moved to remain on it. While these weapons have an unprecedented capability to destroy hardened point targets they still have several drawbacks that can be capitalised upon by the airbase should it be the potential target.

- The laser must be aimed by a platform that has a direct unobstructed line of sight to the target. If the line of sight is blocked, so will be the laser and the system will fail. This can be achieved by deliberate obscuration, or unintentionally by thick smoke, cloud or fog. Where the target is being designated by a ground party, they must also be physically able to see the intended target or they cannot designate it

[11] Starr, B. and Evers, S., 'US Aims to Penetrate Subterranean Centres', *Jane's Defence Weekly*, 26 February, 1997, p.35.

with a laser. When attacking hardened point targets (such as hardened aircraft shelters) high levels of accuracy are required. The obscuration of the designating laser at even late stages of descent may be enough to cause a sufficiently large miss distance to ensure target survival.

- Being in a direct line of sight with the target exposes the designating platform to defensive weapons.

- The laser can be detected by the target, indicating attack is imminent and allowing counter-measures to be enacted.

Recent developments in the US have produced the Enhanced Paveway LGB that combines semi-active laser homing with Global Positioning System (GPS) guidance. The stated aim of the program being to optimise the bomb trajectory for maximum range, get the weapon closer to the target before laser designation was required, or provide some degree of terminal accuracy if the laser homing was interrupted completely.

Given the ability of GPS guided weapons to strike targets without needing laser illumination, LGBs are likely to become specialist fair weather weapons for use against high value moving targets or pin-point fixed targets where the current generation of GPS guided bombs have insufficient accuracy.[12]

Electro-Optical Guidance

Electro-Optical (EO) guidance encompasses a family of guidance methodologies all based around the concept of placing an EO sensor in the nose of the weapon. The sensor may view visible light, infra-red or a combination of both. Additionally, the weapon may interpret the viewed image itself and guide itself autonomously or it may pass the image back to a controlling platform and be guided by command. Again, electro-optical guidance has drawbacks that can be exploited by the potential target.

- The weapon seeker will view the target scene in either a fixed part of the electromagnetic spectrum or a range of frequencies. Typical examples are imaging infra-red or visual (video) imaging. Obscuring the target in these wavelengths will impact on the ability of the weapon seeker to see the target.

- Many of these systems use a command data link between the weapon and the controlling platform. This data link may be susceptible to jamming or disruption.

[12] Kopp, C., 'Breaking Serbia: The Allied Force Campaign Part 3', *Australian Aviation,* October, 1999, p 27.

Spatial Guidance

Spatially guided weapons are launched at a fixed impact point, ie. they are directed to a point in space as opposed to homing in on a feature of the target or designated point. Once launched they normally can make no correction for target movement. Various systems can be used to accomplish spatial guidance including GPS or more traditional Inertial Navigation Systems (INS), terrain matching or comparison systems or a combination of these. Spatial guidance systems have the primary advantage that the launching platform or the weapon itself does not need to be able to see the target physically. Laser or EO guided weapons may be ineffective if the target is obscured by cloud or smoke. Weather over target areas severely impacted upon F-117 LGB operations over Iraq during the 1991 Gulf War.[13] With the fixed target coordinates programmed into the weapon the launching platform simply needs to deploy the weapon from a position where it has sufficient energy to reach the target. In modern systems a combination of GPS and INS is used to provide the desired accuracy. The use of GPS for weapons guidance introduces the potential for jamming of these signals to prevent weapons targeting. Jamming of GPS guidance systems is discussed in more detail in Chapter Eight.

GPS guided direct attack munitions were used extensively during Operation *Allied Force* in 1999. The primary weapon used was the Joint Direct Attack Munition (JDAM), which has been designated the GBU-29 with a 2,000 pound warhead or GBU-30 with a 1,000 pound warhead.[14] These weapons have an advertised CEP of 12 metres, slightly less accurate than the latest generation of LGBs.[15] This difference in accuracy may seem small, but when attacking hardened point targets this miss distance may prove critical. These weapons incorporate a Boeing developed GPS featuring electronic counter-counter measures designed to resist jamming.

The accuracy of systems relying upon the currently available GPS guidance will vary according to the relative number of GPS satellites visible at that point in time and their relative positions. This error can be calculated and weapons used when it is the lowest. This was undertaken during *Allied Force.*[16]

Active or Semi-active Radar Homing

Weapons guided by these systems employ radar energy reflected from the target to identify target features. With active systems the weapon itself provides the energy and with semi-active homing the energy is provided from an external source, usually the launching aircraft. Laser energy can also be used in a manner similar to radar to paint a target and generate image returns. Active homing methods have the disadvantage of alerting the target to the weapon's presence and can be susceptible to jamming or deception.

---

[13] Hallion, R.P., *Storm Over Iraq: Air Power and the Gulf War,* p 177.
[14] Jane's Air Launched Weapons 31,
http://defweb.cbr.defence.gov.au/disjanes/janes/jalw32/jalw3367.htm accessed 9 September, 1999.
[15] Tirpak, J.A., 'Brilliant Weapons', *Air Force Magazine,* February, 1998, p 53.
[16] Kopp, 'Breaking Serbia: The Allied Force Campaign Part 3', p 26.

Passive Homing

Passive homing bombs or missiles home on emissions generated by the targets themselves. The emissions most commonly targeted are radio frequency energy produced by radars, and infra-red energy emitted by hot surfaces, machinery or engines.

Area-denial munitions may also utilise passing homing once deployed. They can utilise a variety of signals such as acoustic noise, seismic vibration or the target's magnetic signature to initiate themselves.

Surface-to-Surface Ballistic Missiles or Tactical Ballistic Missiles

The first example of the Tactical Ballistic Missile (TBM) was the German V2 rocket used to bombard England during World War II. These weapons project a warhead high into the upper atmosphere where it then falls in a ballistic trajectory onto the target. TBMs have become important components of the military inventories of many Third World or lesser developed nations. They can provide a long range strike capability at a lower total system cost than other methods such as a squadron of strike aircraft (including infrastructure support and training costs).

These weapons have generally only ever been used in combat as terror weapons; that is, weapons designed to cause fear, damage and casualties within a targeted civilian population. Attempts to use them against military targets, such as by Iraq during the 1991 Gulf War, were greatly hampered by the inaccuracy of the weapon and those that did strike targets were unusual. As in other forms of weapon, GPS has the potential to increase the accuracy of TBMs. However, some early (but still widely deployed) systems lack any form of steering during re-entry so the use of GPS improved guidance during the boost phase would provide highly limited benefit. The SCUD family of TBMs is typical of this and without the addition of terminal phase guidance the addition of GPS is unlikely to produce a CEP of less than 600 metres.[17]

The advantages of TBMs include:

- TBMs can carry relatively heavy payloads over long range. Some submarine and silo launched nuclear ballistic missiles have intercontinental ranges in excess of 12,000 kilometres.

- They are difficult to intercept. TBMs re-enter the atmosphere and fall in a ballistic profile to their target. During the descent phase they generate very high speeds and only very sophisticated area defence surface to air missiles are capable of intercepting them. The US Patriot missile system was able to intercept and destroy a large number of Iraqi Scud TBMs during the 1991 Gulf War, the first operational application of this capability. Even when successfully intercepted the

[17] Stillion, J. and Orletsky, D., *Airbase Vulnerability to Conventional Cruise Missile and Ballistic Missile Attacks,* RAND Corporation, Santa Monica, 1999, p 9.

nature of their terminal flight path usually causes most of the debris to fall around the target area anyway.

- Many can be fired from mobile launchers, which are difficult to find and attack.

The disadvantages of TBMs include:

- Some older versions require a large support infrastructure at the launch point. This is particularly the case if fired from fixed launchers as opposed to mobile launchers.

- They cannot be fired at moving targets. The location of the target must be known and fixed before firing.

- In most cases TBMs are of limited accuracy. Although development work is underway to improve this, the majority of TBMs currently in service (eg. SCUD) are traditionally considered as not being capable of striking point targets.

- Because of their high curving flight paths TBMs can normally be detected by radar from very long range, unlike cruise missiles which can employ slealthy low altitude profiles.

During the 1991 Gulf War Iraq fired many SCUD TBMs against Israeli and Coalition forces and cities. Due to the inaccuracy of the weapon it was not used against mobile military formations. However, it was seen as an effective weapon for use against area targets such as cities or airbases. One such Scud was fired against Dhahran airbase and it struck an accommodation block on the base killing or wounding 125 service personnel.[18] Even considering the limited damage done by TBMs during this war, the countermeasures required to reduce the threat were considerable.

By the end of the decade three non-major powers will field ballistic missiles with ranges up to 5,500 kilometres.[19] For forces deployed overseas, particularly into South Asia or Africa TBMs may be a real threat. By the year 2000, 24 Third World countries may field ballistic missiles. Of even greater concern is that by that same date 30 countries will have a probable offensive chemical capability. Forward based deployed air units, even if not in the immediate combat zone, may be targeted by ballistic missiles equipped with chemical warheads. 'A credible threat to launch missiles armed with weapons of mass destruction against vulnerable targets could paralyze out-of-area operations.'[20] During these kind of expeditionary operations our deployed air power would not only contribute to combat operations it may be the unquestioned life-line of the operation. The vulnerability of our forces, particularly those air assets, to indiscriminate attack (even if of questionable military effectiveness) may make the conduct of that expeditionary operation untenable.

[18] Hallion, R.P., *Storm Over Iraq: Air Power and the Gulf War*, p 185.
[19] Payne, K.B., 'Defence Against Missile Proliferation', *Jane's Intelligence Review*, May, 1992, p 235.
[20] *Ibid.*, p 236.

Defence against TBMs relies upon either destroying the missiles and transporters before launch or during their pre-impact descent. The Gulf War demonstrated how difficult it was to find mobile launchers, despite cutting edge technology and a featureless terrain that aided aerial reconnaissance. Interception of TBMs in the pre-impact descent requires sophisticated anti-missile defences unlikely to be fielded in quantity by many smaller nations in the near future.

Unless fitted with precision guidance TBMs may generally only harass airbase operations. Destruction of a specific aircraft or support service target is unlikely, but possible if multiple TBMs are used. If a barrage of missiles with a 1,000 metre CEP were fired at a typical airbase, using the base centre as an aim point, almost all the missiles would fall within the perimeter fence. Some destruction and considerable disruption to operations would occur. Guidance systems for TBMs also need not be state of the art to achieve much greater terminal accuracies than a 1,000 metre CEP. A radar scene matching system developed for the US Pershing II missile provided a 50 metre CEP, which is certainly adequate to greatly impact upon airbase operations.[21] Given these inaccuracies, hardening can provide an effective defence against TBM attacks.

Nations seeking a rudimentary ballistic missile capability do not necessarily need to build or acquire purpose built TBMs. High altitude Surface-to-Air Missiles (SAMs) may be modified to function in this role. Some systems, such as the obsolete US nuclear armed MIM-14 Nike-Hercules SAM system was designed to be employed against ground targets if the need arose and crews were trained for this mission.[22] Systems with long range and large warheads are particularly suited to this role, and many such missiles are currently reaching obsolescence in their primary role and are being sold of in vast quantities on the world's weapons markets. Systems such as the Nike-Hercules or the Soviet/Russian S-200 (SA-5 Gammon) are particularly suitable and readily available.

The regular and unpredictable firing of TBMs against an airfield would likely make aerial resupply operations too risky, jeopardising the viability of the complex. This, combined with the casualties which are likely to be caused (although militarily minor) have the potential to make the continued occupation and operation of the airbase politically untenable. If the airbase is providing an air-head and air support for a wider mission in the region, that whole mission may be jeopardised.

THE SUSTAINED FIRING OF TBMS, EVEN WITH POOR ACCURACY, HAS THE CAPACITY TO MAKE OPERATION OF AN AIRBASE POLITICALLY UNTENABLE.

[21] Carus, W.S., *Cruise Missile Proliferation in the 1990s,* Praeger Publishers, Westport, 1992, p 6.

The disruption to coalition activities by the 88 Iraqi SCUDs fired during the 1991 Gulf War was certainly out of all proportion to the predicted military utility of the weapon. Like the German V2 TBMs, the impact they can have is mainly one of disruption and a strong political message. Following a night of heavy SCUD activity, the US air component commander during the Gulf War is quoted as saying 'Last night could have been the turning point of the war. If [Saddam Hussein] had hit Riyadh Airbase and destroyed six AWACs or put chemicals on the F-15s at Dhahran, think of how the attitude and support of the American people might have changed'.[23]

An enemy with a timely intelligence capability could use this to specifically target high value aircraft when they were present at the airbase. This intelligence could be anything from real-time satellite data to human intelligence provided by personnel near the airbase observing an aircraft on landing approach. The short preparation and flight times of TBMs make them ideal for responding to this form of intelligence.

Cruise Missiles

Cruise missiles fly to their targets using a flight path similar to the one taken by an aircraft. Depending upon the sophistication of the missile and the desired mission profile this may include both high altitude cruise and low-level flight. Normally powered by a rocket motor or small jet engine they can be air, surface or sub-surface launched. Many specific definitions exist to separate cruise missiles from other types of self-propelled flying ordnance. One definition is 'a long range missile, powered by a jet engine, equipped with a guidance system and having some sort of aerodynamic lift'.[24] For the purposes of this book this definition is too specific and here a cruise missile is considered a long range guided missile, capable of sustained flight and generally launched at a target not directly visible to the firing platform.

Cruise missiles can be fitted with a variety of warheads including nuclear, unitary high explosive (including enhanced penetration warheads) and sub-munition dispensers. Advanced cruise missiles such as the American Tomahawk fly at low-level using advanced terrain matching guidance systems and terrain masking to avoid air defences. Cruise missiles will normally employ some form of spatial guidance to reach their targets and may feature additional terminal guidance systems. Table 3.1 details some characteristics of typical cruise missiles.

[22] Zaloga, S.J., 'Back-Door BMs: The Proliferation Threat Posed by Converted SAMs', *Jane's Intelligence Review*, 1 April 1999, http://defweb.cbr.defence.gov.au/jrl/janes/jir99/jir00200.htm accessed 11 August 1999.
[23] Story, W.C., *Third World Traps and Pitfalls – Ballistic Missiles, Cruise Missiles, and Land Based Airpower,* Air University Press, Maxwell AFB, 1995, p 52.
[24] Bonsignore, E. and Friedman, N., 'The Cruise Missile and Their Technology', *Military Technology,* April, 1983, p 64.

Missile	Range (kilometres)	Guidance	Warhead
Kh-15 Kickback (AS-16)	150	INS, Active or passive radio/radar	150 kg HE
AGM-86C CALCM	1,100	INS, GPS	910 kg HE
AGM-130	45	TV or Imaging Infra-red (IIR)	890 kg HE (Mk84)
AGM-84H SLAM-ER	280	INS, GPS, IIR	318 kg HE/Penetration
RGM-109 TLAM	900–1,700	INS, GPS, Tercom	454 kg HE or sub-munition
Kh-59M Kazoo (AS-18)	115	INS, TV command guidance	320 kg HE or 280 kg sub-munitions.
AGM-158 JASSM	250	INS, GPS, IIR	410 kg HE/Penetration
AGM-88 HARM	80	Passive radar, anti-radiation	66 kg blast/frag

Table 3.1 Leading Characteristics of Indicative Cruise Missiles[25]

Cruise missile systems are generally less complex, more accurate and cheaper than TBMs.[26] Accordingly, there is presently occurring a shift in many nations from TBMs to cruise missiles. By the year 2000, 24 developing countries will have operational TBMs or cruise missiles, six of which will have ranges in excess of 3,000 kilometres.[27] The French made Exocet anti-shipping cruise missile, which is deployed by over 17 countries world wide,[28] is presently being modified into a ground attack missile.[29] Any country operating the anti-shipping version could be a candidate for this medium-range precision strike capability. Boeing have also recently advertised their Block II Harpoon missile as being capable of striking land targets, using a combination of GPS and inertial guidance.[30]

Cruise missiles present a potent hazard to the airbase. However, they come at a considerable cost. The AGM-130 is a 2,000 pound warhead with a rocket motor and mid-course and terminal guidance package. Depending upon the information source, it has a unit acquisition cost of between $250,000[31] and $1,270,000. The AGM-142

[25] *Jane's Strategic Weapon Systems Update 30* and *Jane's Air Launched Weapons Update 32*, Jane's Information Group, Coulsdon, 1999.
[26] Story, *Third World Traps and Pitfalls – Ballistic Missiles, Cruise Missiles, and Land Based Airpower*, p 35.
[27] *Ibid.*, p 50.
[28] *Jane's Air Launched Weapons*, Issue 29, March 1998.
[29] Story, *Third World Traps and Pitfalls*, p 36.
[30] Boeing advertisement, *Jane's Defence Weekly*, 2 June 1999, p 34.
[31] Kopp, 'Breaking Serbia: The Allied Force Campaign Part 3', p 27.

Have Nap or Popeye, recently purchased by Australia has a claimed unit acquisition cost of $1.54 million.[32] At these prices regional air forces will not be able to afford large stocks of these weapons. Accordingly, precision guided long-range cruise weapons can be expected to be used against only the highest profile targets. The sustained restrike capability for most nations will be highly limited.

Another form of weapon which could be classed as a cruise missile is the use of modified Uninhabited Aerial Vehicles (UAVs) to deliver warheads onto airbase targets. Cheap and readily available, and capable of being fitted with a wide range of payloads and guidance systems, these weapons could be used as affordable and effective long range weapons. Fitted with a GPS guidance system, a laser or radar altimeter, and a sub-munition dispensing payload they could be programmed to over-fly known aircraft parking areas. Flying at night, slowly and very low they could also be quite survivable and would pose a unique air defence problem. They could be launched from small mobile platforms and would be difficult to track down and destroy on the ground.[33]

Cluster or Area Weapons

Cluster or area weapons rely on the deployment of a large number of smaller sub-munition warheads to attack a target area. Cluster weapon warheads can be fitted into free fall bombs, cruise missiles, TBMs, artillery shells and can also be released from dispensers attached to attack aircraft.

There are two components to a cluster weapons system — the sub-munitions or bomblets and the dispenser. The sub-munitions are contained in and released from the dispenser, which can either be released from the aircraft or retained. The sub-munitions themselves can have a wide variety of terminal effects including anti-armour, incendiary, chemical, fragmentation or area denial. Modern sub-munitions, such as the RTG SMArt-AT sensor fused weapon, incorporate their own terminal guidance to locate and attack mobile point targets. These weapons may also incorporate stand-off terminal effects such as self-forging fragment warheads which can disable hardened targets. Optimally, attacks with area weapons will utilise several types of sub-munitions simultaneously to attack disparate targets and delay post-attack recovery operations.

[32] Sengupta, P.K., 'Cruise Missiles for Asia Pacific', *Asian Defence Journal*, January/February 1999, p 40.
[33] Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise Missile and Ballistic Missile Attacks*, pp 15-16.

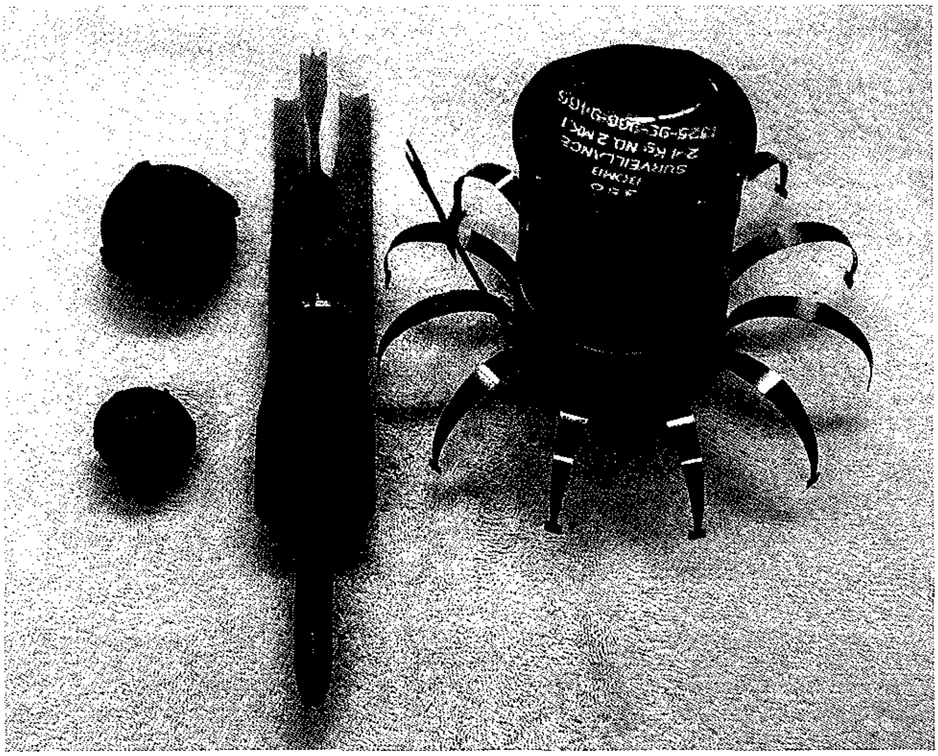

Figure 3.2 Four Different Sub-Munitions. (Photo courtesy RAAF EOD Flight)

The principal advantage of sub-munition warheads is the increased area over which damage will be inflicted. Unlike a unitary warhead, where the damaging effects of blast and fragmentation dissipate quickly with distance, sub-munitions produce moderate damage effects over a large area. This makes them particularly suitable for use against soft targets such as parked aircraft and unhardened airfield facilities. One analysis claims that a cruise missile with a 30 kilogram sub-munition warhead is three times more effective against parked aircraft than the same missile with a unitary warhead. Similarly, a 500 kilogram TBM warhead would cover almost eight times as much area if used to dispense sub-munitions (assuming a perfect scatter pattern).[34]

Chemical or Biological Weapons

Chemical weapons are those that rely on the poisonous or toxic effects of a chemical agent to kill or incapacitate. Biological weapons deploy bacteria or viruses to cause disease and sickness, again with the aim of killing or incapacitating personnel. The

[34] Stillion and Orletsky, *Airbase Vulnerability to Conventional Cruise Missile and Ballistic Missile Attacks,* p xiii.

nature of the modern combat airbase makes them very attractive and viable targets for Chemical or Biological (CB) weapons. These reasons include:

- CB weapons have an area effect, making them suitable for the large 'target zones' encountered on the airbase. This effect can compensate for inaccurate delivery platforms such as older TBMs or unguided bombs.

- CB weapons can have a persistent effect, which will degrade the airbase's ability to generate missions for a considerable period of time. Unlike other military units, an airbase cannot be simply moved to an uncontaminated area.

> THE VERY NATURE OF THE AIRBASE MAKES IT A PARTICULARLY TEMPTING TARGET FOR THE USE OF PERSISTENT CHEMICAL AND BIOLOGICAL WEAPONS

- CB weapons are potentially easy to procure by small nations or groups and can be delivered by a wide range of aerial or ground platforms.

- CB weapons can be used to kill airbase personnel without causing significant damage to equipment or facilities. This can be beneficial if the ultimate aim is to capture and use the airfield.

CB weapons are available with many different natures and capabilities and can also be deployed in a very wide variety of ways. Table 3.2 details some of the methods by which CB weapons can be deployed.

Chemical agents once dispersed can remain in either vapour or liquid form and can enter into the human body through inhalation, absorption through the skin or ingestion. Chemical agents are also further subdivided into persistent or non-persistent agents, depending on how long before the agent dissipates through evaporation, chemical breakdown or weathering.

Possible CB Weapon Delivery Modes	
Point Sources	**Line Sources**
Ballistic Missile • 500 kg chemical • 5 kg wet Anthrax	**Aircraft Spray Tank** • 1,000 kg chemical agent • 100 kg dry Anthrax
Artillery • 5 kg chemical agent	**UAV Spray Tank** • 100–500 kg chemical agent • 0.5–15 kg dry Anthrax
Air Delivered Bomb • 150 kg chemical agent • 5 kg wet Anthrax	**Covert Vehicle Spray Tank** • 150 kg chemical agent • 50 kg dry Anthrax
Improvised Man Portable Covert Bomb • 5 kg dry Anthrax	

Table 3.2 Possible CB Weapon Delivery Modes[35]

Non-persistent agents are likely to be deployed against the airbase in a surprise attack, with the aim of killing or incapacitating as many people as possible. Lethal chemical agents such as GB or GD nerve agent are almost undetectable without specialist detection equipment and can cause extremely rapid death from very small doses. Persistent versions of these agents, such as VX, possess the same lethality and can contaminate areas for extended periods of time until cleared by decontamination. Persistent agents would normally be deployed against airbases in repeated attacks to force personnel to remain in a protected posture degrading their ongoing performance.

According to one source at least 14 countries outside NATO and the Warsaw Pact had an offensive chemical weapons capability in 1992, and that 10 more were actively seeking or developing the capability.[36] Another source reports that 10 nations possess or are developing biological weapons.[37] Work is also under way in the former Soviet Union to design biological agents that destroy crops or livestock or damage military equipment by corroding specific materials, destroying plastics or rendering fuel useless.[38]

In addition to the lethal nerve agents there are many other varieties of agent, both lethal and non-lethal. Table 3.3 presents a representative sample of these agents and their characteristics.

---

[35] Chow, B.G., Jones, G.S., Lachow, I., Stillion, J., Wilkening, D. and Yee, H., *Air Force Operations in a Chemical and Biological Environment,* RAND Corporation, Santa Monica, 1998, p 40.
[36] Carus, *Cruise Missile Proliferation in the 1990s,* p 43.
[37] Beal, C., 'Facing the Invisible Enemy', *Jane's Defence Weekly,* 4 November 1998, p 26.
[38] Venter, A.J., 'Spectre of Biowar Remains', *Jane's Defence Weekly,* 28 April 1999, p 22.

Agent	Agent Group	Identifying Code	Persistency	Rate of Action	Physiological Action and Systems
Sarin	Lethal — Nerve	GB	Non-persistent	Very Rapid	Interferes with nervous system, tightness of chest, sweating, muscular paralysis and cessation of breathing, death
VX	Lethal — Nerve	VX	Persistent	Rapid	
Cyanogen Chloride	Lethal — Blood	CK	Non-persistent	Very Rapid	Interferes with use of oxygen by the body. Accelerated breathing rate, coughing, giddiness, convulsions, coma and death by asphyxiation
Phosgene	Lethal — Choking	CG	Non-persistent	Immediate to a number of hours	Damages lung lining and floods lungs. Rapid shallow breathing, froth at the mouth, weakness and death
Lewisite	Damaging — Blister	L	Persistent	Rapid	Blisters and destroys tissue. Arsenic content may cause systemic arsenic poisoning. Red eyes, burning throat, reddening of the skin, blisters. Can be fatal if inhaled.
Quinucidinyl Benzilate	Incapacitating	BZ	Non-persistent	Delayed	Sleepiness, decreased alertness, progressive intoxication. Flushed skin, dry mouth, constipation, disorientation, maniacal behaviour.
CS	Riot Control	CS	Semi-persistent	Immediate	Watery and painful eyes, runny nose, sinus pain, burns to nose and lungs

Table 3.3 Characteristics of Typical Chemical Agents

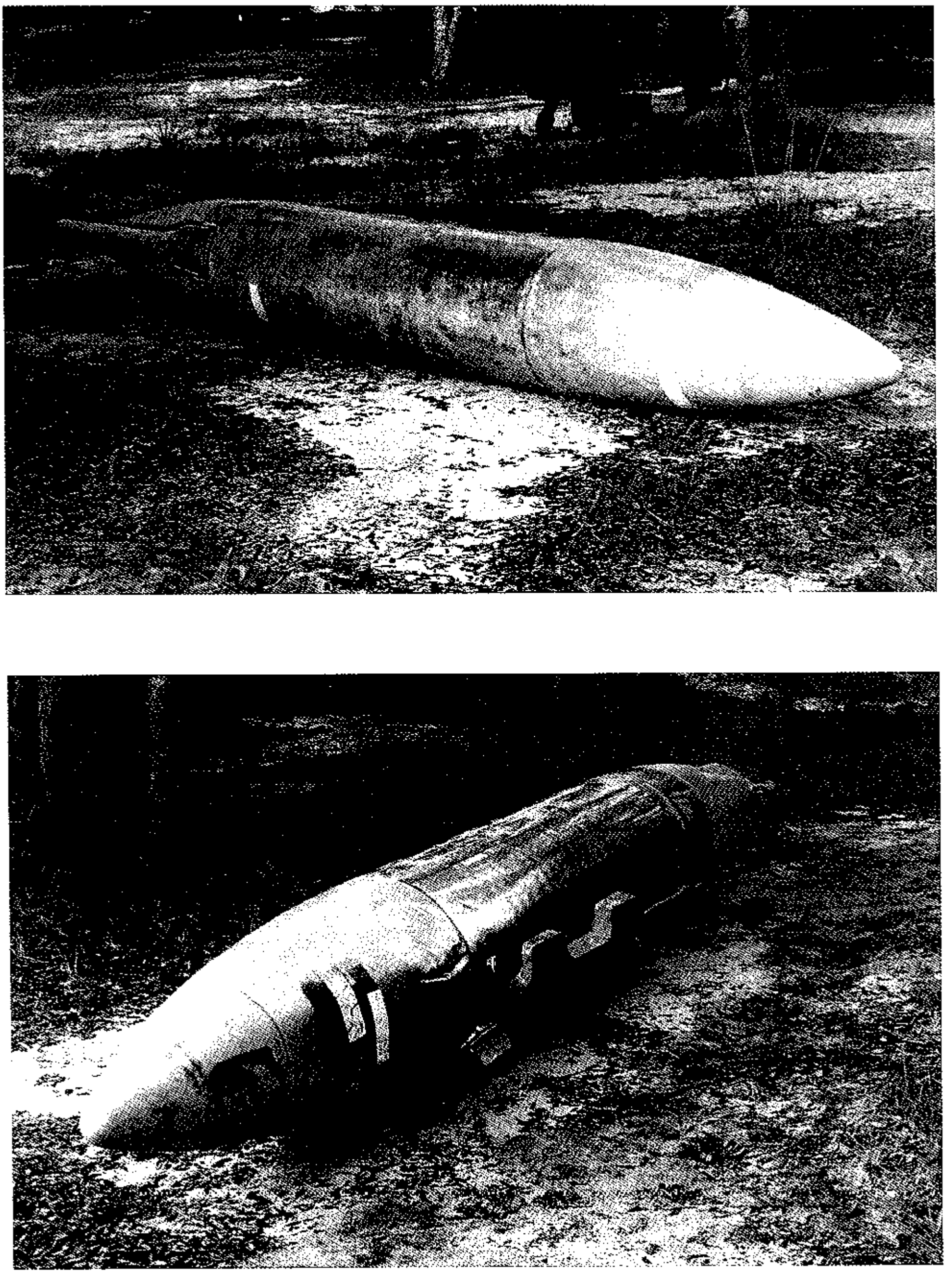

Figure 3.3 Two Views of a TMU-28 Chemical Spray Tank (Photos by Author)

Defences against chemical agents are well developed, and are likely to present at any serious modern military airbase. However, these protective measures can be cumbersome, stifling and can considerably slow down ground operations. This degradation in sortie generation would be the most likely aim of a chemical attack on an airbase. Once the airfield has been contaminated by a persistent agent, three options are available:

- Decontaminate the airfield (or critical areas) to minimise contamination and continue operations.
- Continue operations whilst utilising chemical protective equipment.
- Abandon the airfield and operate elsewhere.

These options are considered in further detail in Chapter 11.

Biological weapons can be a potent threat against an unprepared airbase. 'Given the correct delivery conditions, an attack with anthrax could produce casualty levels approaching those of a nuclear attack. Anthrax is highly infectious at low exposure levels and with over a 90 per cent mortality rate.'[39] Other biological agents such as Q fever are normally not fatal and can be used to incapacitate airbase staff. Despite their potential effectiveness, biological weapons are currently viewed as less of an immediate threat than chemical weapons. Although the technology to breed biological vectors and agents is relatively simple, effectively deploying and controlling the use of such weapons is seen as more difficult. Most biological agents decay relatively rapidly in the environment, particularly when exposed to sunlight. Typical night time decay rates are between 0.1 and five per cent per minute. Like chemical agents the weather can therefore have a very large impact upon the effectiveness of any biological attack.[40]

Most known military biological agents can be countered by immunisation (although at great cost), and basic hygiene and sanitary precautions can be effective in limiting the utility of biological weapons. Many are also only dangerous when breathed in and therefore masks alone offer high levels of protection.

Fuel-Air Explosives

Most military explosives are either solids or liquids, which are self-contained, detonating without the aid of external oxygen or an oxidising agent. FAE utilise the principle that gas or aerosol clouds consisting of vapours or small particles can become explosive when mixed in the correct proportions with air. Modern FAE weapons disperse clouds of ethylene or hydrocarbon compounds which are then ignited after a short delay. The clouds then burn explosively producing very high overpressures and blast effects over a wide area.

[39] Beal, 'Facing the Invisible Enemy', p 24.
[40] Chow, et al, *Air Force Operations in a Chemical and Biological Environment*, pp 29-30.

FAE weapons have many advantages over conventional weapons, particularly for airbase attacks. Some of these advantages include:

- The oxidising agent for the blast is provided by the air, rather than carried within the explosive compound like a conventional explosive. This allows FAE weapons to be more effective, weight for weight, than conventional weapons.

- Since the FAE cloud spreads over a wide area before detonating it can produce a wider and more evenly distributed overpressure than a conventional explosive that detonates at a single central point.

- The cloud can disperse into and around obstacles and unsealed fortifications, and follow the contours of the ground. This reduces the effectiveness of hasty protective works such as foxholes and trenches, which can provide effective protection from the fragmentation of conventional warheads.

- FAE weapons use blast overpressure as their primary damage mechanism and produce little or no primary fragmentation. This localises their damage effects as fragmentation can cause scattered damage out to great distances from a conventional warhead detonation. This makes FAE weapons suitable for use near friendly forces or near facilities that are to be preserved. FAE could be used to attack parked aircraft on an airbase that can be captured and utilised later. FAE could destroy the aircraft and cause minimal damage to nearby facilities or operating surfaces.

As stated before, parked aircraft and soft airfield facilities such as hangers, communications masts, towers and exposed support equipment are very vulnerable to the effect of blast overpressures. Table 3.4 details the damage that can be expected to typical aircraft and airbase facilities when exposed to blast overpressure.

Damage Effect	Overpressure Range (kPa)
90% of exposed glass windows shattered	1.7–4.1
Aircraft — damage to control surfaces and other minor damage to aircraft	6–13
Aircraft — major damage — deep level maintenance required to repair aircraft	13–24
Collapse of steel panel construction buildings	19–24
Aircraft — total destruction probable	24 and above
Severe damage to cars, trucks and ground support equipment	55–206

Table 3.4 Overpressure Effects on Airbase Features[41]

[41] Royal Australian Air Force, *DI(AF)AAP 7039.010 Improvised Explosive Device Disposal,* 1998, pp 4D-1 – 4D-3.

Damage Effect	Overpressure Range (kPa)
Threshold for eardrum rupture	13
Serious missile wounds — 50% fatalities	27–34
50% probability of eardrum rupture	34–48
Threshold of internal injuries	48
99% fatalities from lung haemorrhage	200–240

Table 3.5 Overpressure Effects on Personnel[42]

Typical second generation (currently fielded) FAE weapons can produce overpressures at the centre of the cloud of 3 MPa.[43] Experimentation with advanced mixtures is producing even higher peak pressures, with the programmed ignition of FAE warheads at precise heights believed to be capable of generating peak pressures in excess of 6.2 MPa. By way of contrast, a reinforced concrete aircraft shelter designed specifically to resist blast effects would collapse at 482 kPa.[44] The detonation of a 1,000 pound third generation methane FAE would destroy aircraft parked over 210 metres from the centre of the blast.[45]

Table 3.6 shows the diameters within which four different FAE warheads would produce overpressures in excess of 42 kPa. From Table 3.4 it can be seen that within this large blast area all significant airbase features would be destroyed. Unprotected aircraft and other soft facilities would be destroyed at commensurately greater distances, distances in excess of what they would normally be vulnerable from conventional blast/fragmentation warheads.

FAE Charge Weight (kg)	2nd Generation FAE Warhead Overpressure Diameter (m)	3rd Generation FAE Warhead Overpressure Diameter (m)
553	220	410
1000	310	490

Table 3.6 Effective Blast Areas for Methane FAE Weapons[46]

42 Royal Australian Air Force, *DI(AF)AAP 7039.010 Improvised Explosive Device Disposal,* 1998, pp 4D-1 – 4D-3.

43 Geisenheyner, S., 'FAE development: disturbing trends', *Jane's Defence Weekly*, 21 February 1987, p 280.

44 Ball, D.J. and Rosen, S.J., 'Fuel Air Explosives for Medium Powers', *Pacific Defence Reporter*, April, 1977, p 16.

45 Ball and Rosen, 'Fuel Air Explosives for Medium Powers', p 17.

46 Johannsohn, G., 'Fuel Air Explosives Revolutionise Conventional Warfare', in RAAF School of Air Navigation *Conventional Weapons Student Notes*, East Sale, 1993, p 69.

Area Denial Weapons

Area denial weapons are those which do not detonate or function immediately upon landing or impact, but incorporate a time delay or other activation mechanism causing them to function at a later time. Because the functioning time of the weapon is generally unknown, they deny the enemy the use of the area around them. Area denial weapons will also normally incorporate sensors using a variety of stimuli to cause them to function if approached or disturbed. This feature is designed to prevent their removal from the impact zone prior to detonation.

Area denial weapons may take the form of:

- Explosive Ordnance (EO) with long delay, anti-disturbance and influence fuses.
- A carpet of bomblets, possibly with armour defeating or anti-personnel capability and fitted with the above mentioned fusing.
- Unrecognisable EO that cannot be identified by the unit Explosive Ordnance Disposal (EOD) personnel and therefore they cannot assess the hazard posed by the ordnance, nor what may cause it to function. Accordingly, a worst case scenario may need to be assumed, which is that the weapon incorporates area denial features.
- Non-fused or dummy fused EO can be used to give the appearance of area denial weapons. Where an attacker has only limited stocks of true area denial weapons they may choose to mix these with similar looking weapons which do not have any fusing fitted. The only way to tell the difference between these and the genuinely fused weapons is by close inspection. This is a hazardous and time consuming operation. For little expenditure the attacker can greatly increase the amount of time the airbase is closed to operations. This technique is particularly effective when used with large unitary bombs that often bury themselves on impact. Where some of these bombs are found to have area denial, influence or time delay fusing, then all subsequent unexploded bombs must be assumed to be fitted likewise. To excavate and inspect each and every one of these will dramatically tax the EOD forces.
- Chemical weapons or bomblets, generally with persistent chemical agent.

The normal application of area denial weapons during airfield attack will be as a complement to direct action weapons. The area denial weapons will be deployed around the damage inflicted by the direct action weapons to hinder and delay the repair process. Area denial weapons can be extremely sensitive and can be triggered by a variety of stimuli including acoustic, seismic, magnetic, trip-wires, random time delay or movement.

Area denial weapons can also provide a cost-effective counter to hardened facilities. By effectively preventing movement around these hard-points and preventing personnel, vehicles or aircraft from moving from them, they temporarily negate them as operational assets. Unless specialist resources are available to clear them, this could be for an untolerably long period of time.

Area denial weapons also need not be deliberately fused as such. The presence of unintended UXO will also have an area denial effect, simply because of the unpredictable and dangerous nature of munitions in that state. As an example between 0130 and 0230 on 14 June 1943 the Luftwaffe bombed the English port town of Grimsby in an effort to close the port to naval shipping. Thirty aircraft dropped 18 tonnes of bombs of which:[47]

- 3.5 tonnes were 2,250 anti-personnel bomblets fused to detonate on impact;
- six tonnes were small incendiary bombs (6,000 bomblets);
- 3.8 tonnes were large incendiary bombs; and
- the remainder were large high explosive bombs.

Some results of the Grimsby raid were :

- nobody moved in some areas for three days;
- the initial clearance took 19 days and 10,000 man-hours;
- EOD teams dealt with 1,350 anti-personnel bomblets (60 per cent of those dropped);
- some UXO was so inaccessible that some areas were left for clearance until after the war; and
- during the raid 17 people were killed, but of greater concern, in the days following the raid a further 59 were killed by UXO.

Of note when comparing this historical example to the modern threat is that four modern ground attack aircraft can carry the same payload as the thirty aircraft of the Grimsby raid. A World War II German cluster container held 23 bomblets, modern containers may hold between 150 and 600 bomblets.

Disposal of area denial weapons is the responsibility of EOD teams. These personnel have had extensive training in the identification, render safe and disposal of these types of weapons. Given the sensitivity and unknown nature of many of these weapons the use of non-EOD qualified personnel to approach them will result in high casualties and further damage to airbase features. The EOD teams will use a variety of techniques to dispose of the area denial weapons, the details of which are covered more fully in Chapter 11.

[47] UK Ministry of Defence, *JSP 364 Joint Service EOD Manual*, 1993, p 7-3.

Specialised Runway Attack Weapons

In the last 20 years a number of weapons designed to specifically attack airfield surfaces have been developed. Although generally cluster weapons in nature they have sufficiently unique characteristics to warrant consideration as a separate class. Examples of these weapons are the British JP 233 and the French designed Durandal and BAP100 systems. They all share the common requirement for the attacking aircraft overflying the runway surface. The weapons are released and penetrate the runway surface using a variety of techniques. Once under the runway the main warhead functions creating the largest possible crater in the runway.

These weapons were used extensively in the 1991 Gulf War with mixed results. Two major impediments to their use in that environment were noted. Firstly, these weapons required straight low-level overflight of the runways. The large number of automatic anti-aircraft guns and shoulder-fired surface to air missiles deployed by the Iraqis made low-level attacks more hazardous than higher level bombing. Secondly, the runways in Iraq were built to extremely high standards; they were so thick that the small warheads of the sub-munitions often failed to penetrate. This caused the primary warheads to blow small scabs in the runways rather than causing large displaced craters. One review rates 'the damage caused by the JP 233 sub-munition was inconsequential'.[48] However, against pavements designed with lesser strength, these systems can cause significant damage.

The French Thomson Brandt Armaments BAP100 (*Bomb Accélérée de Pénétration*) has been in production such 1982 and was used operationally by the French Air Force against the Ouadi Doum airfield in Chad on 16 February 1986. Each weapon weighs 36 kilograms and houses a 20 kilogram warhead. Eighteen weapons are carried on a single Jaguar aircraft. Released at speeds of up to 550 knots the weapon is initially retarded by a parachute that is jettisoned when the weapon is pointing towards the runway surface and a rocket motor fires driving the warhead through the pavement layer. The system can be used from altitudes as low as 80 metres and it is claimed that a stick of 18 BAP100s, dropped at an angle of 30 degrees to the centreline of a 45 metre wide runway gives a 90 per cent probability of denying a 15 metre wide gap for operations.[49]

Soft Kill Weapons

Soft kill weapons refers to a family of unconventional weapons whose purpose is to disable or degrade a target without necessarily destroying or damaging it in the traditional manner using high explosives, chemicals or kinetic energy. Weapons of this type under development include:

- **Carbon-graphite fibre bombs.** These weapons are used to disable electrical generation or transmission facilities by dispersing a large number of conductive

[48] Centner, C.M., 'Ignorance is Risk', *Airpower Journal*, Vol 6, No 4, Winter, 1992, p 32.
[49] Braybrook, R., 'Airfield Denial', *Defence*, May, 1986, pp 232-233.

threads or wires over the target. They can be deployed in cruise missile warheads or in sub-munitions, such as in the US CBU-94 system. The wires are deployed over power grids and transformer yards shorting out electrical circuits disabling or destroying them. Such weapons were reputedly used in the 1991 Gulf War[50] and during NATO air attacks on Serbia in May 1999.[51]

- **Electromagnetic pulse weapons.** These weapons generate powerful electromagnetic energy pulses, which are used to destroy electronic circuitry. Generated by a variety of means these weapons are used to destroy communications, computers, electrical systems and weapon guidance systems. Unconfirmed reports indicate that Tomahawk missiles were fitted with high power microwave (electromagnetic pulse) generators and used to disrupt Iraqi electronic circuits during the 1991 Gulf War.[52]

Unexploded Explosive Ordnance Lodged in Aircraft Structures

This particular category of ordnance is unique in that it poses a very different set of challenges to airbase staff. Aircraft returning from combat missions may be damaged by enemy or friendly fire and it is possible that these aircraft may return with UXO lodged within their airframes. This poses a great hazard to Aircraft Battle Damage Repair (ABDR) crews and unless dealt with safely may prevent the repair and continued operation of that aircraft. Dealing with ordnance encountered during ABDR within aircraft is a highly specialist EOD task, and teams skilled in ABDR EOD must be available if ABDR is to be continued on aircraft with UXO on board.

The types of EO that may be encountered during these operations include small and medium calibre gun projectiles and surface-to-air missile warheads. In June 1966 a US F-105 Thunderchief was struck by an air-to-air missile which failed to explode and remained lodged in the rear section of the fuselage.[53] The aircraft was able to land safely following the incident where the dangerous cargo was removed and made safe. It is also reputed that the recovery of an unexploded AIM-9B Sidewinder missile lodged in the rear of a Communist Chinese Shenyang F-6 fighter enabled the Soviets to copy the design and produce the AA-2 Atoll missile.[54] The missile had been fired during combat between Communist and Nationalist Chinese aircraft over the Formosa Straights in the early 1960s.

[50] Marolda, E.J. and Schneller, R.J., *Shield and Sword,* Naval Historical Centre, Washington DC, 1998, p 417.
[51] Fulghum, D.A., 'Electronic Bombs Darken Belgrade', *Aviation Week and Space Technology,* 10 May, 1999, p 34.
[52] Jane's Air Launched Weapons Update 32, Tomahawk missile entry.
[53] United States Air Force, *Air War Vietnam,* Arms and Armour Press, London, 1978, p 16.
[54] Kopp, C., 'The Sidewinder Story', *Australian Aviation,* April 1994, p 82.

DAMAGE CAUSED TO AIRFIELD SURFACES BY AERIALLY DELIVERED WEAPONS

Aircraft Operating Surfaces Construction Methodologies

A principal target unique to airfields are the airfield operating surfaces. Other features such as fuel storage, buildings and other infrastructure are similar to those found on military and civilian facilities other than airbases and will respond to attacks in similar and well documented ways. Runways, and other Aircraft Operating Surfaces (AOS), because of their size, construction and usage are unique and the methods used to damage them need special consideration.

Worldwide, the fundamental principles used in the construction of AOS do not vary significantly. Two main construction methodologies are used — flexible and rigid pavements.

Flexible pavements are the simplest and are constructed from a layer (or layers) of compacted bituminous materials layed over a compacted base course. These pavements are often cheaper to construct and easier to repair, but require suitable soil conditions to provide sufficient strength for jet aircraft operations.

Rigid pavements utilise a hard pavement surface (usually of concrete) over a thicker layer of prepared and compacted base course. Typical thicknesses for modern runways designed to support combat jet operations are pavement layers of 30–45 centimetres thick over base and sub-base courses of 80–150 centimetres. A thin surface covering of bituminous material may also be placed over the concrete.

Damage Caused to Airfield Surfaces by Aerially Delivered Weapons

Given the layered construction methods of most AOS, the most effective means used to damage them is to place an explosive charge under the main hard surface layer. This is then detonated producing the maximum possible crater size and radiated damage. An explosive charge confined under the pavement surface in this manner will produce more effective damage. Two main methods are presently used to place an explosive charge under the main pavement surface using aerially delivered weapons:

- Some weapons use kinetic energy to strike and penetrate the AOS surface layer. This kinetic energy is either imparted by the free-fall of the bomb (such as with the BLU-109 2,000 pound class penetrating unitary bomb) or through the use of a rocket motor (such as with the Russian BetAB-500ShP).

- Other weapons have dual warheads, the first being used to make a hole in the pavement to allow the secondary warhead entry to the AOS sub-layers. The SG 357 component of the UK JP233 system utilises this method.

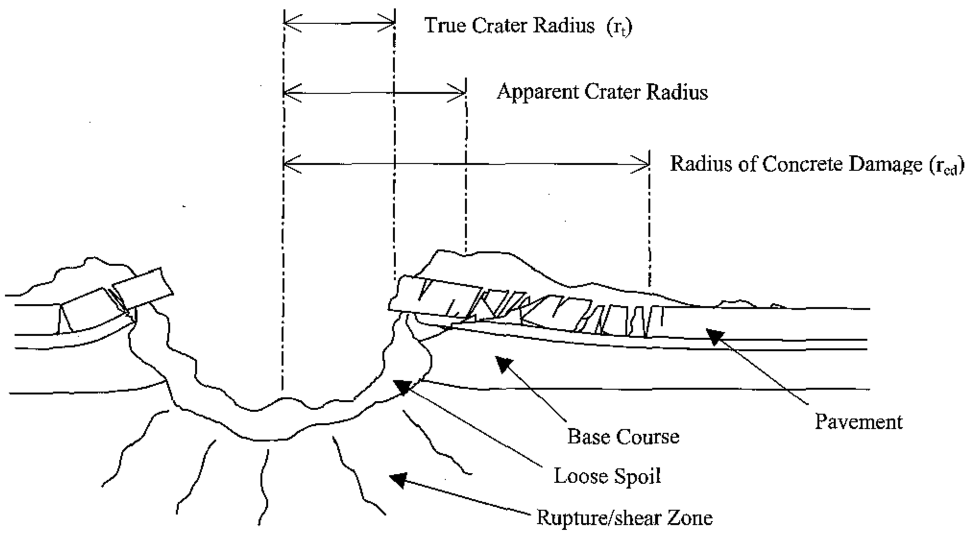

Figure 3.4 Damage Zones Resulting from Typical Crater in Concrete Runway

If the warhead of the weapon is not able to penetrate substantially into or through the AOS surface layer, the damage caused will be greatly reduced. Explosions on, or near, the surface of hardened pavements will cause small craters, called scabs or spalls, which do not penetrate the main surface layer. Most importantly, the damage will be limited to the scab itself with little cracking or movement of surrounding pavement.

If the warhead is able to penetrate the surface layer before detonating far greater damage may be caused. Figure 3.4 shows a simplified model of a typical crater in a concrete runway, illustrating the three main damage zones a buried explosion may generate. Of these, the radius of concrete damage (r_{cd}) is normally the most critical determinant of repair requirements. This area will be composed of concrete which has been cracked or lifted and may be covered by thrown spoil. Given the inability of most Western designed combat jets to tolerate even minor pavement surface irregularities, damaged concrete must be fully excavated (or in some cases effectively tamped down), and replaced before that area can be utilised.

The outermost area of damage encompasses the spoil throw from the crater and is termed the apparent crater lip. This spoil will prevent aircraft operations as it is a significant surface irregularity and presents a serious Foreign Object Damage (FOD) threat. FOD refers to objects that can be ingested into the jet engines of aircraft or cause damage to their landing gear. Typical FOD in a post-attack environment include dirt clods, rocks, pebbles, chunks of concrete and fragments of ordnance. Spoil is normally pushed back into the crater during repair activities and this may need to be done before the extent of true pavement damage can be determined. Table 3.6 provides typical maximum crater sizes for aircraft bombs in a variety of surface types.

Surface Type	Weapon	True Crater Diameter (m)	Actual Damage Diameter (m)
Hard Soil	Mk 82 low drag 500 lb GP bomb	7.9	-
	Mk 84 low drag 2,000 lb GP bomb	13.7	-
Soft Soil	Mk 82 low drag 500 lb GP bomb	11.3	-
	Mk 84 low drag 2,000 lb GP bomb	18.9	-
41.4MPa (6,000 psi) non-reinforced concrete runway 15–61cm (6–24 inches) thick, hard soil underlay	Mk 82 low drag 500 lb GP bomb	9.1–9.5	15.8
	Mk 84 low drag 2,000 lb GP bomb	16.1	27.4

Table 3.6 Typical Maximum Crater Diameters for Various Weapons v Surface Types[55]

In addition to penetrating explosive charges designed specifically to attack pavements, other types of munitions may cause damage to the AOS. These may have been deployed against the AOS or other airbase targets and includes aircraft cannon projectiles, air launched rockets, surface burst bombs and land service munitions such as mortar bombs etc. These weapons will typically cause scabbing of the pavement, and generally will not penetrate the hard surface layer. These small craters or indentations may still need to be repaired before they can be traversed by jet aircraft.

Flight Profile Limitations

When attacking hardened targets or airfield pavements from the air the requirement for the munition to penetrate before detonating severely limits the flight profiles that can be chosen by the attacking aircraft. Weapons without integral retardation/acceleration systems (such as the JP233 system described above) must be deployed in such a way that they strike the surface with sufficient velocity and at an appropriate angle to penetrate. Too slow an impact speed (vertical component) or too low an impact angle may cause the weapon to ricochet or fail to penetrate. Accordingly, the choice of delivery profile will be determined by both the warhead requirements and the capabilities of the airbase active defences.

If stand-off weapons are not employed the following broad categories of attack profile can be used, each with their own inherent limitations:

Laydown or Low-Level High-Speed. This attack profile is good for achieving maximum surprise and minimum exposure to medium level defences. If the weapon is large and is dropped at high speed from low altitude retardation is essential to ensure that the aircraft itself is not caught within the lethal radius of the impacting weapon. This retardation is then likely to prevent the weapon from being able to penetrate a

[55] Data extracted from unclassified components of Appendix B to US FM 101-50-1 Change 7.

hard target, such as a pavement. For this reason purpose designed retarded/accelerated weapons are often employed to support this attack profile. This attack profile has the advantage of short weapon flight times and inaccuracies have little time to build up. Significant errors can occur in range, although considerable range errors can be overcome by using stick deliveries.[56]

Medium Level Delivery. Attacks from medium altitude can be made using either level flight or dive attacks. Weapons delivered from this profile do not need retardation and will generally impact with high speed and a good angle. Accuracy using this method can also be acceptable particularly if dive-bombing or sticks of bombs are used. It also presents the pilot with the best opportunity to acquire the target. The principal disadvantage of this method is it exposes the aircraft to the airfield active defences. Modern surface-to-air missile systems have made this attack profile generally an option only when overwhelming air superiority and defence suppression is available.

Toss or Loft Delivery. Toss deliveries enable the attacking aircraft to run into the target at very low altitude, toss the bomb towards the target, and then egress without being exposed to target point defences. This method of delivery provides the bomb with substantial impact velocity and possibly the appropriate impact angle to penetrate hard targets. The primary disadvantage of this method of delivery is that it can limit the accuracy that can be achieved. Therefore, when attacking point targets, this method will normally be used with guided bombs.

Effect of Surface Thickness on Crater Size

For large unitary bombs (ie those with explosive weights in excess of 23 kilograms) the thickness of the pavement has little effect on crater or damage diameters.[57] For smaller weapons such as sub-munitions, artillery shells or rockets the thickness of the runway pavement is of critical importance. These weapons generally have insufficient kinetic energy or explosive force to penetrate a thick concrete and accordingly will only produce scabs or shallow scraps in the hard surface.

For larger weapons that do penetrate the pavement layer, the density and nature of the base courses is a critical determinant of crater diameter. For a Mk84 2,000 pound bomb penetrating a 30 centimetre thick concrete runway, varying the density of the base course from medium to hard will vary the maximum true crater diameter (horizontal) from 19.8 to 16.1 metres.[58]

[56] Walker, J.R., *Air-to-Ground Operations*, Brassey's Defence Publishers, London, 1987, p 103.
[57] US FM101-50-1 p 5-12.
[58] US FM101-50-1 Appendix B Change 7 p B-494C.

Effect of Depth of Burst on Crater Size

As a weapon pierces the runway surface and penetrates the underlayment, its point of detonation or Depth of Burst (DOB) will be determined by the impact velocity and the delay setting in the weapon fuse. As the DOB for a given weapon varies so will the characteristics and dimensions of the crater formed. Too shallow a DOB will cause a shallow slab or spall crater to be formed with little upheaval of surrounding pavement as the majority of the detonation energy is vented to the atmosphere. Too deep a DOB will reduce the crater volume as the deep earth absorbs the detonation forces. This may cause a camouflet, or subterranean crater, which does not necessarily penetrate the surface.

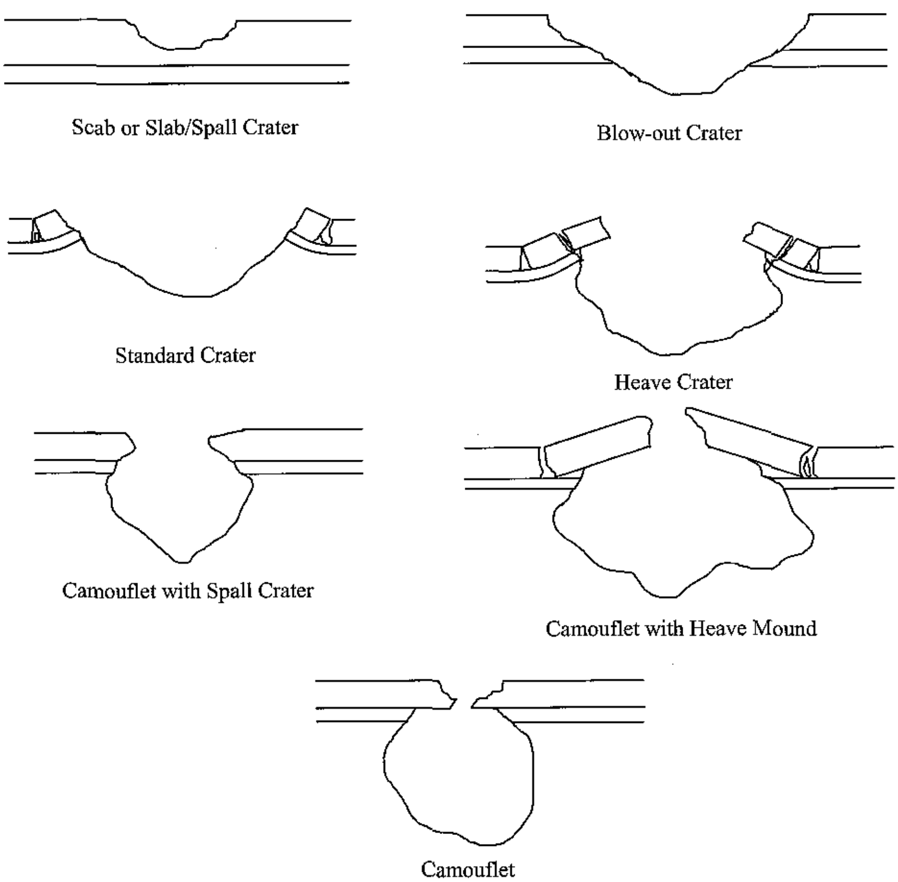

Figure 3.5 Types of Craters on Concrete Runways[59]

[59] Adapted from US FM 101-50-19 p 5-13.

Figure 3.5 shows the basic types of craters that may be formed in concrete runways. It can be seen that the heave crater and the camouflet with heave mound crater cause the maximum damage to the pavement surfaces. To create these effects careful matching of DOB to warhead weight is required.

The optimal DOB will be achieved by maximising the crater volume and area of disrupted pavement. The fuse functioning delay time setting to achieve optimum DOB can be determined if weapon impact velocity and angle are known. One limiting factor with runway penetration attacks is the maximum velocity at which a given bomb can strike a hard surface without breaking up. If the impact velocity is too high case break up or fuse failure may occur. Specialist penetrating bombs are available that can survive these kinds of impact forces at the expense of reduced explosive content.

Figure 3.6 Example of a Scab or Spall Crater

SUMMARY

Airbases have always been vulnerable to attack from the air. Even unsophisticated, inaccurate weapons, such as early generation TBMs, can still pose a real threat to airbase operations. However, in the last 50 years the ability of aircraft to attack, and therefore influence, ground operations has improved by orders of magnitude. Aircraft ranges, capabilities, navigation systems and sortie rates have increased. The weapons they deploy have increased in accuracy, range, lethality and in the choice of guidance methods available.

Of particular note in the last decade has been the emergence and operational debut of air-to-surface weapons guided by global satellite navigation systems such as GPS. These pose a particular threat to airbases as they are purpose designed to attack fixed geographical points. They are especially adept at this task, being able to operate in all weather conditions and freeing the launch platform from the risk of having to aim the weapon themselves after launch.

Airbases can also no longer rely upon their distance from the 'front line' or traditional battlefield for protection. 'The same technological advances in offensive weapons, communications, and transportation that reduced the size of the globe have increased the physical size of the conventional battlefield — particularly the area associated with the conduct of Tactical Air Operations.'[60] The repeated attacks by the Israeli Air Force on Egyptian airbases on the first day of the 1967 war clearly showed that it was not only possible to attack airbases in the rear areas, but they could be attacked several times in a single day.

Despite this, our reliance on fixed airbases and extensive support infrastructures has remained, and in some cases has expanded. Accordingly, the requirement to protect airbase operations from air attack has increased commensurately. Fortunately, as aircraft have developed so have the means of detecting and destroying them. Advanced radar and surface-to-air missile technology can significantly limit the freedom of operation enjoyed by attacking aircraft or cause casualties unacceptable in the long term.

Having just described the range of ways airbases can be attacked this may seem a difficult, if not impossible, task. But, by understanding the means by which airbases can be attacked and knowing the specific capabilities and limitations of the adversary, passive counter-measures can be used to limit the options available to them. Once they have been reduced to a few possible courses of action active defences can be employed far more effectively. When active and passive defences are seen to be orchestrated in this way the airbase will appear a far less tempting target.

[60] Ellis, G.E., 'In Search of a Better Eagle's Nest', *Air Force Journal of Logistics*, Summer, 1986, p 7.

CHAPTER 4

The Threat — Attack From the Ground

In the case of British special forces attacks on Axis airfields in North Africa [during World War II], the loss of aircraft was so severe and the airpower balance so precarious that they may have influenced the outcome of the campaign.[1]

INTRODUCTION

By virtue of their value as a military target airbases have been and will continue to be targeted by enemy ground forces and ground based elements. If air operations are having, or are likely to have, a significant impact on the enemy's objectives the neutralisation or degradation of the ability to support air operations may be given a high priority. Where friendly forces have air superiority over the airbase and its surrounds, or the enemy does not possess an air strike capability, attack from the ground may be the only option to disrupt air operations. Commensurate ground assets may be assigned to accomplish this task.

Ground forces have been used to attack airbases many times in the past. One source claiming that this has been undertaken 645 times in the period 1940–1992 in which over 2,000 aircraft were damaged or destroyed.[2] These attacks have varied enormously in their methodology and the weapons used. Examples range from large SAS and Long Range Desert Group motorised raids on German airfields in North Africa during World War II to single, irregular Viet Cong sappers penetrating US airbase defences in Vietnam.

This chapter seeks to describe the variety of potential ground threats against airbases. It explains firstly why ground forces would be employed against the airbase, and details the missions, methods and weapons they may employ. The geographic scale of this threat is also described, as ground threats need not penetrate the airbase perimeter defences to cause harm to vital assets. Finally, as the first step to defeating an enemy is to understand them, a short description of the planning process used by the ground enemy is presented. This analyses the

[1] Vick, A., *Snakes in the Eagle's Nest,* RAND Corporation, Santa Monica, 1995, p 109.
[2] *Ibid.*, p xiv.

threat from within, discussing their capabilities, motivations and opportunities. Special Forces are a unique and particularly potent threat against airbases and the chapter concludes with a discussion of the methods by which they may select and prioritise targets.

The Australian Context

There is no reason why Australian airbases should be considered immune from ground attack. ADF bases, be they overseas during expeditionary operations, or within Australia, either in the north or more populated south, may be vulnerable to ground attack. 'A determined adversary would be able to penetrate the [air-sea] gap to conduct dispersed special forces operations or rapid attacks, possibly with small or lightly equipped forces.'[3] Under even greater threat still, would be RAAF aircraft, equipment and personnel should they be deployed overseas.

WHY ATTACK FROM THE GROUND?

An aggressor may choose to use ground forces to attack the airbase for the following reasons:

Air Superiority. An important goal of most air power doctrine is to gain control of the air component of the battlespace, and in particular over a nation's own territory, approaches and vital interests. The successful achievement and maintenance of this air superiority will generally protect airbases from air attack, making ground attack the only option remaining to destroy those vital air assets. The more thoroughly friendly forces achieve air superiority the more limited the options available to an opponent to attack aircraft whilst on the ground.

Enhanced Selectivity. The use of ground forces to undertake an airbase attack provides the attacker with a higher degree of subtlety and selection than is available with an air attack. Although the recent use of increasingly precise targeting and precision guided weapons has given the airborne platform previously unheard of accuracy the ground attack still provides the attacker with a higher degree of precision. During Operation *Just Cause* in 1989 the US used a Special Forces (SF) SEAL team to infiltrate Paitilla airport to destroy Manuel Noriega's jet to prevent him from escaping the country. In this example, the use of ground forces provided a high level of selectivity and reduced the potential for civilian collateral casualties.

Lack of Appropriate Enemy Air Forces. In some circumstances airbases may be targeted by forces who do not have access to combat aircraft or whose air power cannot effectively reach the airbase. Examples of this could include lower level or counter-insurgency operations being conducted against terrorist or rebel organisations.

---

[3] Sanderson, J.M., 'Army Beyond 2000', in Stephens, A., (Ed), *New Era Security*, Air Power Studies Centre, Canberra, 1996, p 104.

In this scenario the enemy has no option but to use ground forces as they possess no organic air power in the traditional sense. The asymmetric use of non-conventional air power such as 'Kamikaze' style remotely piloted vehicles or hijacked small civilian aircraft can be considered terrorist weapons. A further situation where aerial forces may not be available to an enemy is during operations against a force with limited air power, and where strategic or tactical considerations mandate the use of that limited air power elsewhere. An example could be a surprise first strike against a nation's national interests by an opponent with only a limited capability to project sea and/or land based air power into the region. Political imperatives may have dictated a target list that does not allow air resources to be used in an offensive counter air role. Accordingly, there is potential for Special Forces to be used to suppress the air defences for a limited period to allow the strikes to be undertaken.

Cost Effectiveness. The acquisition and maintenance of air power assets capable of conducting strike operations against airfield targets is expensive. Even older aircraft with unguided ordnance have high procurement and upkeep costs. The mounting of an air strike is an expensive decision, particularly where there is potential for losses or attrition. The loss of two or three jet combat aircraft during an airbase attack will incur a multi-million dollar replacement cost. The loss of combat aircrew during these operations will further increase the ongoing cost of the operation.

Anonymity. Unlike attacks from the air, ground parties can attack or sabotage an airbase target with a potential degree of anonymity or non-attributability. The use of proxy warfare, or third party irregular or terrorist forces to undertake attacks on behalf of a sponsoring nation-state is a highly feasible method of striking at an enemy without necessarily escalating the conflict. It is normally easier to disguise the national origins and/or patronage of a ground party than combat aircraft.

CATEGORISATION OF THE GROUND THREAT

For the purposes of this analysis categorisation of ground threats can be achieved three different ways — by the mission of the attacking force, by the methodology of the attacking force or by the main weapons employed by the attackers. Any attacking group can be categorised by each of these distinguishing features. Table 4.1 details a selection of potential categorisation methods.

Obviously, these categorisations are neither exclusive nor exhaustive, and there are many alternative ways of undertaking this task. Also, an attacking group may fall into several of these categories. It would be unlikely in fact for an attacking group to have one mission, one method of attack and utilise only one basic weapon type. Simultaneous attacks, with a variety of objectives and using a variety of attack methods are typically more likely to be successful than single attacks that can be responded to with the full weight of available airbase active defences.

Mission
Harass personnel
Destroy aircraft
Halt operations
Distraction
Political statement or demonstration
Reconnaissance or surveillance
Target designation or forward observation
Capture Airfield
Destroy supporting or co-located facilities

Methodology
Sapper or penetration party
Reconnaissance party
Air mobile, air/land or airborne forces
Remote/stand-off attack
Main force ground party
Non-lethal attack element
Raiding party

Weapons
Direct fire weapons
Indirect fire weapons
Surface to air missiles
Demolition charges
Improvised explosive devices
Chemical or biological weapons
Alternative or non-destructive methods

Table 4.1 Categorisation of Airbase Ground Threats

The RAND Corporation in its analysis of ground threats to USAF facilities describes a similar, but simpler range of threats.[4]

- Destroy high value assets critical to USAF operations.
- Temporarily suppress sortie generation at a critical moment in a crisis or conflict.
- Create a 'strategic event' — an incident that is as decisive politically as loss of a major battle is militarily — which could reduce US public or government support for ongoing military operations.

Historically the greatest proportion of airbase attacks have been aimed at destroying aircraft. Figure 4.1 details the relative proportion of attack objectives during the period 1940–1992.

[4] Shlapak, D.A. and Vick, A., *Check Six Begins on the Ground,* RAND Corporation, Santa Monica, 1995, pp 15-19.

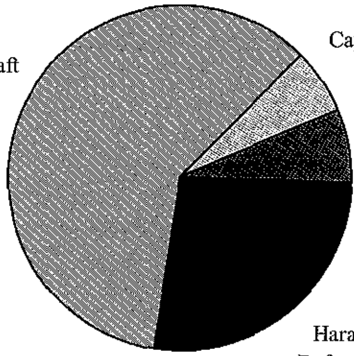

Figure 4.1 Relative Proportions of Airbase Attack Objectives[5]

Ground Attack Missions

Destroy Aircraft

During the period 1940–1992 the most common airbase attack objective was to destroy aircraft.[6] Aircraft are soft targets and are highly susceptible to damage from impact, overpressure or fire. Small arms damage to the electronic components of an airborne early warning aircraft may be sufficient to cause a mission kill. That is, the targeted aircraft can no longer perform its designated mission and may need to be returned to a rear echelon maintenance organisation for repair.

Further compounding this problem, as more maintenance services are commercialised the ability of front line operational level maintenance staff to perform unscheduled repairs such as battle damage repair may commensurately fall. This is a natural result of this maintenance shift causing detailed aircraft systems knowledge to be transferred from uniformed technical personnel to their civilian counter-parts.

As military combat aircraft become progressively more expensive, and accordingly fewer are purchased, they will become individually more valuable targets. The use of very small numbers of force multiplier platforms such as airborne early warning and control or airborne tanker aircraft will make them exceptionally attractive targets, the destruction of which will have a disproportionate effect on a nation's ability to project air power. This vulnerability is magnified by the fact that most non-super-power nations are likely to never operate more than a handful of these aircraft with little hope of timely replacement should a proportion be destroyed or disabled.

[5] Vick, *Snakes in the Eagle's Nest,* p xvii.
[6] *Ibid.*, p 109.

Further compounding the problem, these aircraft are normally too large to be accommodated in hardened shelters or effectively revetted. Accordingly, an air force's continued investment in small numbers of these high value force multiplier aircraft without a commensurate investment in their defence introduces unprecedented vulnerabilities to a well briefed enemy.

> FORCE MULTIPLIER PLATFORMS SUCH AS AIRBORNE EARLY WARNING AND TANKER AIRCRAFT ARE PARTICULARLY ATTRACTIVE TARGETS TO A WELL BRIEFED ENEMY AND ARE VERY DIFFICULT TO DEFEND EFFECTIVELY.

Halt Operations

A potential objective of a ground party may be to disrupt operations from the airbase for a period of time. This may be to allow other enemy operations to be undertaken without disruption from aircraft based at the airbase. It would be unlikely that a potential adversary could mount a sufficiently strong ground offensive to completely overrun or capture a major operating airbase. However, it may be desirable for the enemy to disrupt air operations at that base for a short period of time. Where the objective of this attack was an airlift hub, the resulting suspension of operations can conceivably produce significant 'virtual attrition'.[7] That is the temporary suspension of airlift operations reduces friendly capability in the theatre by reducing available forces and consumable supplies.

The use of a small ground attack element to pin down airbase operations and prevent aircraft preparation or take off for a period of 20 minutes could allow an air attack to be mounted on the base or an airborne insertion of forces.

Distraction

The objective of the raiding party may be to cause a distraction either to the airbase defenders or at a higher strategic or operational level. By engaging airbase defences at one point it can create opportunities for penetration or raiding parties to assault from another direction. Where an airbase has limited ground defence force in reserve or a single mobile reaction force the distraction can be particularly effective. Continued deployment of a reaction force will tire it and reduce its effectiveness during a real assault.

[7] Shlapak, D.A. and Vick, A., *Check Six Begins on the Ground,* p 17.

The distraction can also be used to harass the defenders and to deny them rest periods. The continual probing of perimeter defences, particularly at night can be used to maintain an extended defence alert state. Personnel not normally employed in ground combat occupations are particularly susceptible to this form of probing. This will tire defenders and eventually lead to a reluctance by the ground defence headquarters to signal higher alert states until individual threats are better identified. This may assist penetration parties.

These attacks may also be used to probe the defences. This can be undertaken to establish the strength of the defences or to determine the procedures and routes used by mobile defensive reserves or reaction forces.

Political Statement or Demonstration

Airbases are highly visible targets, which can be used quite effectively to make highly visible public statements. The actions undertaken to make this statement may not necessarily be destructive or overtly violent, but may be part of a program of civil unrest or demonstration. The violent political statement can take the form of a terrorist incident or bombing. The non-violent protest can take the form of peaceful demonstrations at the gates of airbases.

Terrorist attacks, particularly by those with religious or quasi-religious motives are far more likely to cause casualties than other forms of attack. 'Although religious terrorists committed only 25 per cent of the recorded international terrorist incidents in 1995, their acts were responsible for 58 per cent of the terrorist-related fatalities recorded that year. The attacks that caused the greatest numbers of deaths in 1995 — those that killed eight or more people — were *all* perpetrated by religious terrorists.'[8]

With the rise in the religious imperative for terrorism since the 1970s there is more potential for attacks to be directed against targets for the purpose of purely making a 'statement'. 'During the 1990s, the proportion of religious terrorist groups among all active international terrorist organizations [sic] grew appreciably.'[9] Airbases are potentially popular targets for terrorist organisations as they have a high profile and are full of visibly expensive and sophisticated equipment.

Their targets of choice on the airbase may not necessarily accord with what would be considered militarily significant or of importance to a conventional military campaign. Wanton destruction or maximum casualties may be their aim. A popular term in use today for these kinds of enemy mission planning is asymmetric warfare — their objectives, values and methodologies may be very different from ours. Many potential threats to the airbase may choose to prosecute their campaign in a very different manner from which forces representing a modern industrialised nation state would. Airbase defenders must avoid 'cultural myopia' and try to predict attacks based upon

---

[8] Hoffman, B., *Old Madness New Methods,* RAND Review, Vol 22, No 2, Winter 1998-99, pp 14-15.
[9] *Ibid.*, p 14.

the beliefs, values and motivation of the likely threat groups, not on what they themselves would do.

Reconnaissance or Surveillance

Perhaps one of the most common missions of a small party will be to infiltrate on or near the airbase to undertake surveillance operations such as observation or reconnaissance. This information may have a wide range of purposes, however, the two most common are: collection of operational intelligence, termed intelligence collection reconnaissance; and preparation for an impending attack, termed local reconnaissance.

- Intelligence collection reconnaissance is more strategic in character than local reconnaissance and will normally take place over an extended period of time. The enemy is seeking to determine the salient features of the airbase, its contribution to the broader campaign and develop an understanding of the operating procedures and patterns of the unit and its assigned elements. Intelligence collection can occur at any time and at all places in the spectrum of conflict from peacetime through to total war. Intelligence collection agents work during peacetime and will employ a wide variety of clandestine, covert and open source methods to obtain information about airbase activities.

- Local reconnaissance is used as a preliminary for an attack or other overt operation. The attack may be mounted by the same individuals undertaking the reconnaissance or by a separate party. Normally personnel undertaking this mission will be attempting to localise targets and determine the exact nature of the airbase defences. They may employ entirely stand-off methods but are more likely to be active, probing the defences to find weaknesses. Conducting local reconnaissance can alert the airbase defences to the existence and intent of the potential attacking force. Careful analysis of ground combat incident reports can help defenders interpret these probing operations and improve their defensive positions.

All forms of reconnaissance can be undertaken with varying degrees of intrusiveness. The intelligence collection may be undertaken by an observer on a hill, who simply logs aircraft movements in and out of the airbase. Similarly, coastal airbases could be monitored by a submarine or 'fishing vessel' nearby. This will enable operational patterns to be documented aiding future attacks or providing intelligence to distant commanders who wish to know when aircraft are launching from that airbase. Intelligence collection and reconnaissance can also be highly intrusive with the use of covert agents or local employees who have access to the airbase to provide support services. The increasing reliance of many air forces on contractor support, particularly locally in deployed locations, makes this form of intelligence collection more difficult to prevent.

During operations other than war, the threat to airbase security from criminal elements ensures that a reconnaissance threat will also exist. Organisations such as criminal motorcycle gangs have been known to encourage their female supporters or contacts into employment with police departments, government offices and security firms providing security for defence establishments.[10]

Target Designation or Forward Observation Party

A common mission or secondary task of a ground party is to act as forward observers and controllers providing fire adjustments in support of indirect fire directed at the airbase. By watching the fall of shot from the indirect fire and advising the firing party on how to adjust their point of aim, effective artillery, mortar or rocket fire can be directed at targets within the airbase. Another task may be to use a laser to designate targets for an air attack using laser-guided bombs. This technique has been recently employed in the 1991 Gulf War and during operations against Serbia in 1999 to obtain complete assurance that the designated target was the correct one and to relieve the attacking aircraft of the designation role. A common link between these tasks is that the party must get to a position where they can physically see the desired target.

Capture Airfield

If given this mission the assigned ground forces will attempt to capture the airfield to allow it to be used for their own purposes. This will normally either be to deny the use of the airfield to the enemy or to allow the use of the airfield and facilities as an air-head for the insertion of follow on forces during an invasion or occupation. Airborne or air mobile forces will often be used for this role. German forces used this type of attack successfully in World War II in Belgium, the Netherlands, Norway and Crete. British forces parachuted into the Egyptian El Gamil airfield during their occupation of the Suez Canal in 1956. More recently US forces captured airfields in Panama and Grenada to allow the insertion of forces during their respective occupations of those islands.

Destroy Supporting or Co-located Facilities

It is often the case that supporting facilities at the airbase may be more mission critical or valuable than the aircraft themselves. An example may be a maintenance facility for a piece of mission critical aircraft equipment. The destruction of this facility may jeopardise the airbase's ability to support missions for a considerable period of time, whereas the destruction of a limited number of aircraft may only interrupt operations until new aircraft can be flown in.

The identification of vital supporting facilities is a crucial and often difficult step in a base survivability plan. It requires wide consultation with all personnel involved in airbase operations and aircraft support. Functional area managers often do not have the highly detailed knowledge of their own area's activities to enable them to identify less obvious mission critical items. The personnel who actually undertake the tasks

[10] Jones, C., *A Security Police Strategic Vision for Operational Considerations into the Next Century: New Criminal Threats and the Australian Defence Force,* Air Power Studies Centre Paper No 67, Canberra, 1998, p 27.

and have a highly detailed knowledge of their procedures may not possess the broad appreciation of where they fit into the mission support picture to make these judgements either. It requires input from all parties to generate a complete and prioritised list of vulnerabilities.

> THE FAILURE TO IDENTIFY EFFECTIVELY AND THEN DEFEND APPROPRIATELY CRITICAL SUPPORTING FACILITIES CAN MAKE THEM A MORE ATTRACTIVE TARGET THAN HEAVILY DEFENDED AIRCRAFT.

Ground Attack Methodologies

Sapper or Penetration Party

The mission of this group is to penetrate the defences of the airbase to attack at close quarters aircraft, facilities, materiel or key personnel. The penetration party will normally seek to penetrate the outer defences without engaging them. If the unit is detected and engaged by airbase defenders at the perimeter it greatly reduces their chances of successfully reaching and attacking their target of choice.

The principal means of defeating the penetrating ground threat are deterrence, detection and mobility.[11] The main aim should be to deter the enemy from attempting the attack through a variety of means. These include the use of intelligence information to thwart the attack before it can be started. Detection requires that the defences are able firstly to detect the incursion, preferably before it is well underway, and secondly to pass clear warning of the attack effectively to the relevant command presence. Ideally, the impending attack should be detected, denied or defeated as far from the airbase as possible, thus avoiding decisive engagements close to the airbase. Where the attack is detected relatively close to the airbase mobility will be the key to enable the placement of sufficient personnel and firepower at the attempted incursion site to defeat the attack.

Reconnaissance Party

The mission of the reconnaissance party is to observe the activities of the airbase and report this back for later use. The distinguishing features of the reconnaissance party are:

- It will avoid contact with airbase defences whenever possible.

[11] Shlapak and Vick, *Check Six Begins on the Ground,* p 66.

- It may require a communication link back to its supporting forces, to relay what has been observed.

Air Mobile or Airborne Forces

Air mobile or airborne troops will seek to attack the airfield by avoiding the external or perimeter defences and deploying directly onto their target of choice. This can be achieved by:

- Landing troops in fixed-wing aircraft on the airbase's own runways.
- Helicopter insertion directly onto the airfield or immediate surrounds.
- Parachute landings directly onto the airfield or immediate surrounds.
- Glider landing on runway surfaces or other flat unobstructed areas.

Normally a combination of these methods may be used, with a simultaneous or preparatory air or ground attack used to create a diversion. The aggressive maintenance of effective air superiority over the airbase will greatly reduce the opportunity for enemy forces to assault the airbase in this way. However, as demonstrated by the use of Syrian helicopters against Israeli troops in Lebanon during 1982 air superiority may not always be able to prevent low-level helicopter operations.[12]

The insertion of ground forces utilising airborne or air mobile methods has been used previously. The most famous example was the capture of British airfields on Crete by German airborne and glider borne forces. More recently US forces used a variety of air mobile or airborne assaults on airfields during the Panama and Grenada invasions.

Airborne or air mobile forces can also be deployed onto the ground directly outside the airbase perimeter or close defences. This may be the only or most expedient method for inserting ground troops into that theatre or it may be undertaken to avoid stand-off defences around the airbase.

Remote or Stand-Off Attack

Remote or stand-off attacks employ indirect fire weapons to attack airbase targets from a distance, usually outside any perimeter defences. Where an airbase is well defended, the use of stand-off or indirect attacks becomes particularly attractive.

[12] Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia,* Air Power Studies Centre, Canberra, 1992, p 157.

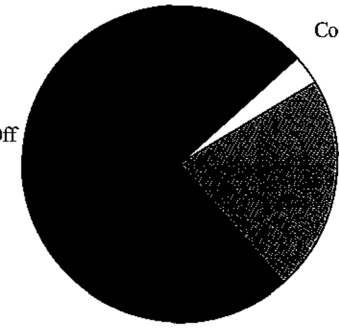

Figure 4.2 Relative Airbase Attack Tactics, 1940–1992[13]

As can be seen from Figure 4.2 the majority of ground attacks on airbases during the period 1940–92 have been stand-off attacks. With recent advances in terminal guidance for typical stand-off weapons such as mortars and rockets there is great potential for stand-off attacks to present not only a lower risk for the attacker but to be increasingly effective. The weapons can also be positioned and then fired after a delay by a timer, allowing the firing party to escape before the attack has even begun. This technique was popular with the Viet Cong/NVA in Vietnam and was also used often by Irish Republican Army terrorists when attacking targets in the United Kingdom using improvised stand-off weapons.

Viet Cong attacks on US airbases in Vietnam were preponderantly stand-off attacks using indirect fire weapons.[14] North Vietnamese Army (NVA) and Viet Cong teams would attack US airbases with rockets and mortars from outside the perimeter defences. Using this technique the attackers did not have to penetrate or engage the airbase defences, which in most cases were formidable. US forces found the most effective ways of preventing these attacks included the use of on-call close air support, the denial of an outer defence zone to the maximum range of the enemy weapons, the use of immediate counter-battery fire, and passive defence measures such as the construction of hardened facilities to protect aircraft and vital installations.[15]

Stand-off attacks on airbases using artillery have been used during other conflicts. Iraqi artillery was used to render the Ali Al-Salim airbase unusable during the initial assault on Kuwait in August 1990. The aircraft based there were evacuated to Bahrain and Saudi Arabia.[16] Similarly, the Isaraelis made good use of American made 175 millimetre guns during the 1973 Arab–Israeli conflict — bombarding Damascus airport for ten straight days during the war.[17]

[13] Vick, *Snakes in the Eagle's Nest*, p 107.
[14] *Ibid.*, p 107.
[15] Vick, *Snakes in the Eagle's Nest*, pp 85-88.
[16] *Loc cit.*
[17] Cordesman, A.H., and Wagner, A.R., *The Lessons of Modern War Volume I: The Arab-Israeli Conflicts, 1973-1989,* Westview Press, London, 1990, pp 67-68.

Indirect fire may also be directed at a coastal airfield by naval vessels nearby. Japanese naval gunfire was used to attack Henderson Airfield on Guadalcanal successfully during October 1942. With the use of extended range and guided or wind corrected munitions airfields, a considerable distance inland can be attacked in this manner. However, given the vulnerability of surface combatants without air protection to air attack, this method of attack would perhaps normally be limited to pre-emptive attacks on unoccupied airbases prior to their being activated.

The Main Force Ground Party

The main force ground party is a conventional military unit, present in some degree of strength, perhaps a battalion or more, generally with considerable supporting assets. The airbase may be the primary target of the offensive, or may be a secondary objective as part of a larger advance. Attacking formations of this size should be detected and countered by allied forces under the control of the theatre commander, as they will pose a threat far beyond the destruction of the airbase.

Where defence of the airbase from this level of threat falls to the organic airbase defence, air support provided by the airbase's own aircraft may be critical. Airbase defensive formations, local manoeuvre units and air support need to be all coordinated into a single cohesive plan to counter this threat.

Non-Lethal Attack Element

The aim of the non-lethal attack element is to employ unconventional typically non-physical methods to disrupt airbase operations. Common examples include the use of computer hacking or electromagnetic weapons to disrupt airbase information systems and operations. Other methods could include:

- Stand-off jamming or interference with airbase communications;
- Peaceful demonstrations or civil action to disrupt airbase operations or access to the base;
- The use of propaganda or psychological operations against the airbase or supporting personnel; and
- The use of a variety of methods, such as legal action or union militancy, to interfere with airbase logistic support.

The Raiding Party

The raiding party is a small unit who will attempt to attack the airbase using direct weapons, and whose method of penetration into the critical parts of the airbase is to engage and penetrate the outer perimeter defences. The principal difference between the raiding party and the penetration party is the chosen method by which entry to the airbase is obtained. The penetration party will attempt entry by stealth, the raiding party by more direct and violent means. Obviously, if compromised and provided with sufficient firepower the penetration party may attempt to complete their assigned mission using raiding party tactics.

Ground Attack Weapons

Direct Fire Weapons

Direct fire weapons are aimed at the target, generally visible to the firer, with the round taking a relatively flat trajectory to the target. Direct fire weapons can take numerous forms comprising small arms weapons, unguided explosive weapons and guided explosive weapons. Table 4.2 details some operating characteristics of typical direct fired weapons.

Weapon	Weight/Portability	Effective Range	Terminal Effect
Arsenal 7.62 mm AK-47M1 assault rifle.	4.19 kg loaded.	200–600 m.	7.62 x 39 mm round.
IMI 7.62 mm Galil Sniper Rifle.	6.4 kg including bipod & sling.	600–1,200 m.	7.62 x 51 mm NATO round.
Barrett Model 82A1 0.50 cal rifle.[18]	13 kg.	1,500–1,800 m.	.50 cal round. High explosive, incendiary and armour piercing effects available.
RPG-7 family.	Launcher (with sight) 6.3 kg, grenade 2-5 kg depending upon type.	Stationary targets 500 m.	Anti-tank, fuel-air, tandem anti-tank and high explosive.
9K113 Konkurs (AT-5 Spandrel) Anti-armour guided missile.	Launcher, with thermal sight and one missile — 62 kg.	4,000 m in good visibility.	Anti-armour or tandem anti-armour warhead, to penetrate up to 800mm of armour plate.
Talley M72 series 66mm Lightweight Anti-armour Weapon (LAW).	Carry weight 2.53.5 kg depending upon model.	Stationary targets 350 m.	Variety of light anti-armour warheads.
84 mm Bofors M3 Carl Gustav recoilless rifle.	22 kg (packed with accessories).	Practical range (dependent upon target and round) 1,300 m.	84 mm HE, anti-tank, smoke, illumination or dual purpose.

Table 4.2 Indicative Characteristics of Various Direct Fire Weapons[19]

However, it is also important to note, particularly when designing counter-measures to direct fired weapons, that their trajectory is not completely flat. It will be a shallow ballistic arc from firer to target, which may allow it to fire onto targets that are obscured by low obstructions.

[18] Tillman, A., 'Sniper Rifles', *Jane's International Defense Review*, Vol 26, December 1993, p 945.
[19] Jane's Infantry Weapons 1999-00 (Except where specified), Jane's Information Group, Coulsdon, 1999.

Indirect Fire Weapons

Indirect fire weapons are fired at a target that cannot necessarily be seen by the firer. The projectile or rocket fired normally taking a ballistic or arcing trajectory to fall onto a target some distance from the firer. Normally, a forward observer will be used who can see the target and the fall-of-shot and advise the firer on how to correct the firing parameters. The principal advantage of indirect fire weapons is that they can be used at greater ranges and can be fired at targets obscured by obstacles such as intervening high ground. Current developments in projectile guidance systems have made available terminally guided projectiles that seek out their targets during descent and do not require fire adjustment by a forward observer. The US National Ground Intelligence Center has predicted that the number of such Artillery Delivered High Performance Munitions (ADHPMs) will grow by more than 500 per cent in the next decade.[20]

Figure 4.3 RAAF Caribou Aircraft destroyed by mortar fire at That Son Airbase, Vietnam, March 1970. (RAAF Photograph Courtesy Mr Ted Strugnell)

[20] Ogorkiewicz, R.M. and Hewish, M., 'Active Protection: Providing a Smarter Shield for AFVs', *Jane's International Defense Review,* http://defweb.cbr.defence.gov.au/jrl/janes/idr99/idr00420.htm accessed 13 September 1999.

Indirect fire weapons can also be fused for air-burst, the projectile or rocket detonating in the air above the target, showering it with metal fragments. This is a particularly effective technique for attacking aircraft in uncovered revetments or personnel in open trenches.

Table 4.3 provides pertinent details for a number of indicative indirect fire systems. These weapons range from man-portable equipment to towed guns and rocket systems. The featured systems have been chosen because of their wide use throughout the world and to provide a good representative sample of these types of systems. It can be seen that many of the smaller systems are either man-portable or can be broken down into individual loads. This provides the ability to carry the weapons into the area surrounding the airbase and place accurate (potentially terminally guided) fire onto vulnerable targets. The firing party may then quickly move to a new firing point or escape completely. It is also possible to set up mortars, rockets or improvised indirect fire weapons on timers so that they fire a round into the airbase after the firing party have departed.

Developments in the last 20 years have seen the fielding of autonomously guided artillery and mortar projectiles. These allow a small stand-off party to fire rounds into the airbase and attack high value targets individually. The Strix 120 millimetre anti-armour mortar bomb uses an infra-red seeker during its descent phase to identify armoured targets. The bomb's guidance package then allows it to strike the top of the target destroying it. The use of this type of technology to fire mortar bombs into the general vicinity of a flight line of aircraft would enable pin point destruction of them without the firing team being exposed to perimeter or close in defences. It also obviates the need for a forward observer to direct the fire accurately onto the chosen targets.

The use of GPS guidance in artillery munitions has been pioneered by the US XM982 155 millimetre shell. This round enables GPS guided projectiles, carrying a variety of warheads to hit targets at ranges of 57 kilometres with accuracies of 20 metres.[21] These technologies are being applied to smaller and smaller projectiles and give the stand-off attacker a far greater ability to attack and defeat high value point targets from stand-off ranges without the need for a forward observation party.

Surface-to-Air Missiles

The first individually portable Surface-to-Air Missile (SAM) was the US FIM-43A Redeye missile, which weighed 13 kilograms (with launcher) and used an infra-red seeker to home in on the hot exhaust tail-pipe of an aircraft engine. Introduced in 1964, the missile was housed in a disposable launch tube and had an effective range of 3.3 kilometres.[22] These weapons are ineffective against aircraft at normal cruising altitudes but can be very effective against aircraft in the process of taking off or

[21] Jane's Ammunition Handbook, 1998-99, Jane's Information Group, Coulsdon, 1999.

[22] O'Neill, R., (Ed), *An Illustrated Guide to the Modern US Army,* Salamander Books, London, 1984 p 114.

landing. The area of land from which these weapons can be successfully used to attack arriving or departing aircraft is commonly termed the Missile Engagement Zone (MEZ). By carrying these weapons into the MEZs at either end of the runway, aircraft can be targeted during these vulnerable stages.

Weapon	Weight/Portability	Effective Range	Terminal Effect
Yugoslavian 60 mm M-70 mortar	7.6 kg total weight	2,540 m	HE, fragmentation, smoke, illumination
Yugoslavian 120 mm M74 light mortar	120 kg total weight	6,200 m	HE, fragmentation, smoke, illumination
Yugoslavian 82 mm M69A mortar	45 kg	6,050 m	HE, fragmentation, smoke, illumination
122 mm D-30 howitzer	Towed gun	21,900 m with rocket assisted projectile	HE, anti-tank, carrier, smoke, incendiary or rocket assisted
122 mm BM-21-P single rocket launcher	Launcher & tripod — 50 kg, Rocket — 45.8 kg	10,800 m	HE/fragmentation or chemical
FROG-7	Fired from mobile launcher	70 km	HE/fragmentation, nuclear, chemical or cluster
SCUD-C	6,400 kg launch weight, fired from a variety of fixed or mobile launchers	550 km	770 kg HE, chemical or sub-munitions. 700 to 1,000 m CEP
Splav 220 mm BM 9P140 rocket system	Fired from mobile launcher with excellent cross country mobility	35 km	16 rockets per launcher, warhead types including HE, or anti-personnel or anti-tank sub-munitions

Table 4.3 Indicative Characteristics of Various Indirect Fire Weapons[23]

Afghan rebel forces used SAMs particularly effectively against Soviet aircraft during the war in Afghanistan. An SA-7 was used to shoot down a transport aircraft on approach to Shindad airbase on 27 May 1986.[24] More recently, rebel forces in Africa have used Soviet-made SA-14 and SA-16s to shoot down aircraft on take off and

[23] Jane's Armour and Artillery, 1998-99, Jane's Infantry Weapons 1999-00, Jane's Strategic Weapon Systems (Update 29), Jane's Information Group, Coulsdon, 1999.
[24] Shlapak and Vick *Check Six Begins on the Ground*, p 31.

landing including an Antanov An-12 near Luanda and a Boeing 727 near Kisangani during late 1998.[25]

Aircraft are most vulnerable when taking off. During landing the pilot is actively looking for impediments to landing and will normally be aware of diversion sites should enemy activity be seen. During take-off the aircrew are concentrating very heavily on aircraft performance and have limited opportunities to see ground threats or react to them. Aircraft taking off are normally heavily laden with fuel and possibly ordnance, an impediment to defensive manoeuvre, particularly at slow speed. Jet engines on high thrust settings for take off and climb out are also easier targets for infra-red seeking missiles, particularly older models which may be commonly encountered in many world trouble spots.

Demolition Charges

Demolition charges are generally packs of high explosive with mechanisms attached to detonate them when desired. They can be of military origin or improvised or a combination of the two. They are commonly attached to high value targets and then detonated by timer, remote control or an anti-tamper mechanism. Military or well-constructed improvised demolition charges can incorporate a combination of these initiation mechanisms to prevent their removal once deployed. If discovered once emplaced, immediate action by a qualified explosive ordnance disposal team will be required to render the device safe to move.

By physically placing a demolition charge on or into a vulnerable part of an aircraft the effective destruction of that target can almost be assured. Demolition charges were used very successfully by British Special Forces to destroy Italian aircraft in North Africa during World War II, and again with Argentine aircraft on Pebble Island during the Falklands War in 1982.

Improvised Explosive Devices

Improvised Explosive Devices (IEDs) are homemade explosive devices that can take an enormous variety of forms. The improvised nature of the IED provides the designer with an enormous degree of flexibility. When employed by regular military forces IEDs will normally be designed to function as demolition charges and will share many of their characteristics. They may incorporate a mixture of improvised, commercially procured or conventional military equipment or explosives. IEDs may be divided into broad categories as follows:

- **Vehicle Bombs.** They can be built to any size specification ranging from a small cigarette packet to a fully laden semi-trailer. The improvised bomb used to kill 19 US airmen in the Khobar Towers bombing in 1996 contained the equivalent of

[25] Ventner, A., 'Mercenary Intentions', *Flight International*, Number 4660, Vol 155, Jan 1999, p 30.

20,000 pounds of TNT explosive.[26] These vehicle bombs may be parked outside a facility fence, such as at Khobar Towers, or driven into a critical facility such as the World Trade Centre buildings in February 1993 where Islamic extremists attempted to topple one of the towers. Vehicle bombs may also be parked outside a facility and used as an ambush weapon, being detonated as personnel or a supply column pass by.

- **Postal, Supply or Letter Bombs.** IEDs can also be constructed as mail bombs that are designed to be delivered through the mail, by courier or a supply delivery. As the precise delivery and handling of these devices cannot be predicted they are almost exclusively designed to be victim-operated, that is, function as they are being opened.

- **Emplaced Devices.** Emplaced devices function in a similar fashion to conventional military demolition charges. They are placed at the desired location and then functioned either by time-delay, when disturbed or when commanded through a variety of means such as a radio link.

- **Improvised Mortars, Rockets or Grenades.** These are fashioned to be similar to their conventional military equivalents and are fired or thrown at the target in the normal way.

Chemical or Biological Weapons

Chemical and biological weapons have often been termed the 'poor man's atomic bomb' due to their ability to cause mass casualties without the high degree of technical sophistication required for the production of nuclear weapons. The facilities required to make chemical or biological weapons are virtually identical to industrial facilities used to produce food, beer, pesticides or other organic chemicals.

Chemical and biological weapons are described in detail in the Air Threats chapter of this book. However, they may also be deployed by ground forces. The most likely means by which this can be done include:

- Chemical or biological warheads in stand-off weapon attacks such as artillery or rocket systems.
- The introduction of contaminants into the water, air or food supply of the base.
- The use of a variety of forms of improvised chemical devices, similar in nature to IEDs but with a chemical or biological rather than an explosive main fill.

[26] Grant, R., 'Khobar Towers', *Air Force Magazine*, Vol 81, No 6, June 1998, p 41.

One method of attacking an airbase with biological weapons would be the use of a spray system covertly mounted in a vehicle. By driving along a road up-wind of the airbase and releasing five kilograms of dry anthrax 130 km^2 could be contaminated with sufficient agent to kill 50 per cent of unprotected people exposed.[27]

Alternative Methods

In addition to the typically military style weapons discussed above the airbase attacker may choose to use alternate, less overt methods. Some of these include:

- Accessing the base's computer networks and information systems from an external point to steal, deny or modify information.
- Stand-off attacks on communications systems, land-lines and frequencies through jamming, electronic warfare, deliberately induced power fluctuations, etc.
- Attacks on supporting infrastructure external to the base, such as electricity supply, communications land-line or microwave connections, fuel or water supply.
- The introduction of contamination into the airbase's water, fuel, air or cryogenics or food supply. This could be the use of chemicals of biological agents to target personnel or contaminations designed to damage equipment or prevent operations.
- The use of psychological operations such as leaflets, harassment or continued attack warnings to demoralise the airbase defenders. This could include the targeting (or threat thereof) of personnel's family.
- The physical destruction of vital components or obstruction of airbase activities by such activities as vandalism or blockade.
- The theft of important equipment or supplies which are required to support airbase operations.

TOPOGRAPHIC SCALE OF THE GROUND THREAT

Clearly the use of weapons such as mortars, rockets and long range direct fire weapons will enable the enemy to attack targets at the centre of the airbase without having to penetrate the perimeter defences. The US and Australian experience in Vietnam demonstrated that where perimeter defences are formidable this will often be the attack methodology of choice.

Tables 4.2 and 4.3 provide indicative distances over which long range attacks can be mounted using the weapons detailed. These templates are shown diagrammatically in Figure 4.4. A range of typical airbase targets are used and dotted circles (footprints) indicate how far away these targets can be engaged using a variety of weapons. Of importance in this diagram is the size of these footprints as compared to the shaded

[27] Chow, B.G., Jones, G.S., Lachow, I., Stillion, J., Wilkening, D. and Yee, H., *Air Force Operations in a Chemical and Biological Environment,* RAND Corporation, Santa Monica, 1998, p 36.

area enclosed by a typical base perimeter fence. Obviously, to prevent such attacks the use of the ground encompassed by these footprints should be denied to the enemy.

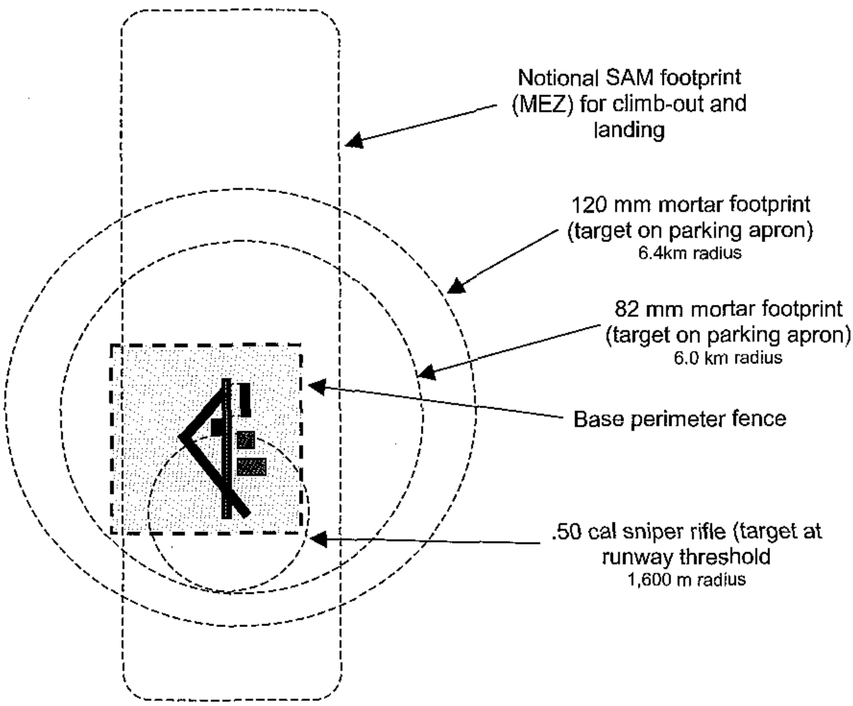

Figure 4.4 Notional Threat Stand-Off Footprints[28]

Also, it is important to control this extended area to provide the airbase's own defences and support services freedom of movement. Perhaps the most common example would be to to deploy air defence assets such as surface to air missiles or mobile radars into this zone without having to provide them with heavy ground defence.

Motivation, Capability and Opportunity

Having discussed the spectrum of ground threats against airbases there remains to be defined the common requirements of all of these disparate groups. To prevent attacks that can be undertaken in so many different ways it is important to find and identify these common needs.

[28] Shlapak and Vick, *Check Six Begins on the Ground*, p 59.

There are three primary ingredients that are normally required before a ground party can successfully attack airbase targets. These are motivation, capability and opportunity. Each element is generally required for a successful airbase ground attack to be prosecuted. The motivation leads to the development of a capability, and the capability allows the exploitation of an opportunity. To prevent the ground attack on the airbase any one of the three tiers can be eliminated. The combined effect of motivation, capability and opportunity is shown diagrammatically at Figure 4.5.

By replacing the term motivation with 'intent' it can be seen how this model relates to the commonly used military assessment technique of threat = capability x intent + opportunity.

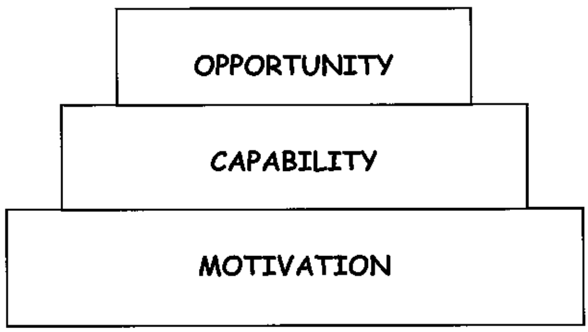

Figure 4.5 Motivation, Capability and Opportunity Pyramid

Motivation

Firstly the group must have a reason to wish to attack assets within the airbase. This is the hardest requirement for airbase commanders to target, as it will normally be beyond their capability to influence. However, some measures have been tried previously to reduce the motivation of personnel to want to attack an airbase. This has included the use of civil affairs programs surrounding the airbase (further detailed in Chapter Seven).

The objectives or purpose of the attack will be crucial in determining how it can be thwarted. The attack can have one or a combination of several broad aims as has been presented above. These are:

- Harassment of personnel,
- Destruction of aircraft,
- Interruption of operations,
- Distraction,
- Political statement or incident,
- Reconnaissance or surveillance,

- Destruction of supporting facilities, or
- Capture of the airfield

Capability

Secondly the group must possess the capability to attack the base. Capability reflects the physical ability of the raiding team to carry out its intended mission. There are many factors that will determine whether or not a group has the capability to attack the airbase.

- Equipment,
- Training,
- Provisions & resupply,
- Mobility, and
- Determination.

Opportunity

The final ingredient is the opportunity to attack their chosen target. The probability that a group will have the opportunity to attack will depend upon the following:

Target Selection. Target selection will be greatly influenced by the higher directives provided to the group. An attacking group which is attempting to destroy a very specific target or facility will have less opportunity to attack than a group which has more flexibility in its target selection. Airbase defenders have little input into this factor. However, effective intelligence can alert defenders to the likely priority targets within the airbase. Depending on the nature of the base some of these may be very obvious, others may be not so and may depend heavily on the specific 'doctrine' of the threat force. An example of target selection that surprised defending forces was the use of a large truck bomb to kill 19 US servicemen at the Khobar Towers accommodation complex in Dhahran, Saudi Arabia on 25 June 1996. Whereas the base housed a large number of expensive combat aircraft the attackers chose to target the accommodation block to achieve the particular aim of their own campaign. A squadron commander from the targeted unit, the 4404th Wing, stated: 'Here we were, one of the most lethal air components in the world, an F-15 squadron, and someone sneaks up in the middle of the night and cuts our underbelly'.[29] Similarly, during the 1991 Gulf War British military personnel employed at the Akrotiri airbase were shuttled to their off-base accommodation by helicopter to avoid potential terrorist attacks on the roads.[30]

[29] Grant, 'Khobar Towers', p 47.
[30] Waters, *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia,* p 154.

Nature of the Target. The target chosen by the raiding force will normally be determined by the motivation and intent of the attacking force. A well organised force may have primary and secondary targets. A force that merely aims to harass the base or make a political statement may be entirely flexible in its target selection, choosing a target of opportunity as one is presented.

Net Effectiveness of the Airbase Defence. An effective airbase defence will obviously reduce the opportunities available to an attacking force. Note, however, the use of the term 'net effectiveness'. An airbase defence can be very impressive but still may have gaps and vulnerabilities that can be exploited by the attacker. A defending force that has no capability to detect intruders in darkness may have little net effectiveness at night, despite the number of guns, vehicles, personnel or hardened positions which they may deploy. Net effectiveness is the ability of the defending force to deploy and utilise its assets in preventing opportunities for the attacking force. The defence net effectiveness will be highly dependent upon the employment of suitable force multipliers such as unattended ground sensors, dogs, heavy weapons, light armour, and night vision equipment.

Capability of the Attacking Force. The more capable the attacking force the more flexibility they will have to exploit opportunities. Mobility and firepower will enable the raiding force to exploit small opportunities. Many recent developments have greatly enhanced the relative capabilities of small parties. These include lightweight, highly accurate GPS navigation aids, lightweight secure satellite communications equipment, shoulder launched surface to air missiles, night vision equipment and heavy calibre sniper rifles.

A final cautionary note. Of the three 'required' ingredients only motivation is truly necessary. Motivated groups who lack the appropriate capability and/or opportunity may still want to attack the airbase. Groups with sufficient motivation may be inspired to attack the airbase defences despite (knowingly or otherwise) lacking sufficient capability or an appropriate opportunity. Such attacks may be born from desperation or from fanatical zeal and may still inflict significant casualties on the base personnel and defence force.

SPECIAL FORCES OPERATIONS AGAINST AIRFIELDS

Special Forces (SF) units are a specific and potent threat against the airbase. They possess a flexibility that is unavailable in other attack methods and can be employed in a wide variety of roles. To defeat a SF enemy the defence must understand their strengths, weaknesses, the ways in which SF are employed and the ways in which they will select their targets.

Special Forces Strengths and Weaknesses

SF groups will normally be selectively recruited, well trained, well equipped and highly motivated. Some of the specific strengths of SF include:

- SF personnel are highly trained and capable of undertaking a wide range of actions and utilising a variety of methods and weapons.
- SF can be retasked, or can modify their goals or tactics on their own initiative, and therefore provide a great deal of flexibility.
- SF can utilise stealth and guile to loiter near or on the airbase to conduct extended operations or to exploit lucrative targets of opportunity.
- SF can be used to provide a great deal of intelligence information back to the tasking authority. This intelligence gathering may be their primary mission or may be gathered incidentally during the course of other tasks.

SF also have significant weaknesses that can be exploited by the airbase defence. Some of these may include:

- SF parties are normally quite small and generally limit the number of personnel they deploy to improve their stealth. They may have been required to use unusual insertion methods to reach their objective or insertion point or to have covered large distances on foot. This may limit their mobility or the equipment, supplies and firepower they may be able to deploy.
- SF parties may be operating far from friendly support, with little potential for resupply or reinforcement.
- SF forces may be operating in unfamiliar territory without local knowledge, undertaking their own reconnaissance as they move.
- SF personnel are a highly limited resource. They are generally only available in small numbers and have a long lead-time to train and replace. Accordingly, they have limited ability to sustain heavy casualties, as this may greatly impact on their ability to undertake further operations.

Special Forces Missions

The inherent strengths and weaknesses of SF are a main factor in determining the nature of the missions assigned to them. Some of the more common SF mission categories include the following:

Surveillance and Reconnaissance. Perhaps the most common tasking for SF is to perform surveillance and reconnaissance. This may be an entire mission in itself or may form the initial stage of further SF or other forces attacks against the airfield. Often, this mission will be achieved using the maximum possible stand-off using night vision devices or other aids. High ground will be exploited where possible, and the SF may construct well concealed hides in which to place long-term observers.

Psychological Disruption. SF possess a strong capability to harass defenders and reduce their will to continue to defend or operate the airbase. SF may deliberately probe defensive perimeters and engage in hit-and-run style attacks to frighten or demoralise airbase defenders. Psychological destabilisation may be preparation for further operations or may be a mission goal on its own. These destabilisation and harassment operations can be a powerful Psychological Operations (Psyops) tool, effectively targeting the airbase defence's morale and determination.

Interdiction. SF may be used to interdict, destroy or harass critical lines of communication, infrastructure or operations away from the airbase itself. This may include ambushing or denying supply lines or the destruction of pipelines or communication links. The mobility and flexibility of SF make them well suited to this role.

Overt Attack. Overt attacks against the airbase involve the greatest risk to SF personnel and accordingly are generally only undertaken when the expected results are sufficient. Overt attacks may be undertaken using direct or indirect fire weapons. The use of indirect fire weapons may be preferred as it has the least potential to expose the SF to the airbase defences. Direct attacks, when used, will normally be attempted using clandestine insertion or speed and guile, possibly under cover of distractions caused elsewhere.

Special Operations Target Analysis Methodology

SF units, being generally the best trained of the potential ground-based airbase attackers, will normally follow a rigorous procedure for target analysis. Although different variations on the theme exist, one generally accepted methodology is the CARVER acronym — Criticality, Accessibility, Recuperability, Vulnerability, Effect and Recognisability. The use of this acronym ensures that each potential mission or target set is assessed against each of these criteria.[31]

Criticality

To what extent does the airbase rely upon the target for essential operations? As stated previously, this analysis must be undertaken from the viewpoint of the relevant enemy. Targets whose destruction would affect multiple airbase capabilities, such as electrical power, are particularly attractive as their destruction has the potential to cause great disruption. Other factors that determine the criticality of a target include:

- **Time.** How rapidly will the attack cause the desired outcome, how much lead time is required? Will the damage inflicted by the attack magnify the effects of other simultaneous activities?

[31] Joint Targeting and Imagery Exploitation Centre, *Special Operations Handbook (Draft)*, Canberra, 1999, p 9.

- **Target quality.** How essential is the product or output of the target and what proportion of it can be destroyed or denied by the attack?

Accessibility

How accessible is the target to the attacking party, and what are the opportunities to reach it with a particular weapon. Factors to be considered when assessing a target's accessibility include:

- The availability of a suitable staging area near the airbase and the difficulty of transporting the attacking force there without detection.
- Movement from the staging area, through the airbase's defended area to the objective.
- The ease of access to the critical component of the target.
- Once the mission objective has been achieved or alternatively compromised, extraction from the target.

Recuperability

How easily can damage to the target be repaired? This is dependent upon the nature of the target, the broader aim of the SF tasking and recovery capability of the airbase. In some cases the SF aim may be to disrupt specific operations for a set period of time. In this situation the target should not be repairable or replaceable in this time frame.

Some specific airbase capabilities that will affect the recuperability of a target set include:

- What degree of emergency or response services are available to limit the amount of damage done in the initial attack? For example, comprehensive fire services can limit the initial effect of an incendiary attack.
- Are back-up or redundant services or capabilities available?
- How quickly can the service be repaired or replaced? What organic repair capability does the airbase possess and what level of spares holdings are present?

Vulnerability

To what extent can the target be damaged or destroyed given the weapons and techniques available to the attacking force? The strength of hardened facilities may deter attacks as the attacking party may foresee little chance of inflicting meaningful damage. Aircraft parked in the open are very vulnerable and easily damaged or destroyed.

Effect

What effect will destroying the target have upon the broader campaign? This can be assessed in terms of purely tactical or short-term objectives or the longer term implications of the operation. Effect can also be considered in terms of both positive and negative effects. The attack on some aspects of an airbase target such as the accommodation may produce negative reactions amongst friendly allies or population who may consider this a marginally ethical target.

Recognisability

How can the target be identified and recognised by the attacking force. The more visible and obvious the target the easier it will be to find. This is particularly relevant during night operations, poor weather and under combat conditions. Some items of technical equipment may require specialist expertise to identify the critical components, and accordingly may not be well suited for targeting. The distance from which the target can be acquired is also important. When the targets can be recognised from a considerable distance, it increases the choice of weapons which may be employed by the SF team, including indirect fire or stand-off weapons. This may improve the survivability and chance of success of the mission.

SUMMARY

This chapter has sought to provide a concise summary of the typical airbase's potential ground threats. It has discussed the reasons why ground forces may be chosen to attack the airbase and the methods and weapons they may chose to use. This includes historical examples and some of the more modern alternatives now available.

The first step in defeating this ground threat is to understand their capabilities and vulnerabilities. A good starting point for this is a thorough understanding of the missions, methods and weapons that they can employ. The next step is to understand how and where these attacks will occur and to appreciate the large amount of land outside the airbase from which indirect attacks may be applied. Finally, an appreciation of the target selection process as would typically be used by a SF unit attacking an airbase is presented. However, a thorough knowledge of their methods, planning processes, strengths and weakness can be used to design an airbase defence capable of deterring or defeating this threat.

In summary, ground forces do pose a major and growing threat to airbase operations. New weapons and supporting technologies are improving the damage they can inflict and the distance they can inflict it from. Stand-off and indirect fire weapons using advanced terminal guidance and warheads stand-out as the premier ground threat. Capable of being bought or improvised these systems are effective against both remote and urban airbases. They also free the attacker from having to penetrate the airbase close defences. Combined with the increasing amount of real-time battlespace awareness available to the remote or tactical user they are capable of inflicting extraordinary damage at low cost.

A potential scenario could involve a small team equipped with man-portable rockets or mortars. They use GPS to navigate to a precise launch point several kilometres outside the airbase perimeter, in either an urban or jungle environment, day or night. Using commercially available satellite communications they know the current disposition of aircraft or targets on the airbase, perhaps downloading their own commercial satellite imagery in near real-time. They then launch a salvo of rounds, perhaps GPS guided, perhaps with submunition warheads, perhaps with infra-red terminal guidance. The end result may be the destruction of all unprotected aircraft on the airbase by a small team using technologies that are either in or nearing the marketplace today.

CHAPTER 5

The Threat — Other Threats

The threat posed by insects, venomous animals, and related vermin is very real. Morbidity and mortality induced by the bites of tiny insects can cripple the best trained armies of the world.[1]

INTRODUCTION

Air and ground attacks are overt and obvious threats to the airbase and are the dominant factors discussed when the survivability of these facilities is considered. However, there are many other threats faced by airbases that although less obvious have just as great a potential to render the airbase inoperable. Indeed, as the opening quote above stresses, disease has historically been the biggest killer in many military campaigns, and it has only been this century that battle casualties have consistently exceeded other causes. Even this century military forces have ignored environmental factors at their peril. On the Western Front during World War I there were 100 casualties from disease or accidents for every 130 battle casualties. During the East African campaign of that war 31 non-battle casualties were incurred for every single man killed or wounded in action.[2] In the Pacific theatre during World War II all forces suffered terribly from tropical illnesses borne by insects and poor hygiene. The Australian and American presence in Milne Bay was nearly compromised by malaria, and Japanese forces on many islands were severely debilitated by disease.

Similarly, weather remains a constant threat to many military operations including aviation. Destructive weather has long impacted military operations. Examples abound from classical history through to modern times. The partial destruction of the artificial harbours supporting the allied landing at Normandy, Cyclone Tracy and Darwin in 1974 and the severe damage of RAAF Base Learmonth by Cyclone Vance in 1999 are just a few.

Some of these less obvious threats include:

- Peacetime security threats
- Information and psychological operations conducted against the airbase
- The use of psychological operations against the airbase staff

[1] Cope, S.E., Presley, S.M. and Bangs, M.J., 'Bug Off', *Armed Forces Journal International,* October, 1998, p 41.
[2] Keegan, J. and Holmes, R., *Soldiers: A History of Men in Battle,* Guild Publishing, London, 1985.

- The debilitating psychological effects of attacks upon the airbase
- Logistic isolation
- Environmental and regional factors
- Destructive weather
- Disease and environmental health issues

PEACETIME SECURITY THREATS

Even when not at war or employed for operations, airbases face a continuous range of security threats. Some of those groups have been considered in the ground threats chapter. However, there are many other groups who wish to do harm to the airbase, either by violent or non-violent means. These include:

- Foreign intelligence services;
- Potential intelligence collectors;
- International terrorist groups;
- Extremist political organisations;
- Issue motivated groups;
- Civil unrest or labour organisation action;
- Industrial espionage;
- Other external elements (criminals, 'nutters', vandals etc); and
- Internal criminal, subversive or malicious activity.

Some of these threats can be considered as adjuncts to normal military operations. However, some of them have unique characteristics, and dealing with them can require approaches different from those used to defeat military threats. Some of these unusual threats are detailed below.

Criminal Threats

With the end of the organised bi-partisan stasis of the Cold War many smaller groups have emerged as the primary threats to peace. With the absence of major power financial support in an unending East versus West competition these groups have had to turn elsewhere for financial support. Many of these groups utilise criminal activity to finance their activities.

These activities frequently revolve around the trade of drugs and weapons, both inherently profitable and violent undertakings. The theft of weapons and war-like stores from Australian Defence Force establishments has been undertaken and many more such operations have been planned.[3] In other areas of the world these thefts have included surface-to-air and anti-armour missiles, which are highly attractive items on the criminal market.[4]

Accordingly, the airbase, with its wide variety of weapons and other valuable commodities can be an attractive target for petty and organised criminals.

INFORMATION WARFARE AND PSYCHOLOGICAL OPERATIONS

The advent of the Information Age has meant that information is now considered a tangible asset that can be either used to assist or compromise a military campaign. Information is now available in an unprecedented quantity and quality. 'The commander with the advantage in observing the battlespace, analyzing [sic] events, and distributing information possesses a powerful, if not decisive, lever over the adversary.'[5] Great advantage will be reaped by the commander who is most able to control and exploit information. Information and psychological operations can be conducted against the airbase during all phases of the peace-conflict spectrum, and accordingly is considered here separately from the peacetime security threats section.

The information revolution has greatly magnified the information available to the airbase commander and supported operational units. However, it has also potentially increased their dependence upon that information and therefore potentially, its vulnerability. Accordingly, it can be expected that in any level of conflict an adversary will conduct information operations against the airbase. These operations will be aimed at either stealing information from the airbase or preventing the airbase from effectively utilising information. The use of information operations both offensively and defensively is considered in detail in Chapter Seven.

These operations may also be designed to destabilise and demotivate the airbase staff. This can be achieved through dedicated Psychological Operations (Psyops) conducted against the airbase or as a natural side effect of physical attacks.

Psychological Operations Conducted Against Airbase Staff

It is possible that as a destabilising campaign or as preparation for a larger campaign an adversary may seek to conduct Psyops against airbase staff.

---

[3] Jones, C., *A Security Police Strategic Vision for Operational Considerations into the Next Century: New Criminal Threats and the Australian Defence Force,* Air Power Studies Centre, Canberra, 1998, pp 29-30.
[4] Jones, pp 17-18.
[5] USAF, *Cornerstones of Information Warfare,* p 1.

A good example of the recent use of offensive psyops against static defensive positions was NATO (mainly US) operations against Serbia during 1999. A broad range of offensive psyops techniques were employed to weaken the morale and resolution of the Serb forces and population. Much of the detail concerning these missions remains classified however, some information was revealed on leaflet dropping and psyops broadcasts.

More than 19 million leaflets were dropped into Yugoslavia urging Serbs to turn against President Slobodan Milosevic or for their military units to leave the disputed territory of Kosovo. The leaflet drops were conducted from high altitude outside Yugoslav airspace with the wind carrying the leaflets to the intended target audience. Specialised EC-130E/RR broadcasting aircraft were also used to transmit television and radio broadcasts into Serbia and Kosovo. These missions were referred to as *Commando Solo* operations. [6]

Figure 5.1 Psyops Leaflet Dropping Operations during the Vietnam War (AWM Photograph VN-67-130-1/1)

[6] Seigle, G., 'Alliance Plays the Psychological Game into Yugoslav Airspace', *Jane's Defence Weekly*, 28 April 1999, p 5.

Similar leaflet dropping operations have been conducted in many other wars. The Luftwaffe dropped leaflets on England during the Battle of Britain, and US aircraft dropped many psyops leaflets during both the Vietnam and 1991 Gulf Wars.[7]

Some other methods by which psychological operations can be conducted against an airbase, without a direct attack can include:

- The use of special or irregular forces to harass or beleaguer defensive positions.
- The use of terrorist tactics such as bombings, shootings or sabotage targeted at either the airbase or at the rear echelon or home.
- The use of propaganda, broadcasts, leaflet drops, telephone calls, electronic messaging or loud-hailers to convey threatening or harassing messages to personnel.
- The use of the local population or groups to blockade the airbase or generate negative publicity through protest action. This can be undertaken either at the airbase location or back on the home front.

Psyops conducted against the airbase staff will rely upon two components: the communication of a *message* via the appropriate *medium* to the target audience.[8] There are a broad range of both messages and media that can be employed to conduct an offensive psyops campaign against an airbase and its supporting rear echelon. Table 5.1 details some of the options available. It shows the different ways in which the message can be composed and conveyed, and the different media choices available.

The bottom half of this table illustrates the variety of media by which a propaganda message may be communicated to airbase staff. These messages also do necessarily need to originate with the adversary. Frequently the free and open news services of democratic states may convey messages contrary to the desires of the government or military authorities. As seen during the Vietnam War, this can have a severe negative effect on the morale of fielded forces. 'Adversaries expertly manipulate the media, leveraging them against our well-publicised lack of tolerance for [friendly] bloodshed or ill treatment of a defenceless people.'[9] Airbase authorities must ensure a comprehensive and open defensive psychological campaign is available to ensure peoples hearts and minds can remain fully focused on supporting allied air operations.

[7] Pile, F., *Ack-Ack: Britain's Defence Against Air Attack During the Second World War,* George Harrap & Co., London, 1949, pp 135-136.
[8] Waltz, E., *Information Warfare: Principles and Operations,* Artech House, London, 1998, p 209.
[9] Bass, C.D., 'Building Castles on Sand: Underestimating the Tide of Information Operations', *Airpower Journal,* Summer, 1999, p 31.

Psyop Dimension	Type	Specific Examples
Message	Policy Attitude Intent	Representative theme (perception goals) Resolve and determination (cease hostilities) Open for discussion (initiate dialogue) Diplomacy (possible compromise) Threaten force (surrender is necessary)
	Press/Media	Formal statement of policy or position Government agency comments to press Planned leaks
Media	Broadcast to the group	Direct broadcast radio or television, or military radio net Internet Posters, leaflets, radios, video/audio cassettes delivered by individuals, air drops or other means Indirect broadcast means (intended for intercept) Loudspeakers
	Communication to individuals	Telephone conversations E-mail messages Letters 'Inadvertent' messages
	Actions	Diplomatic actions Government actions Military actions Coalition actions Actions by non-government organisations

Table 5.1 Examples of Psyops Activities Against Airbases[10]

Psychological Effect of Enemy Attacks

Personnel subjected to attack and the violence of war can be expected to suffer not only physical injuries but also psychological injury. The degree to which psychological injuries (commonly referred to as Combat Stress Reaction (CSR)) may be suffered depends upon many factors. These include:

- The firepower and violence to which they are subjected.
- The duration of the attacks.
- Sleep deprivation.
- The proximity of the personnel to obvious destruction, death and injury.
- The training, experience and mental preparedness of the personnel.

[10] Adapted from Waltz, *Information Warfare: Principles and Operations*, p 210.

- The degree to which the personnel feel they are powerless to stop the attacks or to strike back.
- Support services available to them following the attack.
- CSR is not unique to any one branch or occupation of military service. In the airbase environment there are a number of factors that can exacerbate the potential for personnel to suffer from CSR.
- The high strategic value of the airbase makes it a lucrative target for attack, which is likely to be undertaken using the most advanced weapons available to the enemy force. Aerially delivered attacks can place particularly large ordnance loads on targets in short periods of time.
- The finite size of the airbase and the relatively high population density will ensure that casualties and damage are immediately proximate and visible to larger numbers of personnel.
- Airbase staff may have traditionally considered themselves immune to enemy attack and may not be prepared mentally to deal with enemy attacks.
- Medical and other support services deployed to airbases may not be inadequate to initially deal with combat casualties for the number of personnel deployed. This will be particularly important if sustained ground combat produces casualties over a long period, causing excessive fatigue amongst medical staff.
- The need to provide 24 hour a day support for air operations, combined with base defence duties and the disruption caused by enemy attack will ensure all personnel are sleep deprived.
- Airbase support staff have no personal way of striking back at the enemy, relying upon the ephemeral concept of deploying aircraft to do this for them.

The high firepower delivered by modern aircraft makes their attacks particularly destructive and highly conducive to causing CSR related symptoms. The follow on effects of the use of area denial and delayed action munitions will extend the period in which personnel feel they are exposed to enemy action. Historical evidence has shown that to be made inoperable for extended periods of time airbases should be attacked repeatedly. Repeated attacks, where the airbase personnel cannot move from the target area will enhance the potential for CSR related casualties.

The implication for the airbase is that CSR has the potential to greatly magnify the destructive effects of enemy attacks, particularly air attacks. The trauma such an attack can cause should be swiftly dealt with if airbase operations are not to be adversely affected.

LOGISTIC ISOLATION

Provision of Supply Support to Deployed Air Operations

Modern air operations are highly resource intensive operations. These aircraft and the large numbers of people required to support them consume large quantities of fuel, water, ordnance, equipment spares and food. All of these items will need to be provided to the airbase in order to sustain operations from there. Normally the majority of these stores will be provided from the following sources:

- procured from local civilian sources;
- obtained from local or theatre military sources;
- transported from a rear echelon or out of theatre storage and distribution facility; or
- drawn from on-base storage or bulk-holding facilities.

Procured from Local Civilian Sources

During rear echelon or deployed operations items such as food, fuel and non-specialist consumable stores may be procured from local civilian sources. This form of support was used extensively in the 1991 Gulf War, particularly by UK forces who relied heavily on the local supply of non-specialist equipment and vehicles. The principal problems experienced when conducting these local purchase operations included:[11]

- **Cost.** In austere operating environments there will be a limited number of commercial suppliers of desired items. Military forces may also consume large quantities of supplies, which can lead to higher than normal prices being charged. Often this is due to the difficulties of obtaining these supplies in a conflict zone. Where the price increases are unreasonable, host nation or local civil authorities should be approached for assistance.

- **Compatibility of equipment.** Differing standards around the world can cause compatibility problems with items such as mains electricity powered equipment. Some military equipment is also designed to use military specification components or interfaces and may be incompatible with civilian or locally sourced items. Perhaps the simplest example is the use of differing mains electricity voltages and plugs in different countries.

- **Accounting**. The accounting for locally purchased items can often be difficult, especially during operations in foreign nations. This can lead to abuses of the system and wastage of resources.

[11] Oddie, S.J., 'Logistic Support to Deployed Operations' in Waters, G., (Ed), *Line Honours – Logistics Lessons of the Gulf War*, Air Power Studies Centre, Canberra, 1992, p 33.

- **Exhaustion of available supplies.** Drawing upon limited stocks of locally held items can exhaust supplies of those items quite quickly. With military operations in progress in the area, resupply for these civilian store-holders may be difficult or impossible. The exhaustion of these supplies will prevent further drawings by assigned military forces and may cause animosity amongst the local population who also require these goods. This problem is particularly evident when operating in forward areas, which are sparsely populated and have highly limited civilian infrastructure.

- **Warlike stores.** Equipment such as military weapons, explosives and ammunition may be difficult to acquire locally in most places. These items must be transported into the theatre.

Obtained from Local Military Sources

Particularly during deployed operations, with allied forces, stores may be obtained from the military supply systems of the host or allied nation.

Transported from a Rear Echelon or out of Theatre Storage and Distribution Facility.

Two main methods can be utilised to supply forward operating units from the rear echelon — the 'push' and the 'pull' system. With the push system a precalculated amount of stores is delivered to the airbase irrespective of what is actually required. With the pull system items are not despatched until they are specifically required. The primary limitation with the push system is that it can clog up the distribution system with large amounts of unwanted items. This has occurred often with US forces in places such as Vietnam, Somalia and the Persian Gulf, where limited stores handling facilities were swamped with unwanted and often unknown stores.[12] The primary limitation of the pull system is the lead-time required from ordering an item until it arrives in theatre. Obviously, a combination of the two systems should be used.

Apart from the push-pull dilemma the primary limitation of reliance upon rear echelon resupply is the vulnerability of the resupply link to interruption. This can occur because of either enemy action, natural limitations in the available logistic resources, or diversion of these resources to other units in greater need.

Drawn From On-base Storage or Bulk-holding Facilities

Bulk holding facilities are normally maintained at most airbases for the storage of quantities of fuels, water, ordnance and consumable stores. These facilities provide the airbase with a capability to cater for surge usage requirements and temporary blockages of external supply. The amount that needs to be stored is simply obtained by multiplying the daily usage rate by the number of days between resupplies.

[12] Bowen, J.L., 'Operational Logistics – An Art or a Science', p 5.

A water source, such as a spring or bore field, within the airbase itself is an alternative example of this form of on base storage or resupply. In this case the supply is theoretically inexhaustible, however like other bulk holdings may be vulnerable to destruction or interdiction by enemy action or natural disasters.

Interruption to Airbase Logistic Support Services

Given the volume of stores consumed by air operations support the disruption of these services could have a major impact on airbase operability. Deployed operations at austere airfields in remote locations are the most vulnerable to logistic isolation. 'While the bare bases are configured to be activated quickly and to accept a variety of aircraft types, their distance from the support infrastructure presents significant logistic problems, particularly in transport and supply support.'[13] Logistic isolation or prevention of effective resupply may occur for the following reasons:

- civil action or unrest in supply source;
- interdiction by enemy action;
- unserviceability or lack of capacity in transportation networks; or
- disruption caused by events beyond the immediate control of the airbase such as refugee flows or destructive weather.

Often innovative technologies can be used to reduce the logistic resupply requirement of a deployed airbase, particularly if the base is to be established for a lengthy period of time. An example is the supply of medical quality oxygen. As a compressed gas it can be difficult to transport in certain circumstances and is supplied in heavy cylinders. Recent research by the US Pacific Northwest National Laboratory has produced a portable oxygen generator the size of a laptop computer.[14] The device produces the oxygen from atmospheric air and can be powered by batteries if required.

Morale Logistics

An important but often overlooked logistic requirement of deployed or forward-based forces is that of morale logistics. This is the provision of services and support for personnel, both deployed and remaining at home, to maintain and improve their morale. Morale can have an enormous effect on the effectiveness of a military force and therefore directly upon the operability of the airbase. An example of the requirement to provide morale logistic services was the deployment of UK forces to Kuwait during the 1991 Gulf War. Examples of morale logistic services provided during this campaign included:[15]

---

[13] Radford, E.A. and Knox, I.W., 'Land Based Air Power in Maritime Operations' in Ball, D., (Ed), *Air Power Global Developments and Australian Perspectives,* Pergamon Press, Sydney, 1988, p 499.

[14] 'Weapons and Equipment, Oxygen on Demand', *Jane's International Defense Review,* January, 1999, p 19.

[15] Oddie, 'Logistic Support to Deployed Operations', pp 34-35.

- **Mail.** Mail services were critical to maintaining the morale of deployed forces and the support of their families back home. However, the weight of mail for airbase personnel and other formations nearby was 'at times excessive'. The requirement to transport and distribute this service should be factored.

- **Entertainment and Information.** The requirement to provide some form of entertainment and recreation facility during extended deployments is also essential for maintaining high levels of morale. Deployed forces need access to news from home and information on what is occurring outside their airbase environment. The supply of news services, recreational videos, amusement games and other sources of relaxation will be required for long deployments.

- **Support for Families.** The maintenance of the morale and support of families back home is required as this will have a direct effect on the morale (and hence effectiveness) of deployed forces. Primarily, families need to be kept informed on what is happening to their deployed loved ones to prevent rumours spreading. They also require access to support services such as peer support programs and family liaison services.

- **Provision of Minor Comforts.** The ability to supply deployed forces with small quantities of items such as confectionary, drinks and toiletries will assist in maintaining morale. Often supporting organisations such as the Salvation Army can provide, or assist in providing, these important services.

ENVIRONMENTAL AND REGIONAL FACTORS

Destructive Weather

Much of Australia's expected region of operations is in the tropical weather zone. This zone is characterised by defined wet and dry seasons, high average temperatures and frequent cyclones in coastal regions. Cyclones, and destructive weather in general, have a high potential to disrupt airbase operations and destroy aircraft and facilities. Operations in other regions are also subject to destructive or severe weather, potentially due to ice and snow.

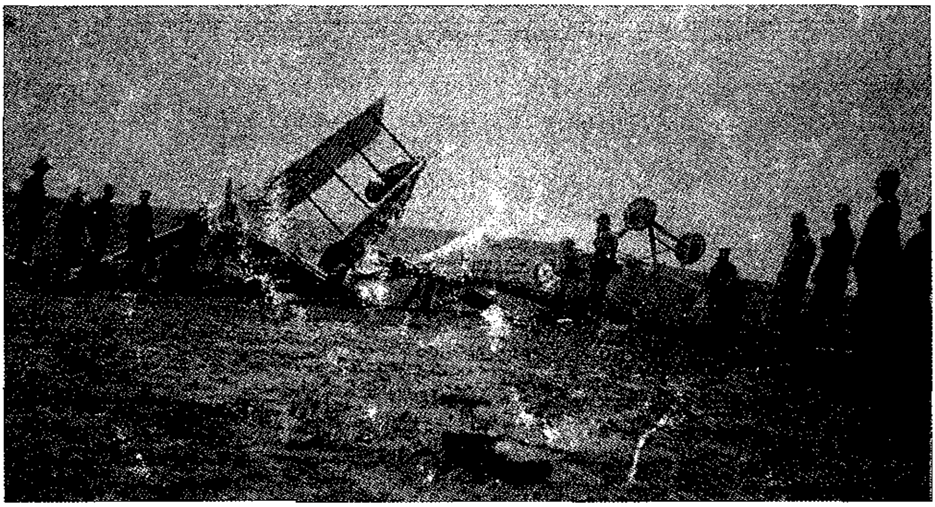

Figure 5.2 Aircraft of No. 1 Squadron, Australian Flying Corps, Damaged by a Cyclone on Christmas Night 1917, Julis, Palestine. (AWM Photograph P1184/26/13)

On Christmas Day 1974 Cyclone Tracy struck Darwin. Much of the city including RAAF Base Darwin was virtually destroyed. 'For a short period the capacity of the base to operate was destroyed.'[16] The effect of Cyclone Tracy on RAAF Darwin was as follows:[17]

- When the cyclone struck Darwin a Dakota DC3 transport and an Iroquois helicopter were unable to be evacuated. Both of these aircraft were placed in hangars and chained to the floor. Despite this, both aircraft were torn from their restraints and substantially damaged. 'The DC3 had been plucked from its hangar and lobbed on its back more that ¼ mile away. Not one light aircraft was intact.'[18]

- All communications with higher command and the outside world were cut.

- All of the base runways were temporarily closed by debris and all landing lights were inoperable.

- There was no electrical power available for pumping of fuel and there were no navigation or landing aids available.

[16] Odgers, G., (Ed), *The Defence Force in the relief of Darwin after Cyclone Tracy,* Australian Government Publishing Service, Canberra, 1980, p 8.
[17] Odgers, *The Defence Force in the Relief of Darwin after Cyclone Tracy,* pp 5-8.
[18] Lackey, R., 'Cyclone Tracy', *Wings,* Vol 50, No 4, Summer 1998, p 9.

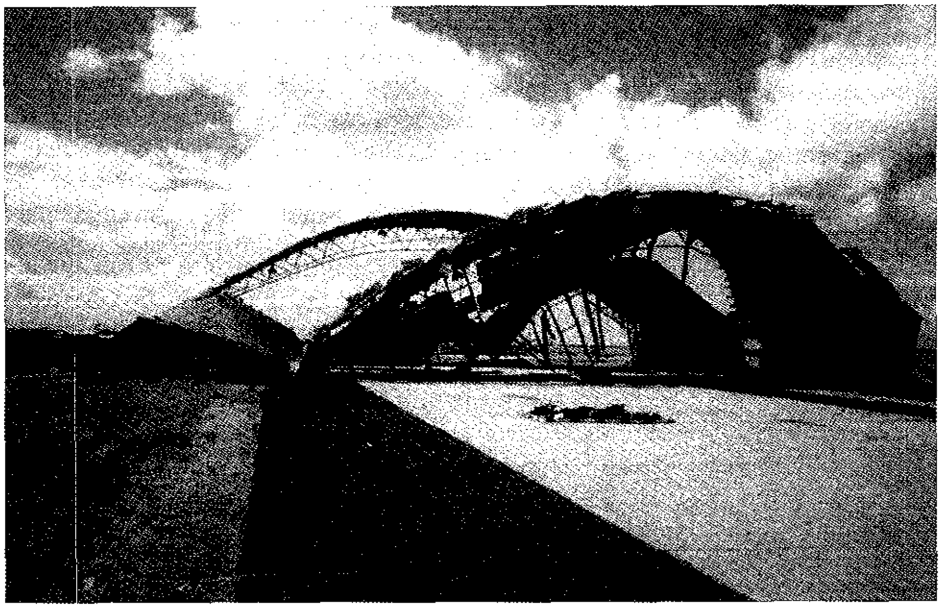

Figure 5.3 Cyclone Damage to Hangar. (Photograph Courtesy DEO)

Weather, other than cyclones, can also interfere with airbase operations. Extreme cold, such as snow, ice or thick fog can prevent operations as effectively as tropical weather. An example of this occurred during US operations against Panama during 1989 when aircraft carrying paratroopers from Pope Air Force Base in North Carolina were delayed due to an ice storm. Bad weather effectively prevented air operations from that base.

Other Environmental and Regional Factors

Apart from the operations of an adversary there are many naturally occurring phenomenon that jeopardise the operability of an airbase. Destructive weather has already been shown as one of these. Another form of threat is the presence of disease in a deployment location. These can be present in the water or soil or transmitted by insects or animals.

The naturally occurring climatic conditions can be detrimental to health and may debilitate unacclimatised personnel. Poisonous plants, insects and animals can endanger the health of critical airbase staff.

Also, when large numbers of personnel are deployed or gathered into a fixed location, such as an airbase, there is great potential for existing environmental factors to be magnified or totally new ones created. The requirement to supply clean water and treat waste can demand consider effort and resources. In Australian native bushland bush fires are a threat during the dry season, a problem magnified by the presence of personnel or military operations.

Subject Area	Potential Problem	Potential Preventative or Remediation Measures
Water Supply	Chemical contamination, ie. workshops, mining, vehicle accident, sabotage, etc.	Provide appropriate emergency response training. Develop appropriate emergency response procedures. Procure spill containment equipment. Have capability to test water supply.
	Biological contamination, ie. parasitic, helminth (parasitic worms), bacterial, viral, sabotage, etc.	Have capability to test water supply. Have capability to disinfect/filter/purify supplies. Ensure personnel awareness.
	Interruptions to the supply through mechanical failure of pumps.	Obtain safe secondary sources. Obtain repair capability for water supply infrastructure.
	Susceptibility of source to contamination.	Provide appropriate security to water source, where possible. Obtain safe secondary sources. Have capability to continually test water supply.
Food Service	Contamination of prepared foods.	Ensure refrigeration, field storage and distribution of foods is suitable. Provide training on food hygiene to all personnel. Monitor food distribution procedures and medical incidents.
	Contamination of stock piles	Ensure refrigeration, storage and distribution of foods is suitable.
Waste Disposal	Sewage — capacity during peak periods.	Ensure design specification is sufficient for deployed personnel. Ensure facilities are appropriately maintained. Instigate where necessary, temporary sewage disposal service.
	Industrial — appropriate/licensed sites available/indiscriminate dumping.	Provide training and disposal procedures. Provide or procure appropriate disposal venue/service.
	Domestic, ie. kitchens, etc.	Provide training and disposal procedures. Provide appropriate disposal venue. Provide appropriate consumables.

Table 5.2 Potential Environmental Threats to Airbases

Subject Area	Potential Problem	Potential Preventative or Remediation Measures
Noise	Aircraft, industrial or weapons	Provide appropriate training, particularly to visiting, attached or inexperienced personnel. Provide appropriate hazard control measures, such as PPE etc.
Climatic	Rainfall	Obtain appropriate local knowledge & forecasts. Secure services of meteorological service/unit. Ensure airbase infrastructure is designed to handle excessive rainfall.
	Heat/cold potential for heat stroke/exhaustion, exposure, etc.	Obtain appropriate local knowledge & forecasts. Provide suitable clothing and shelter. Provide training in extreme hot/cold operations and appropriate first aid.
	Flood	Obtain appropriate local knowledge & forecasts. Procure appropriate machinery (pumps, plant etc) and consumables. Ensure water drainage system is designed and maintained appropriately.
	Bushfire	Obtain appropriate local knowledge & forecasts. Procure appropriate machinery (pumps, fire trucks, back-packs etc). Where appropriate, develop fire breaks, conduct burn-offs and other risk reduction measures. Liaise with local authorities. Provide training to all personnel.
	Cyclone	Obtain appropriate local knowledge & forecasts. Ensure initial and ongoing construction, particularly hasty field engineering, is constructed appropriately. Develop appropriate emergency response and/or evacuation procedures.

Table 5.2 Potential Environmental Threats to Airbases

Subject Area	Potential Problem	Potential Preventative or Remediation Measures
Ecology	Vegetation — expansion, poisonous plants, protected species	Obtain appropriate local knowledge. Develop protection plans. Undertake consultation with environmental and other involved groups. Emplace barriers to prevent movement or destruction of sensitive areas. Provide training. Ensure appropriate medical facilities/supplies are available.
	Fauna — protected species, dangerous/venomous species	Obtain appropriate local knowledge. Undertake consultation with environmental and other involved groups. Provide recognition, environmental and first-aid training to all personnel. Develop procedures to protect endangered species and reduce contact with dangerous ones.
Landforms	Vegetation	Develop and promulgate vegetation plans considering passive defence, conservation, shade, erosion, bush fires, etc. Other measures as detailed above under ecology.
	Drainage/storm water run off	Ensure initial and ongoing construction, particularly hasty field engineering, is constructed appropriately.
	Soils — are they susceptible to erosion?	Develop procedures and training to minimise disturbance. Provide suitable drainage and soil cover to reduce erosion.
Presence of Disease Vectors	Mosquitoes, ticks, rodents, etc.	If necessary, implement a vector control program. Insect or vermin eradication programs. Provision of training, PPE and repellent to personnel. Obtain appropriate local knowledge. Enforcement of waste management and vermin control procedures.

Table 5.2 Potential Environmental Threats to Airbases

Subject Area	Potential Problem	Potential Preventative or Remediation Measures
Endemic Diseases in the region	Typhoid, Cholera, Malaria, Japanese Encephalitis, Ross River Fever, etc.	Obtain appropriate health intelligence. Ensure appropriate inoculation program is undertaken with sufficient lead-time. Ensure personnel are aware of the risk and appropriate personal hygiene measures are followed. Ensure safety of water supply. Implement vector control program. Develop training, procedures and provide facilities for personal hygiene maintenance.

Table 5.2 Potential Environmental Threats to Airbases

Prepared in consultation with SQNLDR M. Paterson, HQAC Environmental Health Staff.

Table 5.2 details some of the potential environmental threats experienced by an airbase. These may be naturally occurring or be directly caused by the human occupation of that area. The third column of the table provides a list of possible measures that can be undertaken to ameliorate these potential difficulties. Generally these measures fall into the following broad guidelines:

- Obtain detailed and current local knowledge of conditions.
- Develop liaison with local authorities or involved groups.
- Train personnel in the hazard or threat, and how it can be avoided or treated.
- Develop procedures to deal with the problem.
- Ensure facilities or constructions are built to be suitable with local conditions.
- Provide appropriate facilities, services or consumables to deal with the threat.
- Develop and rehearse emergency response or containment procedures.

Environmental threats are not always 'Acts of God'. Enemy action can be used to unleash otherwise natural forces upon the airbase. Examples include the release of harmful biological agents on the airbase or the bombing of nearby dams to inundate or isolate the airfield. This particular technique has been used in the past, deliberately in Korea during June 1953, and as an added bonus during World War II when the Luftwaffe base at Fritzlar was flooded following the destruction of the Eder Dam on 17 May 1943.[191] Environmental planning and assessment should therefore consider the potential interference or action of the adversary.

SUMMARY

Enemy forces threaten airbases with much more than bullets and bombs. A broad range of techniques and methods can be used to destabilise and demoralise airbase personnel and reduce the ability of the airbase to support air operations. The advent of the information age has further increased the range of techniques that can be brought to bear. To further complicate the issue, not only can these forms of operation be directly targeted at the airbase itself, but also at the vast supporting infrastructure and 'home front' from which the airbase draws so much support.

Threats other than those posed by enemy forces can directly influence the successful outcome of the airbase mission. Naturally occurring phenomenon and the impact of large numbers of personnel in a small area can act to reduce the effectiveness of the airbase. Also, as the public at large become more environmentally aware, defence

[19] Macbean, J.A. and Hogben, A.S., *Bombs Gone: The Development and Use of British Air-Dropped Weapons from 1912 to the Present Day,* Patrick Stephens Ltd, Wellingborough, 1990, p 169.

forces will be required to ensure that the impact of airbase operations on the natural environment is minimised.

In addition to these long-standing and already demanding requirements the increasingly important discipline of Information Warfare (IW) has recently emerged. Although certainly not new, IW has taken on dramatically increased importance as information, communications and sensor technologies can provide the battlefield commander with an amazing array and volume of knowledge. Knowledge has always been power and the airbase commander must ensure that his knowledge systems remain intact, free from destruction, manipulation or exploitation by the enemy. In an increasingly electronic and interconnected world this is emerging as an extraordinarily difficult task, and consequently an extraordinary threat.

Accordingly, to manage this diverse range of requirements the airbase commander must ensure that airbase operability measures encompass more than defence from air or ground attack. The base must be prepared to meet a range of challenges and broad operability strategies and varied skill sets will be required.

CHAPTER 6

Airbase Operability Planning

To prepare for war in time of peace is impracticable to commercial representative nations, because the people in general will not give sufficient heed to military necessities, or to internal problems, to feel the pressure which induces readiness.[1]

INTRODUCTION

Each airbase requires its own unique operability plan. The operability plan will normally be a overarching document that addresses a series of subordinate plans, many of which will already be in place. Plans that cover security, ground defence, communications and logistics support all combine to influence total airbase operability.

The overall operability plan may be based on a common template but will contain components unique to that base's environment and needs. This book provides the common methodology for generating the operability plan which each commander must then overlay with specific details considering local conditions and utilising expert local advice.

AIRBASE OPERABILITY PLAN DEVELOPMENT

The development of an effective airbase operability plan follows a similar planning methodology to many other defensive or security development plans.[2] Each base plan will be unique, but a consistent methodology should be used to draft each one. Figure 6.1 illustrates the airbase operability planning cycle.

The basic rationale of this planning methodology is to take a broad operability template and mould it for the specific circumstances encountered at a given airbase. A logical progression through the process is followed until the desirable operability enhancements have been identified, prioritised and implemented. This will produce a baseline level of operability for the airbase. A comprehensive system of education, monitoring, evaluation and feedback should then be implemented. If variables at any point in the planning cycle change with time the impact on the whole base operability plan should be reconsidered from that point downwards. Small changes to threats,

---

[1] Mahan, A.T., *Naval Strategy: Compared and Contrasted with the Principles and Practice of Military Operations on Land,* Greenwood Press, Westport, 1911, p 447.

[2] This planning process adapted from US Air Force, *Installation Force Protection Guide.*

vulnerabilities or extant operability measures can produce significant positive or negative changes from this baseline.

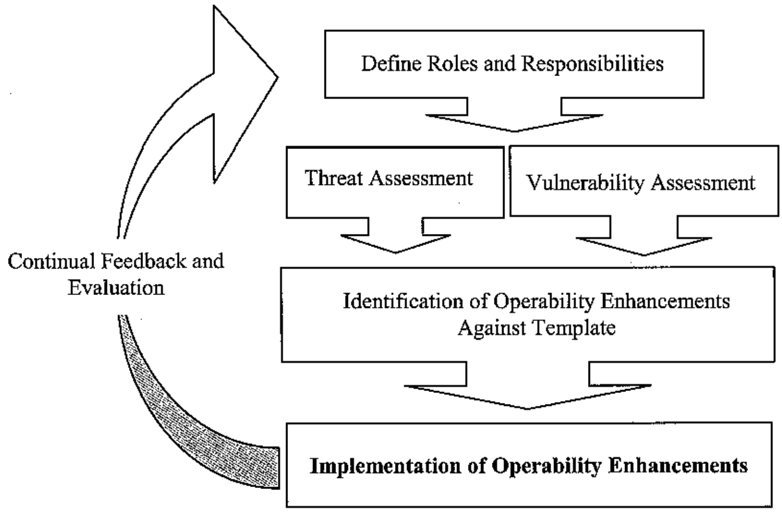

Figure 6.1 Developing a Unique Operability Plan

The first task to be undertaken is to develop a clear understanding of the mission of the airbase. This will define the roles and responsibilities of the unit and what linkages it will have with external agencies, be they customers, suppliers or peers. The next step is the clear identification of the threats faced by the airbase. This must be undertaken broadly with all possible contributors to mission degradation considered. Next, the vulnerabilities of the airbase must be understood. This step requires extensive consultation with staff at all levels who have the most detailed understanding of the vulnerabilities of their own fields of operation. It also requires consultation with customers and lodger units, who will introduce additional vulnerabilities into the installation. An important point is that the threat and vulnerability analyses should be undertaken by separate groups of people, or at a minimum conducted independently. The next step compares the threat and vulnerability analyses and develops a prioritised program of improvement activities. The final step is one that is most often overlooked in resource squeezed environments — actually getting in and implementing the chosen operability improvements. It is one thing to know how to make an airbase survivable, it is another altogether to make it actually happen.

These five main steps in producing an airbase operability plan are detailed below.

Define Roles and Responsibilities

As would be expected, before any planning process can begin the mission, goals and unique environment of the airbase must be understood. (This process is often referred to as the mission analysis phase). This produces a clear and common understanding in the minds of all participants of the planning cycle of what they are trying to achieve and what their goals and constraints are.

The following specific requirements and preconditions should be initially defined:

- What is the mission of the airpower supported by the airbase?
- What assets will the airbase be supporting in terms of aircraft, other combat services etc? What is the potential for additional forces requiring support being transferred to the airbase?
- What warning or lead time can be expected to allow mobilisation and airbase preparation?
- How long are operations from the airbase to be maintained, and at what tempo?
- What level of command will be exercised from that airbase? Where does it sit as far as command and control and span of authority are concerned? How much autonomy will the airbase have in determining and implementing its own operability enhancements?
- What organic capability does the airbase possess to provide operability enhancements? This would include engineers, EOD personnel, ground defence personnel (both full and part time), relevant plant and equipment, heavy weapons, organic air support capability, etc.
- What capability to provide these services is available from forces either nearby or those who have been assigned to assist? What is the potential for these forces to be reallocated away from the airbase because of conflicting task priorities?
- What capability to provide these services can be provided by local infrastructure or host nation support? What is the capacity, technical competence and reliability of these alternate supply sources?
- What logistic support arrangements are in place for the airbase? Where do first, second and tertiary resupply come from? This includes resupply of fuels, rations, ordnance and ammunition, water, aircraft maintenance spares, casualty evacuation and replacement.

Threat Assessment

The potential threats to an airbase have been described in the preceding chapters. When developing a unique operability plan for a specific installation a careful balance must be drawn between ruling out potential threats and compiling a list which is too long to be effectively dealt with. Too pessimistic a threat assessment will cause:

- Scarce resources may be expended on unnecessary defences and excessive operability enhancements.

- Basing of aircraft in safer areas further from the area of operations, which may reduce sortie rates and the responsiveness of the air power they generate.

- Excessive dispersal of assets and operations security measures, which can increase ongoing logistic and management costs.

The threat assessment will depend upon a large number of factors. The largest determinants of the threat faced by a particular airbase include:

- The nature of the conflict, the operations being conducted and the broader strategic outlook.

- The cultural, operational and political characteristics of potential adversaries and their order of battle.

- The nature of the forces and assets (including co-located non-aircraft assets) at the airbase.

- The geographic location and tactical topography of the airbase.

- The perceived vulnerability of the facility may either attract or deter potential threats before they become viable.

As a starting point the entire range of potential threats as detailed in the preceding two chapters should be considered, and potential threats only discounted when positive information is available to do so.

Vulnerability Assessment

The vulnerability assessment should initially be conducted in isolation from the threat assessment. This ensures that the vulnerabilities of the airbase are not derived (intentionally or otherwise) from the *perceived or known* threats. This method allows as a first step the development of the broadest possible vulnerability analysis which will not be automatically flawed if the threat analysis phase is subsequently found to be incorrect or incomplete.

THE THREAT AND VULNERABILITY ANALYSES SHOULD BE CONDUCTED AS INDEPENDENTLY AS POSSIBLE.

When conducting a vulnerability assessment a two step risk management approach can be used. The first step is to identify the critical capabilities or features (nodes) of the airbase. These are the facilities, assets, personnel or operations without which the airbase may not be able to conduct the essential tasks defined at the first stage of the operability planning process. The second step is to determine the different ways in which these nodes may be destroyed, degraded or denied to the airbase.

For example, a critical node at a typical airbase may be the supply of liquid dry breathing oxygen for flight operations. The vulnerabilities determined to be associated with this node could include:

- Contamination of the available local supply by sabotage, spoilage or accident.
- Destruction of the available local supplies by air or ground attack.
- Prevention or delay of resupply, by a variety of means.

This example is shown diagrammatically at Figure 6.2. At this step it is also important to note interrelationships between the vulnerabilities. With the breathing oxygen example sufficient local stocks may exist to support all credible operations for the foreseeable future. In this case denial of resupply is only a vulnerability if local stocks are destroyed, prematurely exhausted or contaminated.

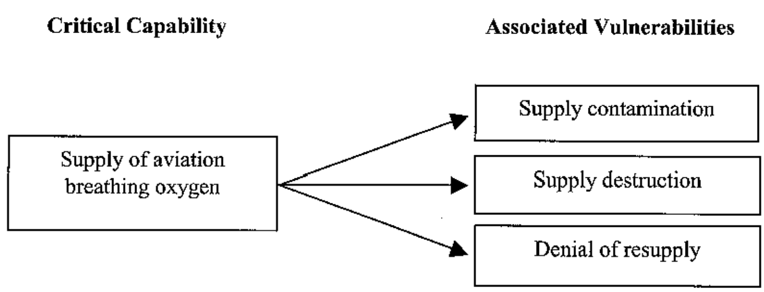

Figure 6.2 Vulnerability Analysis Example

Identification of Operability Strategies and Enhancements

By methodically comparing each vulnerability with the range of applicable threats (including internal threats) operability gaps can be identified. In some cases, the actions required to remedy these gaps might be self-evident; in other cases a more thorough analysis of the problem may be required.

With the breathing oxygen example above, some operability enhancements that could be identified to negate these vulnerabilities could include:

- **Supply contamination**. Enhanced training and procedures for oxygen handling to prevent accidental contamination.
- **Supply contamination**. Enhanced security procedures and placement in a secure or defended facility to prevent tampering.
- **Supply destruction**. Dispersal of stocks to prevent total destruction by air or ground attack.
- **Denial of resupply**. Enhanced arrangements to provide more reliable resupply of compressed gases during crisis.

This example is far from complete, and as can be imagined even without exhaustive analysis, there are many more potential threats, vulnerabilities and remedial measures which could be included. Figure 6.3 shows this process diagrammatically demonstrating the flow from critical capability to vulnerability, through an applicable threat to the determination of a suitable range of operability enhancements. It follows the flow shown at Figure 6.1. Each capability has its vulnerabilities detailed. Each vulnerability is then compared to the potential threats producing a list of vulnerability-threat pairs or operability gaps. These are then examined in turn and a range of potential operability enhancements is developed. From these the most efficient and effective enhancements are selected for implementation. This process can be quite lengthy as can be seen from the number of potential options in the simple example of Figure 6.3 (shown as arrows that do not lead to subsequent steps) which have not been detailed further.

The layered template provided later in this chapter can be used to assist in the development of the required operability enhancements. The checklists at the back of this book can also be used to ensure that important areas are not neglected.

Evaluation and Implementation of Selected Measures

The final stage is perhaps the most important and often the most commonly neglected- the physical implementation of the required operability measures. With aircraft procurement and replacement costs increasing, particularly those limited numbers of force multipliers, the budgets allocated to protecting those assets and ensuring that they remain mission capable should be commensurate. It is no longer generally possible to replace aircraft, or even stocks of complex support equipment or precision guided munitions, once conflict has been joined.

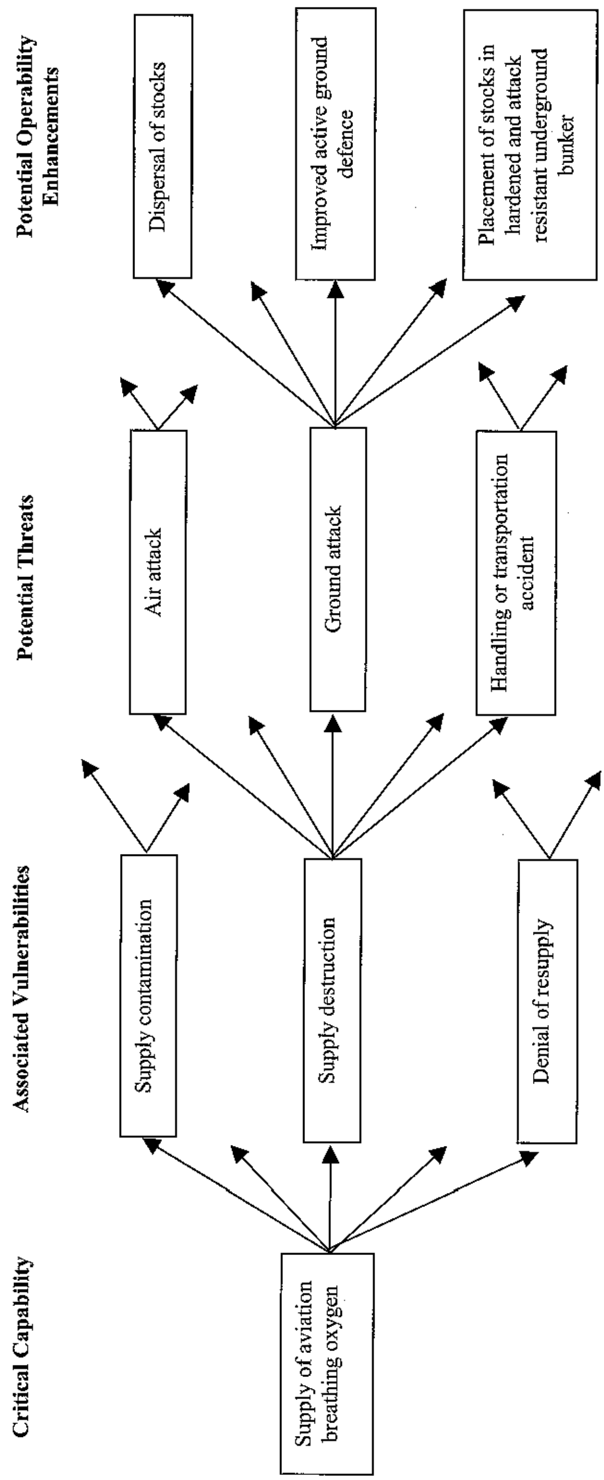

Figure 6.3 Operability Analysis Example

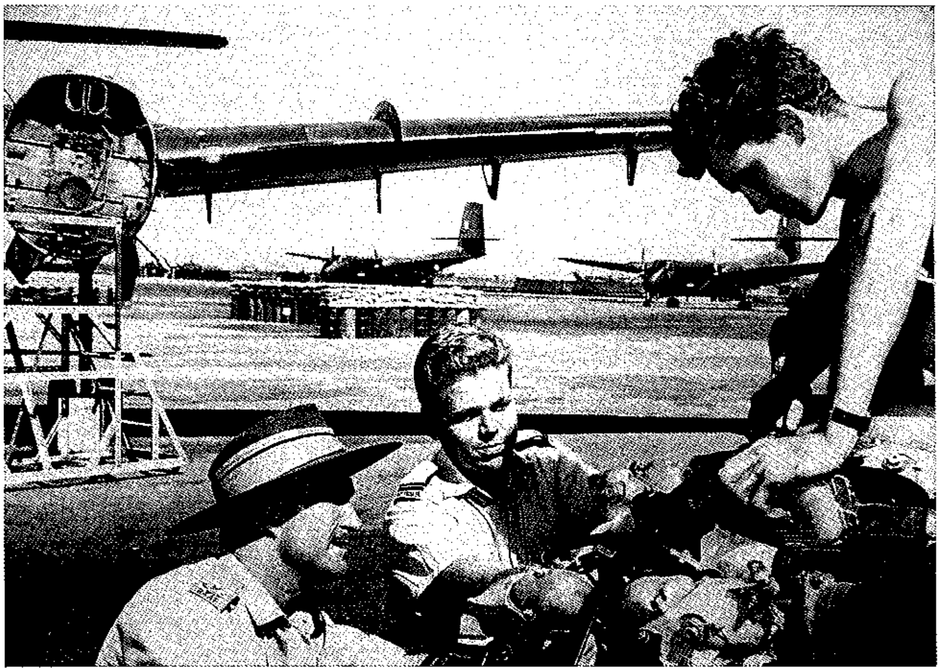

Figure 6.4 RAAF personnel service a 35 Squadron Caribou at Vung Tau, Vietnam, 1967. Note the drum and sand-bag revetment in the background used as protection from the rocket and recoilless rifle attacks periodically mounted by the Viet Cong against the airbase. (AWM Photograph P01953.005)

As each operability enhancement measure is identified, its required implementation time should also be derived. This prediction should be a realistic one, and should take into account the wide range of conflicting and simultaneous demands that will be placed on the organisation during any mobilisation or escalation to conflict. By placing this list in reverse order, with the enhancements requiring the longest lead-time first, a 'minimum time before conflict to start work' schedule can be developed. Where operability enhancements are dependent upon one another for their completion schedules, process planning tools, such as Gantt charts may be employed.

If the resultant operability plan is fully adopted it may make it impossible for an attacker to disable the airbase with limited or surgical strikes. They must apply a far larger amount of force. This may have a strong deterrent effect, as the application of total force may be a cost they are not prepared to pay. This could be for three reasons:

- Application of high force levels to achieve airbase neutralisation raises the potential for higher attacker casualties. The high attrition rates may not be acceptable militarily to the attacker and may be out of proportion to the goals of the conflict.

- The devotion of a large proportion of the attacker's resources to airbase neutralisation precludes attacks on other targets, potentially leaving the attacker vulnerable to these other platforms. Also, resources devoted to airbase neutralisation are not available to meet the military and political aims of the broader campaign.

- The enemy may not be prepared politically or militarily for the application of total war force. The high cost of waging total war, as opposed to a highly successful surprise first strike (perhaps punitive) may cause them to seek other solutions.

AN OPERABILITY METHODOLOGY

A whole entity approach is important in designing a survivable airbase. Airbases are complex networks of mutually supporting and dependent facilities and organisations. Often the destruction of a single critical element can dramatically affect the ability of the airbase to support air operations. Anyone attempting to disrupt airbase operations will likely be aware of this, and a weakness in one component of an otherwise effective operability plan can expect to be targeted.

Therefore, a key to designing and building a resilient airbase is to adopt a common template or set of standards which is then applied equally to all aspects of the airbase design. This template, or common system of enhancing operability, is used when developing a list of potential fixes to identified operability gaps. As each critical node is considered and its threats and vulnerabilities identified, it is assessed against each of the five aspects of the model. This will provide a range of potential operability enhancements to apply.

The following five key words summarise the operability methodology — knowledge, deception, strength, redundancy and recovery. Figure 6.5 shows how this methodology functions as a layered protection.

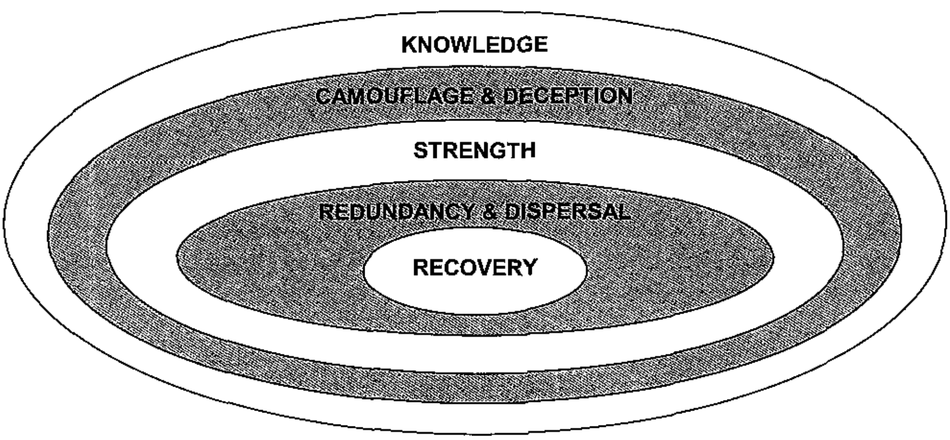

Figure 6.5 The Layered Resiliency Methodology

Knowledge. Knowledge is the use of information to provide a tangible military advantage. It refers to the collation, interpretation and use of data, and the planning and execution of operations. Knowledge can be used to thwart attacks before they form or ensure that enemy methodologies are well known and can be countered when attacks occur. Control and exploitation of information is the first step to maintaining operability.

Camouflage and Deception. The use of camouflage and deception entails preventing the enemy from being able to target whatever they wish. These techniques are used to prevent the enemy from knowing the true disposition and vulnerability of your assets and possibly presenting them with a range of false targets to draw attacks. The successful implementation of these techniques requires the comprehensive and imaginative use of camouflage, concealment, fabrication and information operations. Camouflage and deception can be employed at all levels from the tactical to the strategic.

Strength. Strength provides the capability to physically withstand attacks once an airbase asset has been targeted and attacked by an enemy. Providing an airbase target with strength makes it more difficult for an adversary to inflict damage or degrade mission capability. Strength can be either active or passive. Active strength or active defence (both ground and air based) is used to prevent the enemy from effectively attacking by fire or manoeuvre through the use of weapons and forces deployed by the airbase. Passive strength is used to prevent the attacks from causing damage or disruption to airbase operations through hardening.

Dispersal and Redundancy. Once an airbase asset has been targeted, and successfully destroyed or damaged, redundancy provides the airbase with the capability to continue to support air operations. Dispersal and redundancy seeks to make the airbase more difficult to target by demassifying vulnerable assets, dispersing them over a wide area and ensuring that in the event of their destruction or failure a back-up or alternate system is available.

Recovery. A recovery capability allows the airbase to restore operational capability despite having suffered degradation. This includes disposal of unexploded ordnance, repairs to infrastructure and pavements, the continued activation of medical services and the ability to replace damaged stores and consumable resources.

When effectively implemented as part of a rigorous ABO plan each layer must be successfully penetrated by the enemy before mission support is affected. The effective use of this layered approach is important as each step down through the layers represents a victory for the attacker and a loss for the airbase. Movement down through the layers reduces the time available for the airbase to enact counter-measures to attack and statistically reduces it ultimate chances for survival.

Ideally, the first defence of the airbase will be achieved by the exploitation of information and intelligence. By a thorough understanding of the potential attacker's capabilities and motivation and the airbase's own vulnerabilities the attack may be thwarted before it begins. This can be done by an offensive action such as a pre-emptive attack on the potential adversary's resources or merely the appropriate disposition of active defences to prevent the attack from developing.

Where this fails deception is used to prevent the attacker from being able to target those assets of importance to your campaign. If deception fails the attack may be thwarted by the strength and protection afforded important airbase features. If the hardening proves ineffective redundancy provides back-up facilities so that airbase operations may continue. An effective recovery capability then allows the airbase to regenerate its operational capabilities if all else fails.

Dr Richard Szafranski, in his paper on parallel war and hyper war, tells planners that to defeat an enemy with a strong air power capability you must disguise, diversify and demassify your systems.[3] These three key words fit neatly into the deception and redundancy shells of the methodology.

The model is also recognition of the nature by which an attack on a capability is prosecuted. An attack on an airbase capability is the culmination of a series of activities. These can be considered as:

- target selection or identification;
- target acquisition;
- safe arrival at the weapon launch/firing point, which implies location of the airbase itself and the failure of any active defences;
- placing a warhead onto or near the target;
- target damage; and
- the target being unable to regenerate.

The probability that an attack will be successful is the cumulative probability of all of these activities being undertaken successfully. It can be represented mathematically as:

$$\boxed{P_{suc} = P_{ti} \times P_{ta} \times P_{ar} \times P_{at} \times P_{d} \times P_{nr}}$$

Where:

P_{suc} = Probability of the desired mission outcome being achieved.

P_{ti} = Probability of successfully selecting and identifying the target set appropriate for your desired mission outcome.

[3] Szafranski, R., 'Parallel War and Hyperwar: Is every Want a Weakness' in Schneider, B.R. and Grinter, L.E., (Eds), *Battlefield of the Future,* Air University Press, Maxwell AFB, 1998, p 139.

P_{ta} = Probability of successfully acquiring all of these targets during the attack.

P_{ar} = Probability of safe arrival at the weapon launch point and the failure of any active defences

P_{at} = Probability of being able to place warheads onto all the desired targets.

P_d = Probability that the weapons will inflict the desired level of damage on the targets.

P_{nr} = Probability that the targets will be unable to regenerate during the timeframe in which the capability must be kept suppressed.

Accordingly, interference with each stage of this process reduces the overall probability of the attack succeeding. By applying an operability methodology that addresses all of these stages the chances of defeating the attack can be greatly improved. As an example, assume the probability of each of these activities being completed was each 90 per cent or 0.9. Accordingly the probability of the entire attack being successful would be

$$P_{suc} = 0.9 \times 0.9 \times 0.9 \times 0.9 \times 0.9 \times 0.9$$

$$= 0.531 \quad \text{or} \quad 53.1 \text{ per cent.}$$

If airbase operability enhancements were to degrade the chances of success of each of these steps by only 5 per cent the new chance of mission success would be

$$P_{suc} = 0.85 \times 0.85 \times 0.85 \times 0.85 \times 0.85 \times 0.85$$

$$= 0.377 \quad \text{or} \quad 37.7 \text{ per cent.}$$

The chance of the attack on the airbase succeeding has been reduced from 53 per cent to 37 per cent, a difference of approximately 16 per cent. This example demonstrates the cumulative effect that operability enhancements can have. Small improvements in a lot of areas can accumulate to form larger chances of sustaining airbase capability in the long run.

Taking the example further, we can now derive the number of individual sorties that must be launched against that airbase target if the attacker desires a 90 per cent probability of its destruction (or mission kill as desired). To calculate the number of sorties to be flown the following formula is used:

$$n = \frac{\log(1 - \text{desired mission success probability})}{\log(\text{probability of individual sortie failure})}$$

Where:

n = minimum number of sorties to be flown to achieve desired mission success probability.

Accordingly, to achieve a 95 per cent mission success probability using the information from the example above 3.95 missions must be flown against the target with no operability enhancements and 6.33 flown against the improved target. Rounding these up (since half sorties cannot be flown) produces 4 and 7 sorties respectively. Using operability enhancements to reduce the chance of successfully achieving each individual mission component has increased the effort required by the attacker to achieve their mission goal by a significant amount.[4]

Application of the Methodology

The layered methodology has been designed to allow it to be applied across all aspects of the airbases operations. Having demonstrated the benefit of a comprehensive operability regime, each component of the airbase should now be considered in terms of the five operability elements. Table 6.1 provides some examples of how each of the five elements can be applied to different aspects of a typical airbase.

Knowledge	Camouflage & Deception	Strength	Dispersal & Redundancy	Recovery
Diplomacy	Camouflage	Hardening	Infrastructure supplies	Explosive ordnance disposal
Planning & design	Concealment	Aircraft design features	Aircraft operating surfaces	Fire fighting, medical and rescue services
Defensive information operations	Counter intelligence	Active anti-air defence	Dispersal of assets, including aircraft	Airfield engineering
Offensive information operations and intelligence	Fabrication	Active ground defence	Demassification of C^3I systems	Ground defence and security
Education & training		Political sanctuaries	Alternate airfields	Repair equipment
On base C3 systems		Chemical and Biological Defence	Rearward basing of vulnerable aircraft	Repair stockpiles

Table 6.1 Typical Airbase Operability Features

[4] For a more detailed consideration of the modelling concept refer to Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, Rand Corporation, Santa Monica, 1987.

IMPEDIMENTS TO OPERABILITY PLANNING

There are many impediments to successful operability planning. These include the following:

- The engagement level paradox.
- The identification of vulnerabilities.
- Not correctly anticipating the enemy's likely motives, methods or targets.
- Law of armed conflict considerations.
- The offensive military mindset.
- Limited resources.

The Engagement Level Paradox

The major complicating factor in undertaking this task is the variety of threats which have been portrayed and the range of scenarios in which the threats can be manifest. Survivability methods that provide effective wartime protection against air attack may make those facilities more vulnerable to a terrorist threat during lower level contingencies. The barracking of support personnel away from the airbase itself may make them less exposed to direct air attack (intended or otherwise) during conflict, however, it makes them far more vulnerable to terror attacks, particularly during travel. The easy destruction of US aircraft at Hawaiian airfields during the Pearl Harbor attacks was due in part to their being tightly bunched up as an anti-sabotage precaution.

Effective and timely intelligence can be used to assess the threats present at any given time as accurately as possible. The thorough operability planning process will then determine the relative trade-off the different operability measures allow.

Identification of Vulnerable Assets on the Airbase

The identification of airbase vulnerabilities can be a long and difficult task. The planning process presented in this chapter can be time and resource intensive, and further planning processes presented throughout this book can be similar. It also requires a detailed knowledge of the airbase's own requirements and dispositions. Given the complexity of modern aircraft and airbase support systems their intricate requirements may only be known to a select few experienced or trained personnel. These people may be employed at the lowest level of the organisation and are often overlooked or not included in the planning process. When analysing vulnerabilities, job and system knowledge is critical, not an understanding of the adversary's capabilities or intentions. That is examined during the threat analysis.

Not Correctly Anticipating the Enemy's Likely Motives, Methods or Targets

It has been shown that surprise is a vital ingredient in conducting a successful airbase attack. One method of obtaining this is to attack in a way unanticipated by the airbase defence. Although assymetric thinking is firmly established in modern military doctrine, it is still common for defenders to be caught unaware. One recent example of this was the terrorist attack on the Khobar Towers accommodation complex during 1996 in which 19 US airmen were killed. Conventional western thinking would not have considered the accommodation block a target, however, radical organisations obviously did. Accordingly, it is essential to invest great effort in trying to anticipate the thinking of threat groups, regardless of how alien that thinking may seem.

Law of Armed Conflict Considerations

The conduct of modern warfare between nation states is governed and regulated by a variety of international laws and conventions designed to reduce unnecessary suffering and prevent indescriminate loss of civilian life. Collectively termed the Laws of Armed Conflict (LOAC) these laws and conventions would normally provide protection from attack for such airbase facilities as hospitals, dependant housing and prisoner-of-war internment camps. However, to gain this protection these facilities must be clearly role identifiable and their location should not unreasonably interfere with attacks on legitimate targets. As an example, the placement of an airbase hospital above a buried command bunker would effectively strip the hospital of any protection from aerial attack it may previously have expected.

Furthermore, the international protocols, to which Australia is a signatory, require that protected facilities, such as hospitals, be positioned so that attacks against military targets cannot imperil their safety. Given the relatively large damage templates and potential inaccuracies that can be reasonably expected of aerial and indirect fire weapons this requires protected facilities be placed some considerable distance from legitimate targets. From a pragmatic point of view the positioning of a hospital away from military targets also maximises the potential for that facility to be able to operate as designed during and following an attack on the airbase.

The principal difficulty LOAC introduces into the planning of an airbase layout is when it is uncertain to what extent an adversary may respect LOAC requirements. If it is known that the enemy is likely to observe the conventions then planning is simplified by the placement of all LOAC 'protected' facilities well away from critical airbase facilities. This may place them outside the defended ground perimeter. However, if there is some uncertainty over the intentions of the enemy, then it may be naive to deprive these facilities of all physical protection. This is most likely the case during deployed operations when the adversary may be undisciplined militia, irregulars or guerillas with little knowledge or respect for LOAC conventions. In this case the planning process is complicated, as the protected facilities should be sited in accordance with the LOAC principles, yet at the same time defended appropriately. Using the example of the hospital, it may require placement inside the defended perimeter to afford physical protection, but must still be placed clear of other legitimate targets. Similarly, there is the difficulty that medical personnel and other non-combatants may be armed for their own defence, but not to the extent that they form an integral part of the airbase ground defence perimeter or system.

The clear identification of the airbase hospital with large 'red cross' symbols visible from the air may compromise a base-wide camouflage and deception plan. Fortunately, the fixed geographic location of airbases and their characteristic appearance from the air make hiding of the entire facility unrealistic, with camouflage of important individual assets more feasible. In this case, the clear identification of protected facilities is not undesirable, and the further they are from more legitimate targets the better.

The Offensive Military Mindset

Military thinkers and planners are taught to think offence, not defence, and this is particularly true of airmen. This has perhaps arisen because military aircraft are almost exclusively offensive in nature, and that even when deployed defensively they contribute to the battle by destroying enemy assets either on the air or the ground. This philosophy has been described in detail during the discussions on counter-air operations in Chapter Three. Accordingly, it is often difficult to get military airmen to apply thought and resources to ostensibly defensive works such as operability enhancements.

Norman Dixon, in his work *On the Psychology of Military Incompetence,* discusses in detail the reluctance of some military commanders to invest in defensive works. He uses the example General Officer Commanding Singapore, Lieutenant-General Percival, who ignored the advice of subordinates and superiors alike and failed to fortify the Malay Peninsula during the Japanese advance on Singapore in late 1941. His sole reason was 'I believe that defences of the sort that you want to throw up are bad for the morale of troops and civilians.'[5] Dixon goes on to speculate as to why commanders in this and other examples found the idea of constructing defensive enhancements distasteful. One reason is that to erect defences is to admit to themselves the danger in which they stood. Perhaps the reluctance by air force commanders (almost exclusively pilots in virtually all nations) to invest in operability enhancements reflects their viewpoint that to undertake these works is to admit that they are incapable of defeating or stopping the adversary in the air?

Limited Resources

Since the end of the Cold War in the late 1980s the armed forces of most developed nations have seen continuing reductions in defence spending. This limits the resources available for different activities and support functions typically take the brunt of these reductions. This has had two main impacts on airbase operability planning — a tendency to delay the implementation of operability enhancements until the last possible moment, and the increasing reliance on out-sourcing of support functions.

[5] Dixon, N.F., *On the Psychology of Military Incompetence,* Pimlico, London, 1994, p 139.

Individual operability enhancements are often small in scale and can generally be incorporated into an airbase at any stage from base design through to during combat operations. Projects such as the placement of camouflage on a facility or the construction of individual protective works are often viewed as trivial matters that can be undertaken when required. In a genuinely resource-tight environment this may be appropriate or simply unavoidable. However, when delaying the implementation of operability projects the following pros and cons should be considered:

- Are stockpiles of materials available at the airbase for the construction of operability enhancements? These may be difficult to procure or transport in sufficient quantity at short notice, especially when a general mobilisation program is generating large numbers of competing demands.

- Has the operability planning process been undertaken to develop a baseline operability plan for the airbase? This planning process can be time consuming and can impact significantly on preparation times. The earlier in the base development the enhancements are planned the more likely they will form an integrated scheme.

- Are the personnel and resources going to be available to implement the operability plan once mobilisation is directed? Is there potential for these resources to be given conflicting tasking and are they aware (and appropriately resourced) of this requirement? Will their use to build last minute improvements compromise other activities they should be undertaking?

- In some circumstances enhancements built into the original base design can become obsolescent or irrelevant before any crisis actually occurs. Enhancements need to be upgraded when required.

- Will sufficient lead-time be available before the onset of hostilities during credible scenarios? The required lead-time will be equivalent to the time required for operability planning, mobilisation of resources and manpower, acquisition of materials and implementation of measures.

- Does the work have a significant ongoing maintenance cost?

- Will the early construction of the enhancement be compromised and its value negated by enemy intelligence activities and counter-counter-measure development?

- When incorporated as part of the original airbase development process the enhancements can be built more professionally and with potential cost savings. *Ad hoc* additions can be of poor quality and expensive to maintain.

The increasing reliance upon out-sourcing for support functions will in many cases reduce the availability of 'uniformed' personnel to undertake operability implementation measures in operational areas. The construction of protective works, camouflage and dispersal areas are manpower intensive and may require the use of specialist engineering equipment. There is also a growing requirement for the implementation of high technology operability measures such as computer system security. The availability of personnel and equipment capable of performing these functions, in the operational environment, is crucial to the successful implementation of operability measures. This will require a human resource management function capable of evolving with the changing needs of technological development. The superficially easy method of simply out-sourcing these functions will not meet the requirements of the operational airbase commander who will require that expertise on staff, on the ground and possibly under attack.

SUMMARY

The planning process is the first step in the development of a survivable airbase. Airbase operability has been shown to depend upon a range of base attributes, each of these closely ties with the other. Planning ensures that these complement each other and that no gaps are left to be exploited by an adversary. It will also ensure that operability enhancements are in place at the appropriate time. Too late and they will not be effective during hostilities, too early and they may be a waste of limited resources or be obsolete before hostilities begin. Although the process will undoubtedly take a considerable period of time to undertake fully, it should only need to be undertaken once to produce a solid operability baseline, with constant reassessment used to maintain its relevance.

A rigorous planning process and the development of a strong body of embedded airbase operability corporate knowledge will also help preserve the lessons learnt during operations and exercises. It is a sad fact that hard-learnt lessons are often quickly forgotten and must be relearnt during each new conflict. 'In fact, some tactical lessons apparently have proven almost impossible to pass from generation to generation of combatants.'[6]

[6] Fulghum, D.A., 'Pentagon Dissecting Kosovo Combat Data', *Aviation Week and Space Technology,* 26 Jul 1999, p 68.

CHAPTER 7

Knowledge

Information is the life blood of command and control; it is vital to the development of military strategy and the execution of tactics; and it is the basis of deception and active countermeasures. The dependency of ADF operations on information is certain to increase in the era of information age warfare.[1]

INTRODUCTION

By effectively managing information the airbase commander can counter attacks in the most successful way possible — prevent the attack from occurring. 'For to win one hundred victories in one hundred battles is not the acme of skill. To subdue the enemy without fighting is the acme of skill.'[2]

To do this the enemy must be prevented from determining the disposition of the airbase's vital assets, including where they are, how they are protected, and what their weaknesses are. By using information offensively the enemy's popular support in the regions surrounding the airbase can be undermined and intelligence collection activities can determine the enemy's offensive capability and weaknesses. On a battlefield where the lethality and accuracy of offensive fire dominates, the ability to supply or deny effective targeting information has become increasingly crucial. 'For it is really the acquisition, processing and dissemination of information that lies at the root of the speed and accuracy with which fire can now be applied.'[3]

The first step in defending the airbase and maintaining its operability is to control information. Modern theories on information warfare view information as an entity in its own right, having inherent vulnerabilities, and providing tangible rewards to those who possess and exploit it most effectively. Information is not a static commodity; it must be acquired, analysed, stored, communicated and disseminated. A wide variety of personnel, processes, systems, and equipment are used to manage information, and all can be broadly referred to as Information Systems (IS). An IS is not simply a computer, as the term is often traditionally defined, but any system that 'consists of data (both as an initial input and as stored information in various parts of the IS), hardware, software, communications, procedures (including the processes used to

---

[1] Royal Australian Air Force, *The Air Power Manual, 3rd Edn,* Air Power Studies Centre, Canberra, 1998, p 18.
[2] Sun Tzu, translated by Griffin, S.B., *The Art of War,* Oxford University Press, London, 1963, p 77.
[3] Simpkin, R.E., *Race to the Swift. Thoughts on Twenty-First Century Warfare,* Brassey's Defence, London, 1985, p 169.

transfer data into information) and people'.[4] Therefore, an IS can be a computer, a radio, a telephone, written information or the knowledge in people's heads.

When information is treated as a physical entity, or as a 'fifth dimension of warfare', it becomes possible to more clearly define the threats to it. To attack an airbase effectively the enemy must possess information or intelligence on that base. Similarly, to operate within the airbase and its broader theatre assigned friendly forces must have unfettered access to their own information, free from disruption or corruption by opposing forces.

The exploitation, defence and manipulation of information has been described as Information Warfare (IW), or more broadly as Information Operations (IO). IOs are defined by the US Army as 'military operations within the military information environment that enable, enhance and protect the friendly force's ability to collect, process, and act on information to achieve an advantage across the full range of military operations: information operations include interacting with the global information environment and exploiting or denying an adversary's information and decision capabilities'.[5]

For the airbase commander the availability and dependence upon a large number of IS introduces new opportunities and also vulnerabilities — 'the rapidly increasing dependence on technology based ISs by military forces is providing the information warrior with a plethora of critical and vulnerable targets'.[6] Accordingly, the ability of airbase staff to control, utilise and exploit information may therefore be crucial to the operability of that unit. The aim of this chapter is to detail how this can be achieved.

THE OBJECTIVES OF INFORMATION WARFARE

The three broad objectives of IW are:[7]

- to control and defend information;
- to utilise information to enhance overall military effectiveness; and
- to exploit information as to use it against an adversary.

Control and Defence

Relying on information as a tool of warfare can create potentially crippling vulnerabilities. Consequently, it needs to be controlled and defended, and this is therefore the first objective of IW. This is perhaps the most critical and relevant class of IO for the airbase as it is the information mission most likely to be undertaken at

[4] Westwood, C.J., *The future is not what it used to be*, Air Power Studies Centre, Canberra, 1997, p 4.
[5] Waltz, E., *Information Warfare: Principles and Operations*, Artech House, London, 1998, p 26.
[6] Westwood, *The Future is Not What it Used to Be*, Air Power Studies Centre, Canberra, 1997, p 6.
[7] USAF, Cornerstones of Information Warfare, p 9.

the airbase staff level and the failure to conduct this mission effectively can significantly jeopardise operations.

Utilisation

Information can be defended and safe-guarded, but it must also be employed effectively to be of any value or to have utility. The effective management and utilisation of information will allow it to be used to further broader military and political objectives. Efficient use of information can enhance total force effectiveness. To be effective, all information systems must possess the characteristics of survivability, alacrity and knowledge.[8]

Exploitation

The third objective of IW is to exploit information to assist in defeating the enemy. This is generally considered an offensive use of information. Exploitation of information is traditionally associated with intelligence operations, which seek to determine the strengths, locations, dispositions, capabilities and intentions of opposition forces. In this way, exploitation goes further than utilisation as it refers to the use of an enemy's information against themselves.

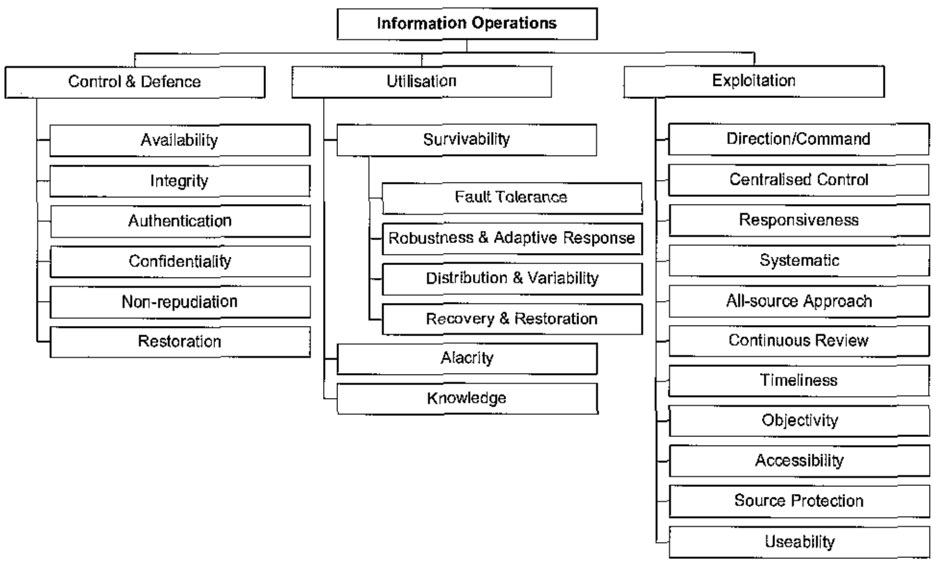

Figure 7.1 The Qualities of Good Airbase Information Operations

[8] Adapted from Westwood, C.J., *The future is not what it used to be,* pp 77-79.

CONTROL AND DEFENCE OF INFORMATION

Airbase Information Vulnerabilities

To defend information it is first necessary to understand where information is located on the airbase and through what avenues potential adversaries may seek to acquire or destroy it. On a typical airbase an extremely wide range of personnel and systems manage information. Virtually every member of the airbase staff will be responsible for preparing, analysing, processing, transporting or utilising information. Correspondingly, the range of potential threats to this information is equally broad. Two main categories of threat can be identified, external and internal.

The External Threat

External threats occur when an adversary overtly seeks to acquire, manipulate or destroy airbase information. Examples include photographic reconnaissance, communications network jamming or malicious attack on computer systems. Table 7.1 details the aspects of airbase information services that are vulnerable to disruption or exploitation by external forces.

Sources	Activities	Countermeasures
Human intelligence	Casual conversations, planted agents, local employees	Training for personnel, counter surveillance, access control, counter intelligence
Signals intelligence	Interception or direction finding on signals, communications or information systems	Emission, Communications and information security
Imagery intelligence	Photography of airbase features or approaches from space, air or land, in a variety of wavelengths or media	Counter intelligence, counter surveillance, access control, active defence, camouflage and deception
Operations intelligence	Observation of operational patterns	Randomised operations, deception techniques

Table 7.1 Typical Airbase Information Vulnerabilities[9]

[9] Adapted from US Army FM 90-12 Base Defence October 1989, p B-9.

The Internal Threat

An internal threat occurs through the action or inaction of airbase staff or systems. It may be deliberate or inadvertent, and includes the disclosure or destruction of important information by airbase or attached staff. This could be a malicious act of sabotage or an inadvertent accident caused through ignorance or violation of procedures. Information can be lost or destroyed most often when its importance is not understood. An example could be the problems caused during post-attack electrical repairs if the original wiring distribution diagrams for the airbase were not kept available (and updated as required) after the construction job was finished.

Unserviceability of equipment essential to the storage, communication, analysis or management of information also poses an internal threat to the effective utilisation of information. A very large number of airbase systems are used to collect, process and transport information. If any of this equipment becomes unserviceable it can interfere with the ability to utilise this information. This unserviceability can and has been caused by the introduction into computer based ISs of software viruses by operators.

Another major facet to the internal threat is the failure by airbase staff to appreciate the vital role that they all play in managing mission critical information. Failure to follow security procedures, disclosure of classified information and the circumvention of security systems all pose as great a threat to information management as any external force. The conduct of the operations security base-line audit (as described later in this chapter) aims to involve as many airbase personnel as possible in this process, and in doing so, emphasise to them all the important place they have in maintaining information security.

Advantages of Using Information Attack against an Airbase

In addition to being used as an adjunct to either a conventional or irregular military campaign offensive, IOs may be employed against a military target such as an airbase in isolation. When compared to other forms of attack IOs offer several distinct advantages that make their use more attractive, particularly at lower levels of conflict. As airbases are not only centres for airpower, but also major centres for information an understanding of these advantages is important.

Harassment via IOs is normally more acceptable politically than the use of physical violence. This makes the use of IOs during lower levels of conflict more likely and the restraints applied to conventional tactics may not be employed when using IOs. The low cost of entry into computing greatly multiplies the threat of electronic information attack because of the increased numbers, kinds, and capabilities of potential adversaries.[10]

[10] Molander, R.C., Riddile, A.S., Wilson, P.A., *Strategic Information Warfare: A New Face of War*, RAND Corporation, Santa Monica, 1996, p 19.

The reliance of airbases upon electronic IS makes them particularly vulnerable to information and electronic attack. As more commercial systems are utilised to reduce costs this vulnerability will increase. Tactical warning of electronic information attack can also be extremely difficult. They can feature speed-of-light attack and withdrawal, and it may not be apparent that one has occurred until it is too late. By utilising global information networks attacks can be mounted on airbase systems from virtually anywhere in the world, robbing rear echelon facilities of any protection they may previously have had by their distance from the traditional battle space.

Information attack can be delivered by proxy, without the actual aggressor needing to develop the technology or physically initiate the operation. This provides benefits in non-attributability and allows specialist IO organisations to function as information mercenaries.[11]

ELECTRONIC INFORMATION ATTACKS POSE A HIGH LEVEL OF THREAT TO AIRBASES. THESE ATTACKS EXHIBIT LONG RANGE, HIGH SPEED, AND CAN BE UNDERTAKEN BY A WIDE VARIETY OF GROUPS OR INDIVIDUALS.

Countering Information Vulnerabilities — Defensive Information Operations

Defensive IOs are those conducted to protect information and deny both internal and external threats. Their broad objective is 'to deny to an adversary certain information that is considered advantageous'.[12] More specifically, the objectives of a balanced defensive airbase IW strategy can be:[13]

- Deter any potential attack on airbase (or assigned force) information activities.
- Protect information activities.
- Detect an attack on information activities.
- React to preclude further attack, ameliorate damage and restore services.

There are six capabilities and component properties that each aspect of an airbase's IOs and ISs should possess. Each IO and IS on the airbase should be assessed against these six criteria, which are:[14]

---

[11] Westwood, *The future is not what it used to be,* pp 72-73.
[12] Jelen, G.F., 'The Defensive Disciplines of Intelligence', *International Journal of Intelligence and Counterintelligence,* Vol 5, No 4, p 381.
[13] Adapted from presentation by RAF SyCIS Branch.
[14] Waltz, *Information Warfare: Principles and Operations,* pp 301-302.

Availability. This assures that information, services, and resources will be accessible and useable when needed by the user. The reliability of the system and how well it has been designed determine this.

Integrity. This assures that information and processes are secure from unauthorised tampering. Effective integrity plans will ensure that an adversary is unable to manipulate airbase communications and information processes for their own purposes. An example would be the tapping into an airbase radio network by an adversary to make unauthorised changes to the airbase ground defence disposition.

Authentication. This ensures that only authorised users have access to information and services. Prevents disclosure of private or sensitive information or the break-down of command systems.

Confidentiality. Confidentiality protects the existence of a connection, traffic flow and information contents from disclosure.

Non-repudiation. This ensures that transactions are immune from false denial by providing reliable evidence to establish proof of origin and delivery. This is an important command tool and provides accountability for instructions given and decisions made.

Restoration. Restoration assures that information and systems can survive an attack and that availability can be quickly resumed without loss of connectivity or data. An encrypted radio that requires re-keying in a central facility each time its battery power is interrupted is an example of an IS with poor restoration capabilities.

Principles of Defensive Information Operations

Having determined what the airbase wishes to achieve through the use of defensive IOs, it remains to be shown how this is achieved. Like any airbase operability feature, the key is a thorough planning process and the application of a few sound principles.

Planning, security and intelligence are the keys to conducting IW from the airbase environment successfully. When designing or conducting defensive airbase IOs this are the prime concepts that must be constantly considered. A simple example in which the six principles can be easily illustrated would be the design, activation and operation of an airbase radio network.

Planning

Airbase IS must be designed and planned from the start with the principles of control and utilisation of information built in. The system must be suitable for use in its intended role (ie. it must possess the characteristics of survivability, alacrity and knowledge discussed later in this chapter) but must also be defensible.

Security

Military IOs and information capabilities are most effective when their full potential is unknown to the enemy. Security of the capabilities, deficiencies and weakness of ISs and IOs must be maintained throughout the implementation and operation process.

Intelligence

Intelligence is essential to determine the information attack and exploitation capabilities of the adversary. With an airbase radio network it is important to know the capabilities of the enemy to disrupt, eavesdrop or interfere with that network. An understanding of their capabilities will allow a better and potentially more economical *security* system to be developed during the IS *planning* process.

Types of Defensive Information Operations

To fulfil the objectives of defensive IOs detailed above three broad categories of operations can be conducted. These include Counter-intelligence (CI), Operations Security (OPSEC) and Security Counter-measures (SCM).[15] Each of these operations makes a specific contribution to the successful control of airbase information.

Counter-Intelligence

CI can be defined as those activities designed to reduce the threat posed by an adversary's intelligence gathering. This is its principal difference to the two other defensive IOs, in that it seeks to reduce the adversary's threat, rather than the airbase's vulnerability. The principle aims of an airbase CI plan should be to:

- Identify an intelligence or information threat;
- Determine which airbase information vulnerabilities may be potentially exploited by this threat, and if desired, notifying those responsible to reduce those vulnerabilities.
- Determine measures to eliminate or neutralise the threat.
- Monitoring the neutralised threat for re-emergence or a change in focus.

Security Counter-Measures

Security counter-measures are those activities conducted to protect information from being obtained by or tampered with by an adversary. Typical security counter-measures that may be conducted at an airbase include:

- Physical security, including locks and security containers.

[15] Jelen, 'The Defensive Disciplines of Intelligence', p 381.

- Encryption of communications and stored data.
- Procedures to ensure the correct handling and protection of information.
- The education of base personnel on the need for information security.
- Security audits and reviews.

Some specific security counter-measures designed to solely protect information (as opposed to more general physical protective measures) include:

- **Emanations Security (EMSEC).** EMSEC is the control of emanations from the airbase, principally electronic and radio frequency. These emanations can be detected by an adversary and used to obtain information or in an extreme case can actually form the guidance method for an anti-radiation guided weapon (eg. HARM used against radar emanations).
- **Transmission Security (TRANSEC).** TRANSEC is the protection of electronic transmissions from interception, analysis, reproduction or disruption by an adversary. These measures are also designed to deny the enemy the opportunity to intercept sufficient traffic to permit code-breaking or 'contextual' analysis.
- **Cryptographic Security.** Cryptographic security is the use of codes, ciphers or encryption to protect information whilst being stored or transmitted.

Operations Security

OPSEC differs from the other two types of defensive IO, in that the information it seeks to protect is usually unclassified, or by itself quite innocuous. OPSEC seeks to identify and protect detectable activities, called *indicators*, which may be pieced together or interpreted to discern critical information.[16]

The OPSEC process is a continual operational, the development and implementation of which should be the responsibility of everyone on the airbase. A six-step process can be used to plan, develop and implement an airbase OPSEC plan.[17] This process is lengthy and potentially expensive to undertake. However, once done thoroughly, it provides a base-line level of operations security that needs only to be monitored and adjusted as circumstances change. The steps in this process include:

- Identify critical information.
- Identify and analyse the threat (usually in concert with the CI plan).
- Analyse the indicators and their vulnerabilities.
- Assess the risk.

[16] Jelen, 'The Defensive Disciplines of Intelligence', p 387.
[17] Adapted from Jelen, 'The Defensive Disciplines of Intelligence', p 387.

- Implement selected defensive IO measures.
- Continual assessment, feedback and review.

Identify Critical Information

Information which can be used by a potential adversary to determine the strengths, weakness, capabilities, intentions and dispositions of the airbase, must be initially identified and prioritised. The exact nature of which information is critical will depend very heavily upon the airbase's strategic outlook and mission. Generally, the most common benchmark for determining the criticality of a particular piece of information is to determine the negative impact if that information were to be compromised.

This planning stage must be undertaken in close consultation with the following stakeholders:

- Airbase customers, such as assigned air units.
- Airbase suppliers, such as rear echelon maintenance venues, engineering authorities, logistic supply centres and local supply sources.
- Neighbouring units, allied formations and relevant headquarters.
- Political and sociological advisers such as public relations personnel. This will ensure that information which may have public relations or political implications is managed in the best way possible.
- Intelligence services, to ensure classified information or information with sensitive sources is appropriately protected.

Identify and Analyse the Threat

The next stage in the information security analysis is to determine the specific threats to friendly information. Table 7.1 details some potential airbase information vulnerabilities and some of the broad threat methods that can be utilised to exploit them. The principal typical threat groups could include:

- Foreign or domestic intelligence gatherers, utilising a variety of electronic, clandestine or overt methods.
- Criminal elements, seeking information on vulnerabilities to exploit for their own profit. This includes personnel both outside and within the organisation.
- Internal threats, either malicious or inadvertent.

Analyse the Vulnerabilities

There are four principal sources of intelligence information that can be exploited by a potential attacker. These can be viewed as information vulnerabilities and are summarised in Table 7.1. This table also provides indicative descriptions of these forms of intelligence collection and typical counter measures which may be applied.

The specific vulnerabilities for an airbase will be obtained by a thorough comparison of critical information against applicable threats.

Assess the Risk

Once the information vulnerabilities for the airbase have been determined they must be prioritised, counter-measures determined and a cost-benefit study undertaken to determine the priority for implementing an OPSEC initiative for each vulnerability. These methods then become an integrated base OPSEC plan (which becomes a subordinate part of the total airbase operability plan). This stage of the process is much like a risk management analysis, whereby risks are compared with the cost of appropriate counter-measures and a priority system for implementation is developed.

The creation of an integrated OPSEC plan provides great strengths as measures designed to protect some information will have obvious spill-over effects to protect other important data. A simple example is the use of secure systems for on-base communication, this will protect a large amount of information from widely differing sources.

One method of approaching the assessment task is to develop a table as follows:

Critical Information	**Vulnerability**	**Counter-measures**	**Cost of counter-measure**	**Implementation method and priority**
Number of fighter aircraft presently at airbase	Imagery Int - Aerial photo-reconnaissance	Active air defence	6x fighter aircraft to provide CAP 1 air defence troop	Can be undertaken quickly, although at the expense of forces elsewhere.
		Placing aircraft in covered shelters	$200,000 per shelter, five months construction	Not feasible due to lack of available lead time in this scenario.
	Signals Int - Data on maintenance IS	IS security system	2x computer operators, $5,000 security software, slower maintenance procedures	Selected for implementation.

Table 7.2 Typical OPSEC Implementation Analysis Table

In this example the critical information that requires protection is the number of fighter aircraft presently deployed to the airbase. Obviously, there is a large number of ways that an adversary could acquire this information, however for brevity only two are presented here — imagery intelligence in the form of enemy aerial reconnaissance, and signals intelligence in the form of data stored on the aircraft maintenance information systems. For each of these vulnerabilities several counter-measures are available and all are listed along with their relevant costs. These costs can be expressed in terms of their requirements in money, manpower or operational tempo. A cost benefit analysis is then applied and the most suitable countermeasure placed in a priority queue for implementation. In the earlier example the two options to prevent aerial reconnaissance were the use of active air defences to keep reconnaissance aircraft away or the placement of the aircraft in covered shelters. For this particular conflict the warning time is very short and there is insufficient time to build new shelters, so the active air defence option will be selected.

The layout of this table ensures that the critical pieces of information are placed first, followed by the vulnerabilities, concluding with the available countermeasures. For each piece of critical information, there may be multiple vulnerabilities and for each vulnerability there may be multiple counter-measures. A cost-benefit analysis of each available counter-measure against the effect of compromising each critical piece of information will determine which counter-measures to implement and in what priority order.

Implement Selected OPSEC Measures

Once a security countermeasure has been identified it must then be implemented in a manner that will achieve its desired aim. More than one countermeasure may be required or desirable for some vulnerability-threat pairs.

Continual Assessment, Feedback and Review

The criticality of information is a dynamic and constantly changing variable. The threats to this information are also highly variable. All airbase personnel must take effective ownership of critical information and prompt changes to the base OPSEC plan when the information variables change. To achieve this all base personnel must have an understanding of the OPSEC plan so they can be aware of how changes in their personal work environment could potentially lead to additional vulnerabilities. An example would be the removal of a piece of scrubland along a fence line to create an additional fire-break. This new cleared area may now allow observation from outside of the airbase of work areas that were previously obscured. This introduces obvious additional OPSEC vulnerabilities and the personnel responsible for commissioning or conducting this work must be aware of the OPSEC impact of the project. Additional countermeasures may need to be implemented to overcome the additional vulnerabilities.

ALL AIRBASE PERSONNEL MUST UNDERSTAND THE OPERATIONS SECURITY CONCEPT AND BE AWARE OF THEIR RESPONSIBILITIES IN MAINTAINING THE ESTABLISHED BASE-LINE. EVEN SMALL CHANGES TO CIRCUMSTANCES CAN INTRODUCE SEVERE ADDITIONAL INFORMATION VULNERABILITIES THAT MAY NOT BE DETECTED BY SECURITY PERSONNEL UNTIL A FULL AUDIT IS UNDERTAKEN.

UTILISATION OF INFORMATION

Principles of Information Utilisation

To be successfully utilised in the combat airbase environment, and to contribute to the broader mission of the airbase, information and IS should possess the characteristics of survivability, alacrity and knowledge.

Survivability

The survivability of airbase ISs is critical. The increasing dependence upon the rapid and constant flow of information has made interruptions to this flow unacceptable. Unfortunately, the increasing dependence of military forces on commercial off-the-shelf IS is reducing, rather than improving, the survivability of these systems. More information is being handled solely by computer based IS, and in many cases airbase operations would cease or be severely compromised by the inoperability of these systems.

Commercial systems are also becoming increasingly integrated and networked, with connectivity being maximised. Whilst this can improve productivity and reduce costs, it can also greatly increase the vulnerability of these systems to degradation and attack. One only need look at the vast number of functions at a modern airbase which are computer controlled to assess the impact of the failure of these systems. Extensive networking can either improve or degrade the survivability of an IS, depending upon the manner in which it is undertaken. Many of these systems rely upon central 'hubs', which if destroyed or isolated render the remainder of the system useless. Destructive electronic 'forces' such as voltage spikes or computer viruses can propagate extensively throughout these networks.

However, where efforts are made, these systems can be designed to provide high levels of survivability. The use of peer-level networks that are not reliant on central servers, the use of fibre-optic cabling to provide electronic isolation and relative immunity from electromagnetic attack or interference and the use of high quality power supply isolators or filters should be the minimum survivability features present in any airbase IS.

In more general terms a survivable IS will exhibit four general characteristics:[18]

- **Fault Tolerance.** This is a capability to withstand attacks and 'gracefully degrade' rather than completely fail. The system should be protected physically and electronically from attack.

- **Robustness and Adaptive Response.** Systems used to store, transfer and process information must also be capable of operating in degraded and hostile environments. As an example, systems reliant upon mains electrical power and

[18] Waltz, *Information Warfare: Principles and Operations,* p 334.

pristine operating conditions should be avoided. IS should be able to detect the presence of an attack or degradation and to allocate tasks to undamaged portions of the system. Where applicable the system should also seek to notify the operator of the attack to allow further action to be undertaken.

- **Distribution and Variability.** As the chapter of this book on redundancy shows, any system reliant upon a single central hub has no place on the operational airbase, information systems not excluded. Systems must be capable of dispersed operation in an independent mode, so that destruction or isolation of the central hub will not totally disrupt operation.

> ANY INFORMATION SYSTEM POSSESSING A SINGLE-POINT VULNERABILITY OR WHICH IS RELIANT UPON A SINGLE CENTRAL HUB FOR EFFICIENT OPERATION HAS NO PLACE ON AN OPERATIONAL AIRBASE.

- **Recovery and Restoration.** Once the system has been damaged or degraded it should be possible to assess the damage quickly, plan recovery operations and undertake these in the minimum time necessary. The system should also be able to alert the user that a fault situation or attack has occurred and provide guidance as to what remedial methods or repairs may be required.

Alacrity

The principle of alacrity states that all information systems must be capable of working in and responding to a time-critical environment. They must contribute to enhancing tight decision loops and exhibit a sense of urgency when processing and displaying information. ISs must also be capable of responding quickly to changes in their environment. Similarly, critical information must be separated from routine material to avoid flooding systems with more material than can be effectively sorted and utilised.

In the airbase environment many operations are time critical and often the environment will change quickly. An example would be the communications system used to support airfield damage repair operations. These operations are certainly time critical, and systems that support this operation must be capable of reacting to this requirement, ensuring that priority messages receive priority handling. The system must also be flexible, allowing changes and possibly casualties in the damage repair hierarchy. The system must be capable of being quickly re-routed to allow for the movement of the post-attack recovery command cell without significant degradation or outage of service.

Similarly good Command, Control and Communications (C3) systems should exist at all levels on the airbase. In some cases, such as the post-attack environment, alacrity will be perhaps the preeminent requirement for such systems. In others, such as the routine distribution of information around the airbase it may not be quite so critical. An example of this would be systems designed to distribute routine orders and information. The critical requirement here is to keep airbase staff informed, reducing confusion, rumour and ensuring that all staff are working towards the common goal.

Knowledge

Knowledge is the most pervasive of the requirements and can be a very open-ended requirement. A knowledgable IS must be capable of adding value in the tasks to which it is assigned. The people who design and establish the systems must have a clear understanding of the roles for which the system will be used and the output required by the end user. The system designers must also clearly understand the capabilities of potential adversaries to exploit or destroy the system.

In the airbase environment an example would be the provision of a computer database to support ground combat intelligence activities. The system must provide the information required by the airbase commander, the ground defence commander and the deployed defensive forces. A system designed to deal with large formations of conventional military units may be unsuited to an environment populated only with small Special Forces detachments and local irregular militia. Similarly, if the system cannot be used to record the presence of friendly forces during nearby search and rescue operations it may have little utility in this environment.

Airbase Information Exploitation Management

Within the airbase command centre there will be a requirement to reduce a very large amount of data into a useable intelligence picture. This will include the following sources of data:

- The strategic and political picture normally fed from a parent command.
- The airbase air defence and air control picture.
- The ground combat intelligence picture, including counter-intelligence operations being conducted.
- Information sharing with partner, joint, neighbouring, combined or maritime forces either through established or ad-hoc channels. Where other units (such as ground based air defence etc) are collocated with the airbase all intelligence staffs should be colocated to maximise knowledge distribution.

The Air Defence Picture

One common example of the exploitation of information is the ability to detect airborne threats to the airbase such as those detailed in Chapter Three. Recent conflicts have shown the vulnerability of traditional Integrated Air Defence System

(IADS) incorporating large fixed radar sites. Advances in radar and communications technology have allowed the employment of a new concept in air surveillance, whereby smaller self-mobile radars are networked to provide an entire air defence picture. Each individual radar is only illuminated for a short period of time before relocating and again supplying information to the air defence network.[19] 'The future in battlefield air defence is connectivity, as an isolated air-defence system is of marginal value.'[20]

The systems developed for this concept are ideal for providing an air defence picture to the airbase commander. The employment of several of these radars in the regions around the airbase can provide a wide area radar coverage whilst maintaining their survivability. Their location will be rapidly changeable and not directly tied to the location of critical airbase features. The distributed nature of their networking technologies do not require the large centralised command and control facilities of the older style systems. Modern tactical air defence radars are also designed to be highly deployable and capable of transportation in C-130 Hercules transport aircraft, slung under CH-47 Chinook helicopters, or in cross country heavy vehicles.[21]

The advantages of these linked, mobile systems include: [22]

- They provide a consolidated real-time local air picture and threat analysis.
- Individual units can be positioned to eliminate blind spots in the system's coverage.
- Detection range can be improved by adding and linking more units.
- Electronic counter-counter-measures can be improved by triangulation of data returns.
- Trackers and surface-to-air weapons can be allocated to targets by optimal selection.
- The system maximises the kill probabilities by allowing multiple weapons to simultaneously engage targets at the optimum point.

Passive systems can also be employed to detect or locate air threats. Because they do not emit themselves, unlike radar for example, they are more difficult to detect by the attacking aircraft, making them harder to find and destroy. They also do not provide any warning that to the attacker that they have been compromised.

[19] Lok, J.J., 'Rising Opportunities', *Jane's Defence Weekly*, 2 June 1999, p 21.
[20] Lok, J.J., 'Protecting High-Value Assets Against Threat From the Skies', *Jane's International Defense Review*, November 1999, p 34.
[21] Lok, 'Rising Opportunities', p 22.
[22] Lok, 'Protecting High-Value Assets Against Threat From the Skies', p 34.

PRISM AD (Air Defence) is such a passive location system. It provides passive detection, direction finding and classification of pulsed radar systems in a multi-emitter environment. The system can complement a conventional air search radar and can also be mounted on a light vehicle.[23]

Ground Combat Intelligence

Ground combat intelligence can be defined as that knowledge of the land enemy, weather and geographical features required by an airbase commander in the planning and conduct of ground defence and tactical operations. Basically, its function is to provide the airbase commander with an accurate picture of the ground situation surrounding the base or in areas of interest. Specific items of information that the airbase commander will require from a ground combat intelligence cell include:

- Sociological and regional factors in the local area that may effect ground operations.
- Information on the local terrain and weather.
- The nature, capabilities and intentions of friendly, neutral and enemy forces in or near the airbase.

By its nature, ground combat intelligence will also seek to obtain and exploit information. The process by which information is exploited is detailed next.

INFORMATION EXPLOITATION

The third class of IOs are those designed to exploit information and use it against an adversary. A four-step process can be used to describe the exploitation of information and is presented at Figure 7.2. This process emphasises the difference between knowledge, information and data and describes the manner is which they are transformed. Data becomes information when organised, information becomes knowledge when understood, and knowledge becomes true professional mastery when applied effectively.

> DATA BECOMES INFORMATION WHEN ORGANISED, INFORMATION BECOMES KNOWLEDGE WHEN UNDERSTOOD, AND KNOWLEDGE BECOMES PROFESSIONAL MASTERY WHEN APPLIED EFFECTIVELY.

[23] Jane's Electronic Warfare Systems 1999/2000, Jane's Information Group, pp 314-315.

Principles of Information Exploitation[24]

Direction. Information collection and exploitation must be in response to a clear mission or direction.

Centralised Control. Intelligence collection must be centrally controlled to provide maximum utilisation of scarce resources, avoid duplication, ensure security of sources and more effectively prioritise operations.

Responsiveness. Intelligence must be responsive to the needs of the commander and the operations staff who require the information to support their planning and activities. Ideally, intelligence should be anticipatory and be flexible enough to redirect efforts in support of changing environments.

Systematic. Information collection and exploitation must be systematic. This will avoid duplication of effort in some areas and gaps in others.

All-source Approach. To provide a more complete assessment that is less vulnerable to enemy deception information should be sought from a wide variety of sources. This will increase the confidence in the final intelligence product.

Continuous review. Information collection, analysis and dissemination is a continual process. As the friendly and enemy positions change the information exploitation focus must change with it and continue to provide current information. The processes and methods themselves used to provide information for exploitation must also be continually reviewed and improved. Customer feedback is important to ensure this occurs.

Timeliness. Information must be collected, analysed and disseminated while there is still advantage in its exploitation.

Objectivity. Information collection and analysis must be based on an impartial and objective plan, based upon the commander's intent and the military situation encountered. Activities and analysis should not be based on preconceptions about the enemy or upon what the commander would like to hear. The information presented must be balanced and a clear distinction made between fact and assumption.

Accessibility. Information must be disseminated to the personnel who need to use it, in a format that will enable them to utilise that knowledge.

Source Protection. Information sources must be protected from compromise or unnecessary loss. This entails the use of procedures to prevent compromising sources when information is disseminated and active and passive measures to protect non-human intelligence collection apparatus.

---

[24] Adapted from Department of Defence ADFP 19 Intelligence, 2nd Ed, Defence Intelligence Organisation, Canberra, 1998, p 1-4.

Useability. The end-product knowledge provided to the customer must be useful to them. It must be relevant, accurate, timely and objective. Customer feedback is important to establish and maintain this.

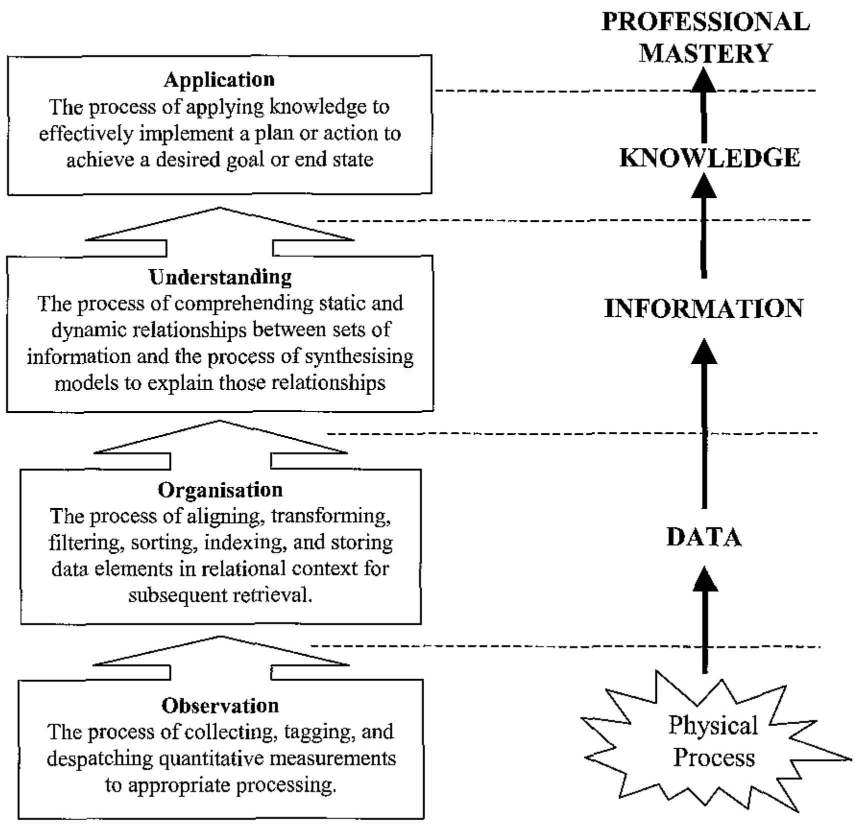

Figure 7.2 Information Hierarchy and the Process of Exploitation[125]

Surprise

The history of airbase attacks clearly demonstrates the value of surprise. Pearl Harbor, the 1967 Israeli attacks on Egypt and the 1982 Vulcan bomber raids on Argentine-held Port Stanley airfield would almost certainly not have been as successful had the airbase defenders not been surprised. The unfortunate thing about all these examples is that in all cases the victims should have been aware that an attack was coming. One of the principal uses of intelligence data by the airbase commander is to rob the

[25] Adapted from Waltz, *Information Warfare: Principles and Operations*, p 51.

attacker of the element of surprise. Surprise has been noted in the past as a major contributing factor in successful airbase attack. Accordingly, an understanding of the nature of surprise attacks is essential for the airbase commander.

> Few defense strategies designed to deter attack lack vulnerabilities. A determined and inventive adversary who is willing to take risks can often discover a way to avoid the strengths of a defence posture and exploit its weaknesses. Designing around the victim's strategy is most devastating when the weaknesses exploited are ones not fully recognised by the victim.[26]

Surprise, as used by a military force can take three forms — performance or technical surprise, tactical or strategic surprise and doctrinal surprise.

Performance, Technical or Technological Surprise

Performance or technical surprise refers to the advantage conferred by the introduction of more capable equipment or materiel. This can either be a long-term significant upgrade of capability, such as the acquisition of a new long-range weapon system or smaller adjustments and enhancements to existing systems. Technological surprise has been defined as 'the unilateral advantage gained by the introduction of a new weapon (or by the use of a known weapon in an innovative way) in war against an adversary who is either unaware of its existence or not ready with effective counter-measures, the development of which requires time'.[27]

For example, during WWII the Americans did not believe that Japanese aircraft based in Formosa had sufficient range to attack Clark Field in the Philippines. However, by adjusting their engines and practicing rigorous fuel conservation flight profiles the Japanese were able to attack.[28]

Normally, however, this form of surprise will be short lived and will exist in a window of opportunity, before the capability is compromised. It would be unusual for one side in a conflict not to have some form of technical capability that was hitherto unknown by their opponent. This is part of the normal race for technical military superiority that most military forces fight, each winning for a short period before their opponent makes a corresponding advance.

Tactical or Strategic Surprise

Tactical or strategic surprise occurs when the victim does not expect the disposition or exact deployment of forces as they occur. Few attacks since 1918 have been prosecuted without some degree of tactical or strategic surprise. Their ability to deploy

---

[26] Betts, R. K., *Surprise Attack,* The Brookings Institution, 1982 Washington DC, p 111.
[27] Handel, M.I., *War, Strategy and Intelligence,* Frank Cass, London, 1989, p 133.
[28] Betts, *Surprise Attack,* p 112.

forces and conduct operations without the enemy having a detailed knowledge is a basic military prerequisite.

Doctrinal Surprise

Technical surprise will normally occur from short term lapses in intelligence information or analysis. Doctrinal surprise will normally occur following a longer term lapse in the collection, analysis and understanding of relevant intelligence data. Doctrinal surprise occurs when a victim, despite having a mechanical understanding of the capabilities and limitations of a potential attackers systems and resources fails to appreciate innovative methods in which they can be used. Often, personnel become set in their ways and fail to see a changing environment, doctrine becomes dogma. Perhaps the best historical example of doctrinal surprise is the crushing German armoured *Blitzkrieg* against France in 1940.[29] The French understood the technical capabilities of the German tanks, but not the revolutionary way in which they would be employed.

Doctrinal surprise is perhaps the greatest threat to face Australian airbases either within Australia or overseas. Through our own and allied intelligence services and a long history of cooperative engagement in our region we have a relatively good understanding of the military capabilities of any potential aggressors. However, the use of those forces in unexpected ways poses a direct threat to airbase operability. As an example, the use of an enemy's limited ground attack assets at the beginning of a conflict to attack, not our extant aircraft fleet, but to seed our inactivated bare bases with area denial weapons could greatly limit our response flexibility.

Doctrinal surprise is also encountered when organisations apply cultural myopia to the intelligence and strategic assessments. Cultural myopia occurs when assessments are made based upon 'what we would do' in these circumstances rather than what 'they would do'. By applying the peculiar racial, national and religious characteristics of your own state to the intentions of the enemy you generate a flawed picture of their probable intentions. The failure of the Americans to predict the attack upon Pearl Harbor was partially based on a belief that Japan would not start hostilities whilst peace negotiations where still underway, because the Americans would not start a war that way themselves.

Perhaps the most curious aspect to doctrinal surprise is that it is rarely a surprise to anyone except the victim state. Western military strategists were aware of the effectiveness of *Blitzkrieg* tactics before 1940, and the Israelis were aware of the capabilities of Arab SAMs and anti-armour missiles before the 1973 October War. However, what was crucial was the failure of the victim to acknowledge the risk posed by these new methods and enact appropriate counter-measures.

[29] Betts, *Surprise Attack*, p 115.

MISCELLANEOUS AIRBASE MILITARY INFORMATION OPERATIONS ISSUES

Electronic Warfare

Airbase Communications Systems

Figure 7.3 identifies the major communications systems which may be present at a typical airbase. Of note is the complexity and variety of linkages in even this simplified diagram. These linkages may be susceptible to interference or break-down. Accordingly, it is important to ensure that the properties of a good IS (as specified earlier in this chapter) are present in these linkages. Also, great care must be taken when deciding what information may be transmitted by non-secure communications links. The OPSEC principle also applies whereby the amalgamation of a large amount of otherwise unclassified data when considered together can betray sensitive information.

Psychological Operations

In addition to the physical dimension of battle, there is also a very important psychological side. The motivation, cohesion and beliefs of personnel, both within and outside the airbase, maybe just as important, if not more so, than their training, equipment and numbers. 'In many other conflicts too, the human factor has been considered the decisive element where levels of technology have been similar.'[30]

Psychological Operations (psyops) are 'planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behaviour of foreign governments, organizations, groups and individuals'.[31] Equating a psyops activity to a conventional military strategy, there are two main types of psyops campaigns, offensive and defensive. Offensive psyops are those designed to alter the perceptions, beliefs and motivations of an adversary's military personnel, population and leadership. Defensive psyops are those conducted to thwart the adversary's offensive psyops campaign and prevent them from successfully employing a psyops strategy. Clearly then, the airbase can conduct both offensive and defensive psyops activities; however, defensive operations are the ones most likely to be undertaken in normal circumstances.

[30] Williams, G., *The Power of Many The Human Factor and Air Power,* Air Power Studies Centre, Canberra, 1996, p 30.

[31] US Department of Defence, *Joint Publication 1-02 Department of Defense Dictionary of Military and Associated Terms,* March 1994, p 304.

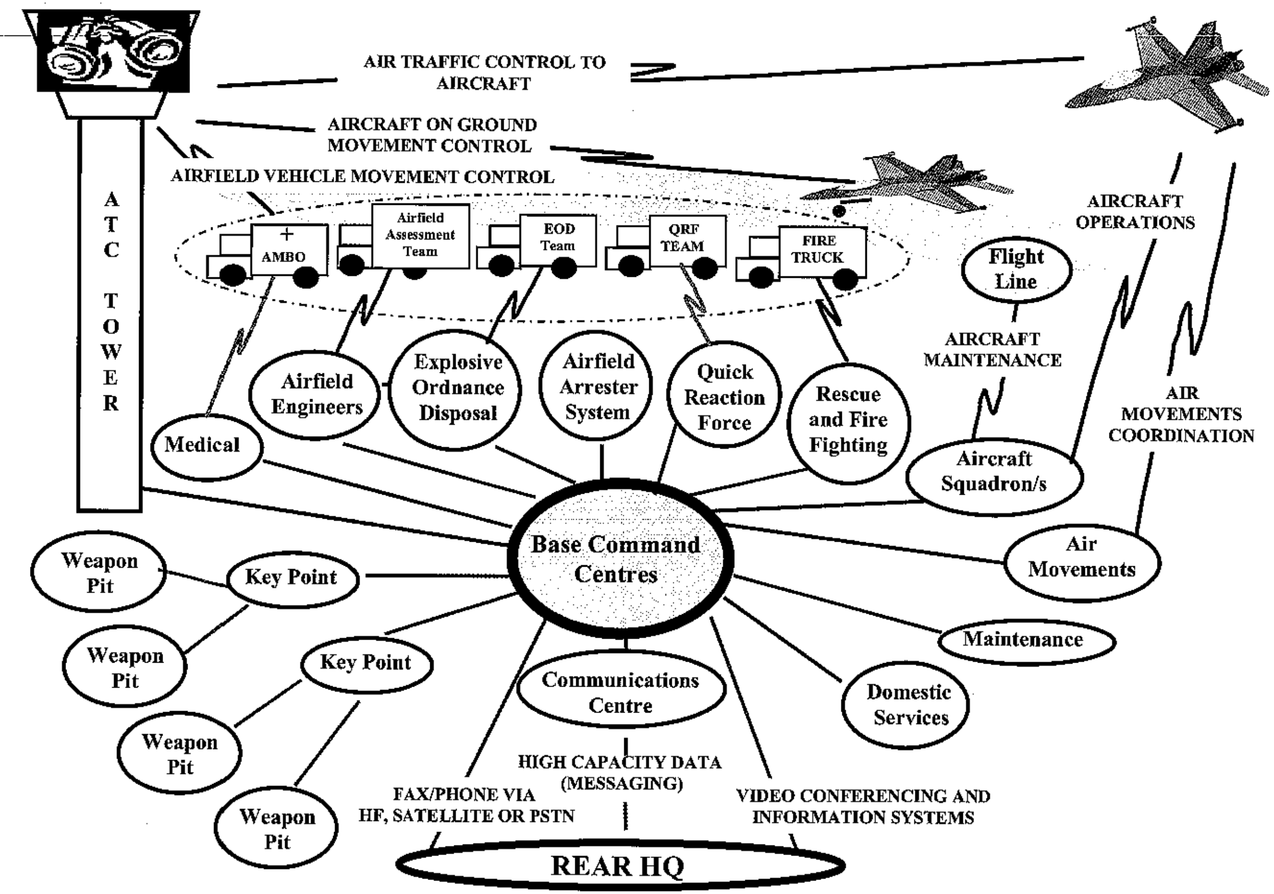

Figure 7.3 Typical Airbase Communications Networks

(Adapted from a diagram originally supplied by Flight Lieutenant Debbie Ward, HQ395 ECSW)

Similarly, opposition forces may conduct psyops, both defensively and offensively against the airbase. The threat posed by the offensive use of psyops by an adversary against airbase staff is discussed as a specific threat in Chapter Five.

This section will consider the use of defensive psyops, including civil affairs action and related methods, to bolster the defensive position of the airbase.

Civil Affairs Operations in Regions Surrounding the Airbase

The need to win the 'hearts and minds' of local populations when fighting in their region has long been acknowledged as a desirable goal. However, it is one that has been rarely achieved and more rarely still seen to provide tangible benefits commensurate with its cost.

During the Vietnam War considerable resources were expended to win the loyalties of the local populations. This was mainly undertaken in an attempt to stifle the Viet Cong and NVA use of these people as intelligence sources, a recruitment pool, a resource base and a base from which to launch attacks. One particular element of the civil action campaign undertaken by the US forces was the use of USAF Military Civil Action Officers (MCAOs) to undertake these tasks in the areas immediately surrounding airbases in Thailand in use by US forces.

The MCAOs undertook the normal civil action tasks designed to improve the living conditions of the villages nearby US airbases. 'Those villages within a 16 kilometre radius of the airbase got top priority for MCAO manpower and financial resources. Why 16 kilometres? Sixteen kilometres is the maximum effective range of the deadly Soviet made 122 millimetre rocket, used so effectively against US airfields and bases in neighbouring South Vietnam.'[31]

Dissemination of information. An important information warfare aspect of the civil affairs campaign is the dissemination of information. This is part of an overarching strategy whereby civil affairs operations support the broader goals of the local commander, in this case the local airbase commander.

Protection of Own Forces and Civilians from Enemy Offensive Psyops

During conflict or tension it is possible that airbase and supporting staff (including civilian personnel) and other civilians such as families may be subjected to enemy psyops or propaganda. This may be undertaken to reduce their support for the campaign being waged or to reduce their effectiveness in conducting it. As stated in Chapter Five, psyops conducted against the airbase staff will rely upon two

[31] Haas, Michael E., *Apollo's Warriors – US Air Force Special Operations during the Cold War,* Air University Press, Alabama, 1997, p 240.

components: the communication of a *message* via the appropriate *medium* to the target audience.[32] Defeating a campaign of this nature will rely upon three things:

- Defeating the message being delivered to the airbase staff;
- Defeating the media being used to deliver the message, and hence preventing its arrival; or
- Ensuring that the airbase staff are sufficiently resilient against this form of campaign that no overt counter-measures are required.

Figure 7.4 MCAO Operations in Vietnam (AWM Photograph JON/70/0385/VN)

[32] Waltz, *Information Warfare: Principles and Operations*, p 209.

More specifically, the following measures can be undertaken to reduce the effectiveness of enemy psyops and propaganda:

- leadership;
- discipline & morale;
- countering rumours;
- conviction of purpose;
- reliable public relations; and
- civil affairs operations.

Restrictive Measures. Restrictive measures are those designed to prevent the flow of enemy propaganda or messages to friendly forces or supporting personnel. Methods such as radio jamming, censorship, the destruction of printed matter or punitive action against personnel possessing or viewing enemy material may be attempted to control this. These methods may be of questionable value, as they tend to generate additional audience interest in that material which does penetrate the controls. It also can convey the appearance that airbase management has something to hide.

Electromagnetic Weapons[33]

Virtually all modern systems from car motors, radios, computers, telephones and weapons contain miniaturised electronic circuitry in the form of solid-state electronics or silicon ship architecture. These systems can be highly sensitive to electrical interference and may be easily destroyed or damaged by excessive voltages. These excess voltages can be created in these circuits either through physical contact, such as connecting mains power voltage to the video signal input of a television or through an induced voltage. Voltage induction occurs when an electrical circuit is exposed to a high power electromagnetic field. Voltages are induced in the circuitry, which may be sufficiently high to interfere with its operation or even cause physical damage or overload.

In the airbase context there are an uncounted number of electronic devices, many of them essential to airbase operations. The deliberate creation of high intensity or focused electro-magnetic fields near around these devices has the potential to disrupt or destroy them. The cause of the damage or source of the disruption may be difficult to isolate initially, and subsequently difficult to attribute to a source.

[33] For a detailed discussion of electromagnetic weapons refer to Kopp, C., *An Introduction to the Technical and Operational Aspects of the Electromagnetic Bomb*, Air Power Studies Centre, Canberra, 1996.

Modern weapon systems are usually designed to operate in a high electro-magnetic radiation environment and most systems designed since the early 1990s have been further protected against the effects of electromagnetic weapons.[34] Accordingly, these systems inside the airbase may be difficult to damage with electromagnetic weapons, at least to the extent where they would pose no advantage over conventional 'hard-kill' attacks.

However, within the typical airbase there exist a vast number of electrical or electronic systems that are not protected against electromagnetic interference to these military specifications. Indeed, the blundering search for monetary savings has led to the demise of many military specifications as inefficient or unnecessary. The end result being that a typical airbase will contain a large number of mission critical electronic devices not protected against deliberate or consequential attack by electromagnetic weapons. Again, the dependence upon computerised information-systems, utilising off-the-shelf computers, for many functions must be highlighted.

Until recently the only field deployed and tested electromagnetic weapons are nuclear warheads detonated high above the earth and generating large electro-magnetic pulses. A single 10 kiloton nuclear weapon detonated at an altitude of 300 miles would be capable of affecting an area the size of the continental United States.[35] More localised effects can be obtained by lower burst heights and the use of micro-yield (two kiloton) nuclear warheads.[36] The detonation of such a device above an airbase could destroy or disrupt all unprotected electronic systems on that airbase. Development in non-nuclear systems to create similar effects is progressing. Unconfirmed reports indicate that Tomahawk missiles were fitted with high power microwave (electromagnetic pulse) generators and used to disrupt Iraqi electronic circuits during the 1991 Gulf War.[37]

SUMMARY

Knowledge is the outermost ring of the operability template and accordingly will be the first area a potential adversary must contest. Knowledge is an essential asset, which must be controlled, utilised and exploited by the airbase to maximise the potential to maintain operability.

To possess knowledge requires the exploitation of information, which is sourced from data, the product of the observation process. When information is treated as a critical asset, all the people and systems used to acquire, process, transmit and disseminate it can then be considered as IS which must meet a common operability standard. The characteristics of survivable IS are fault tolerance, robustness, distribution, variability, recovery and restoration. The requirement to protect airbase IS from interference has expanded greatly as the threat posed by electronic information attack has greatly

[34] Waltz, *Information Warfare: Principles and Operations*, p 289.
[35] *Ibid.*, p 290.
[36] *Ibid.*, p 291.
[37] Jane's Air Launched Weapons Update 32, Tomahawk Missile Entry, Jane's Information Group, Coulsdon, 1999.

increased with the vast increase in the number of interconnected electronic systems around the world. However, not only must airbase systems be protected from the external threat, they must also be guarded from the deliberate or inadvertant actions of airbase staff themselves.

Complementing these protective disciplines are a range of operations designed to acquire intelligence from the enemy and deny them access to sensitive friendly material. These are termed offensive and defensive information operations. Knowledge required to support air operations from the airbase must be collected, analysed and then disseminated to the right people in a useable and timely manner.

CHAPTER 8

Concealment and Deception

In war time, truth is so precious that she should always be attended by a bodyguard of lies.[1]

Winston Churchill to Joseph Stalin, 1943

INTRODUCTION

Of all the developments during the previous 20 years it can arguably be stated that advances in sensor technology have been amongst the most revolutionary. Night is no longer a quiet time during war and target acquisition is as achievable in the dark as it is during daylight. Acquisition ranges have increased and the ability to process sensor data to produce useable intelligence has improved commensurately. This ranges from the theatre wide, or operational level, collation and analysis of data from airborne or space borne sensors such as the US JSTARs aircraft, through to advanced processing capabilities in weapon seeker heads which are capable of discriminating hidden targets. Weapons with long range, high lethality and pinpoint precision can then be deployed against any target so detected.

Against this greatly increased offensive threat the ability to conceal assets from these sensors is of greater importance than ever before. Fortunately, there has been commensurate development in techniques to conceal real targets and deceive the enemy into seeing false ones. However, despite this, Camouflage, Concealment and Deception (CCD) remain the poor cousin of modern warfare, and little thought is given to it until it is desperately needed.

> By using a combination of coatings, chemical treatment, earthworks, screens, nets and decoys to form an effective multi-spectral camouflage, concealment and deception system, critical installations can be disguised to confuse the attacking force and so markedly reduce the probability of vital resources being denied by enemy attack. This can be achieved at relatively low cost compared with the cost of enhancements to active defence systems.[2]

---

[1] Brown, A.C., *Bodyguard of Lies,* Star Books, London, 1977.

[2] Glover, G.H. and Jackson, D., 'Camouflage, Concealment and Deception', *Defence Systems International 1992*, p 283.

When used appropriately deception can be an effective force multiplier. By presenting multiple false targets, hiding real ones, and forcing the enemy to undertake continual reconnaissance, deception can be used to dilute an opponent's concentration of force and effort. Accordingly, deception has historically been used at the tactical level, mainly by the weaker of two opponents. In their various conflicts against the US, nations such as Korea, Vietnam and Iraq all employed tactical and operational deception to the maximum extent feasible. 'Deception in war should be considered a rational and necessary activity because it acts as a force multiplier, that is, it magnifies the strength or power of the successful deceiver. Forgoing the use of deception in war is tantamount to deliberately undermining one's own strength.'[3]

The aim of this chapter is to detail the range of CCD measures that may be applicable in the airbase environment. This chapter includes:

- A description of the principles and objectives of deception and a discussion of the aims appropriate for an airbase CCD plan.
- A brief description of the capabilities and limitations of the reconnaissance platforms and sensors currently available.
- Comments on the historical and theoretical effectiveness of CCD in achieving desired objectives.
- Comments on the initial and ongoing costs of employing camouflage and deception.
- A detailed description of different methods of employing CCD in the airbase environment.
- A methodology by which the most appropriate CCD method can be selected for any given objective.

PRINCIPLES AND OBJECTIVES OF DECEPTION

'Military deception includes all actions taken to deliberately mislead adversary military decision makers as to friendly capabilities, intentions and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of a friendly mission.'[4] Within the military context, the aim of deception can be either offensive or defensive. Defensive deception prevents your assets from being targeted by an adversary, whilst offensive deception enables your forces to position themselves to attack the enemy more effectively. In the airbase environment where the aim is to preserve assets and capabilities within the base, deception is primarily used defensively.

[3] Handel, M.I., *War, Strategy and Intelligence,* Frank Cass, London, 1989, p 400.
[4] Waltz, E., *Information Warfare: Principles and Operations,* Artech House, London, 1998, p 211.

Broadly, deception can be used to:

- **Interfere with planning at the strategic or operational level.** In this role deception is used to prevent an adversary from accurately determining your military capability or posture. Through the use of deception and other information operations (refer Chapter Seven) the potential attacker can be prevented from understanding how important the airbase, and each airbase feature or asset, is to the broader campaign or capability. This reduces their ability to select, identify or prioritise airbase features for targeting attention.

- **Interfere with targeting at the operational or tactical level.** Preventing a potential attacker from knowing precisely where your assets are at any given point in time. This reduces their ability to target assets once they are selected for destruction. This can be achieved at the attack planning stage by using CCD to provide the enemy with a defective intelligence picture or during the physical attack itself.

- **Interfere with post-attack damage assessment.** This prevents the adversary from being able to determine the effectiveness of their actions following an attack, by denying them a true picture of damage caused and residual capability levels. This reduces the enemy's ability to determine whether the original intent of the attack has been achieved. The inability to determine the residual level of capability present at the airbase following the attack will complicate the adversary's future planning process and introduce uncertainties into their understanding of the airbase's ability to contribute to its force structure.

A further use for deception can be found when the deterrent effect of operability enhancements is acknowledged (refer Chapter Six). By using deception to give the appearance that a significant operability program has been undertaken, it may be possible to make an adversary reluctant to attack the base for fear of not being able to inflict sufficient damage for a given expenditure of effort. The use of deceptive techniques to make 'soft' buildings appear hardened or a fictitious airfield recovery capability are possible examples of this concept.

THE RECONNAISSANCE THREATS

Space Based Reconnaissance

Satellites are available which can capture and relay incredibly precise reconnaissance data to ground stations in virtually real time. The US and several other nations are known to operate constellations of intelligence gathering satellites. Nations who do not own their own satellites can purchase this reconnaissance imagery from commercial suppliers. Commercial satellite imagery with resolutions down to one metre is presently available. The US firm Space Imaging's Ikonos 2 satellite was successfully launched in September 1999 (Ikonos 1 was destroyed on launch on 27 April 1999) and released pan-chromatic images that met this long-awaited goal.[5]

During the 1991 Gulf War, American Broadcasting Corporation television was able to purchase five metre resolution imagery of Dhahran airbase, which was sufficiently detailed to be able to identify every aircraft on the strip.[6] Iraq, which used commercial and Soviet imagery heavily during the various Iran–Iraq wars was prevented from exploiting this same information by the UN embargo. During 1999 imagery from the French SPOT satellite was published showing damage to the Batajnica Airbase in Serbia inflicted by NATO bombing.[7] The imagery clearly showed bomb damage to the air defence radar and aircraft repair facility. It also showed an aircraft using the undamaged runway.

Figure 8.1 Ikonos Imagery of Dili Military Heliport, East Timor
(Photograph courtesy SpaceImaging and Defence Imagery and Geospatial Organisation)

Another 46 commercial remote sensing satellites are planned for launch in the next six years. QuickBird 1 was to be deployed by US firm Ball during 2000 however, like Ikonos 1 and its predessor, EarlyBird 1, it was lost soon after launch. Amongst others,

[5] 'Commercial Satellite Reaches 1m Resolution', *Jane's Intelligence Review,* November, 1999, p 3.
[6] Story, W.C., *Third World Traps and Pitfalls,* Air University Press, Maxwell AFB, 1995, p 38.
[7] Hough, H., 'Sat-images: A Window on the War', *Jane's Intelligence Review,* May 1999, p 2.

American company OrbImage claims to be planning to expand its constellation of imaging satellites. OrbView 3 and OrbView 4 are slated to be in orbit by the end of 2001, both offering one metre panchromatic and four metre multispectral capability. In addition OrbView 4 is promised to be the first commercial satellite with a true hyperspectral capability.[8] This will allow it to image in 200 different spectral bands making it far less susceptible to conventional camouflage and concealment techniques. Recent US legislation will allow US firms to sell 50 centimetre resolution imagery.

Military reconnaissance satellites offer far greater capabilities. The US KH-12 series of imaging reconnaissance satellites provide high resolution imagery of targets of interest from low earth orbit. Although the detailed capabilities of military satellites are highly classified, they are believed to be able to provide visual images with resolutions of better than 30 centimetres, which can be downloaded in real time to transportable ground stations.[9] One report credits the older US KH-11 satellites with a 15 centimetre ground resolution.[10] These satellites also have infra-red sensors allowing them to produce imagery at night time. In addition to these capabilities the KH-12s also possess a variety of signals intelligence receivers, allowing the satellite to monitor a variety of radio, telephone, video and microwave signals.

Satellites can also employ radar. The new US Lacrosse series of radar mapping satellites produces images of the earth's surface using synthetic aperture radar. This has the ability to discern objects as small as individual vehicles both during the day and at night and in all weather conditions. It even has some degree of ability to penetrate foliage. Equivalent commercial radar mapping satellites, albeit with lower resolutions, are also available. Research is rapidly improving the capability of commercially available radar imagery. American company OrbImage is planning the launch of their second radar satellite, Radarsat 2, in 2001/2002 to provide all-weather three metre resolution.[11] European research into technologies for a one metre resolution synthetic aperture radar is progressing with the first launch of a satellite with this radar scheduled for 2003.[12]

Smaller nations are also developing indigenous satellite reconnaissance capabilities. South Korea launched KITSAT-3 during May 1999 to conduct 'earth observation, scientific research and telecommunications experiments'.[13] This satellite, launched from India, is part of a continuing campaign by South Korea to ultimately field its own advanced national observation satellite. Contracts are presently being let for

---

[8] Bates, J., 'At Long Last, Imagery Business Takes Off', *Aviation Week and Space Technology*, 4 October 1999, p S26.

[9] Ball, D., 'The Lethal, Critical and Costly Intelligence War', *Asia-Pacific Defence Reporter*, February 1991, p 6.

[10] Forestier, A.M., *Into the Fourth Dimension: An ADF Guide to Space*, Air Power Studies Centre, Canberra, 1992, p 3-9.

[11] Bates, 'At Long Last, Imagery Business Takes Off', p S26.

[12] Taverna, M.A., 'Italy Commits to Galileo, Radarsat', *Aviation Week and Space Technology*, 5 April 1999, p 66.

[13] Karniol, R., 'Seoul in Space-Based Surveillance Race', *Jane's Defence Weekly*, 9 June 1999, http://defweb.cbr.defence.gov.au/jrl/janes/jdw99/jdw02027.htm accessed 2 September 1999, p 1.

various components of the satellite. An Israeli company was selected to provide the optical camera for the system, which is planned to have a one metre resolution.[14]

The open availability of this sophisticated reconnaissance information places a stronger emphasis on the need to use deception during airbase operations. Old five and ten metre satellite imagery that has been on sale for many years is more than adequate to allow pin-point targeting of fixed installations with long range weapons. More advanced commercial satellites with better resolutions and fast response times increase this hazard. By providing this reconnaissance information in virtually real-time it may allow the targeting of mobile assets such as parked aircraft with long range weapons such as tactical ballistic missiles. Even the US military, in the form of the National Reconnaissance Office, is planning on buying $US500 million worth of commercial imagery from space.[15] With prices falling severely as more commercial providers enter the market, this represents a lot of imagery. Radarsat International has recently advertised a 'One + One' deal where customers who purchase new Radarsat-1 images for $US3,500 each, can obtain an archived scene of the same location for only another $US600.[16]

Availability of this imagery may benefit both sides during any conflict, but for the commander of a fixed installation such as an airbase, space-based remote sensing presents a high threat. 'Not only will ensuring the element of surprise in military operations be infinitely more difficult, the imagery becomes the targeting database for the rogue nation or terrorist.'[17]

Accordingly, to protect their national security interests the US implemented the Land Remote Sensing Act of 1992, which governs the use and dissemination of commercial space based imagery. Companies must maintain detailed user logs or who requests their imagery and must be able to limit collection or dissemination of data upon request by the US government. For other countries, this protection has two large limitations. Firstly, it must be visible to and in the interests of the US government to prevent the target nation's potential threats from obtaining detailed imagery of their facilities. Secondly, there are a growing number of imagery providers based in countries such as Russia, Europe and Japan who are not subject to US law.

A primary disadvantage of most satellite reconnaissance platforms, particularly the commercial ones, is the predicability of their orbits. These satellites follow orbits around the earth and information on the orbit of virtually every satellite in existence, including classified military ones, is freely available. Also available is software which using this data can predict the location of any of these satellites at any point in time. Both the orbital data and software is presently available on the Internet.[18] Military intelligence organisations have used similar information for years to provide warnings

---

[14] *Ibid.*, p 1.
[15] Bates, 'At Long Last, Imagery Business Takes Off', p S26.
[16] Bates., J., 'Radarsat International Offers Image Package Deal', *Space News,* 10 January, 2000, p 8.
[17] Moorman, 'The Explosion of Commercial Space and the Implications for National Security', p 16.
[18] Mateski, M., 'Managing ASATs: The Threat to US Space', *Jane's Intelligence Review,* 1 May 1999, http://www.defweb.cbr.defence.gov.au/jrl/janes/jir99/jir00246.htm accessed 11 August 1999, p 3.

as to when these satellites will be overhead sensitive activities, allowing them to be concealed. When an adversary is relying upon a very limited number of commercial satellites to provide data, airbase staff can exploit this weakness. However, notwithstanding this, providing overhead concealment for all significant airbase activities and indicators should be considered part of the normal operating routine.

Airborne Reconnaissance

In the last 30 years tactical airborne reconnaissance and surveillance has undergone major improvements. During the Cuban missile crisis in 1962, USAF efforts to obtain data on Soviet missiles deployed to Cuba mainly consisted of daytime manned overflights of potential missile sites. After the flight's return to base the commander then had to wait for the film to be developed.[19] Night-time aerial reconnaissance began during the late sixties in Vietnam with the use of night vision cameras and 'starlight scopes'. These magnified existing light sources and could not work in total darkness.

Infra-red imagery which detects heat emissions also began to be used during this period but were bulky and took longer to develop into lightweight tactical systems. They use the heat generated by potential targets and the background to develop an image despite total darkness or smoke obscuration. Modern infra-red systems use line scanning techniques to generate digital or film outputs of infra-red signatures below and to the sides of the aircraft. This allows a reconnaissance aircraft to obtain infra-red imagery of an airbase target and determine recent movements. This is done by detecting the warm engine nacelles of recently flown aircraft, or warm or cool patches on the ground where aircraft or vehicles were recently parked.

Side-looking Airborne Radar (SLAR) has been used since the 1950s (RB-47H and RB-57D aircraft) to provide map type plan views of large areas of land. Modern systems incorporate synthetic aperture radars that produce higher resolutions and good stand-off ranges in all weather conditions. Modern systems can image areas 50–70 nautical miles off their flight path with resolutions of less than three metres.[20] These systems are able to distinguish individual buildings, parked aircraft, vehicles and surface features such as runways. Pod mounted synthetic aperture SLAR systems are available for installation on many fighter/bomber aircraft.

SLAR technology has several applications in the military environment. Large versions of these radars are employed to produce broad area imagery without requiring direct overflight, for example in the US Joint Surveillance and Attack Radar System (JSTARS) aircraft. Smaller systems can be used in penetrating aircraft to obtain detailed imagery of specific battlefield areas. Further developments in the field are leading to bi-static systems where the emitting and detecting antennae are mounted in two separate platforms. This allows a powerful transmitter to be mounted in a large

[19] Nordwell, B.D., 'Signal Processing and VHSIC Transforming Reconnaissance', *Aviation Week and Space Technology*, 7 September 1987, p 68.
[20] Scott, W.B., 'Side-Looking Radars Provide Realistic Images Under Adverse Weather Conditions', *Aviation Week and Space Technology*, 7 September 1987, p 93.

aircraft away from the battlespace, whilst a small stealthy receiver flies by the target area to collect the reflected energy and therefore imagery. These systems pose a great threat to airbase targets as they allow detailed maps of airfield surfaces and aircraft positions to be obtained in virtually real time without directly overflying the airbase itself.

Figure 8.2 Hidden Serbian Fighter Aircraft Revealed by Overhead Imagery (NATO Photograph)

Ground Reconnaissance

Observation of the airbase by ground forces can provide intelligence that cannot be otherwise obtained from air or space. Special Forces personnel have been traditionally used in this role and can provide a broad range of intelligence about activities and dispositions on the airbase.

The principal advance which has occurred in ground based reconnaissance is the wide spread use of devices to improve vision during the hours of darkness. Two principal technologies have been developed to allow this — image intensifiers and thermal imagers. Although used to broadly the same purpose, these two technologies operate on different principles and have different strengths and weaknesses.

Thermal Imagers. Thermal imagers present a visual picture of the target scene using infra-red energy, rather than visual wavelengths. They use false colours to represent different temperatures and are very sensitive to small disparities in surface temperature. They are capable of discerning the difference in colour temperature of foliage and other items such as concrete, metal or personnel. Accordingly, thermal imagers are useful in day or night to determine the presence of equipment, personnel or facilities that are otherwise obscured by vegetation, smoke or other obscurants. Although they are capable of viewing through a reasonable degree of normal smoke and haze they can be blocked by the use of multi-spectral obscurant which diffuses infra-red energy.

Image Intensifiers. Image intensifiers magnify the available light to produce a visual image where there was previously insufficient light. Modern, third generation, image intensifiers are capable of providing quality vision in bare starlight conditions. Earlier versions, such as those introduced during the Vietnam War, required a much higher level of ambient light to produce a decent image and usually required clear skies and some moonlight. Image intensifiers are only useful at night and are susceptible to the same counter-measures and obscurants that effect normal eye sight.

These systems are now also generally totally passive, in that they do not need to illuminate the scene with infra-red radiation to view it. Active systems are sometimes still employed, particularly on vehicles, however, they have the major disadvantage of immediately betraying the location of the viewing platform to anyone else with an infra-red night vision system. Passive systems do not have this vulnerability.

In addition to these sensor advances, two other technologies have greatly assisted those who wish to conduct reconnaissance on airbases. These are man-portable global satellite navigation systems and satellite communications systems. Commercial examples include hand held GPS receivers and Iridium or Globalstar phones. These provide the reconnaisance party with precise navigation and direct communications back to their home base.

EFFECTIVENESS OF CAMOUFLAGE, CONCEALMENT AND DECEPTION

CCD techniques are as old as warfare itself. However, as the lethality and effective ranges of weapon systems improve it has become more important to avoid being targeted by those weapon systems.

A small joint field trial was conducted in Europe during 1972 to determine the effectiveness of applying CCD measures to fixed air defence sites. The tests concluded 'that camouflage has a significant effect on the probability of successful attack and it was recommended that existing air defence sites should be camouflaged with particular attention to their permanent features'.[21] Given the advances in sensor technology and weapons guidance since 1972 it is possible to question the results of these trials. However, there have also been significant improvements in the technology of CCD since this time which can redress this imbalance.

[21] Glover and Jackson, 'Camouflage, Concealment and Deception', p 284.

During 1991 the US Department of Defence sponsored a major trial to determine the effectiveness of CCD measures to protect a wide range of assets against aerial attack. The trials tested a range of CCD measures against a range of ground targets in a wide range of environments. CCD measures which were tested include camouflage nets, disruptive patterns, false operating surfaces, decoy aircraft and structures, obscurants, radar corner reflectors, heat suppression techniques as well as hasty measures employing the use of locally available materials.[22]

Results of the trials indicated that the CCD measures employed were effective in improving the survivability of high value targets. 'The number of air attacks on the correct targets dropped from 79 per cent to 48 per cent. At the same time, there was a substantial increase in the number of attacks on incorrect targets, and in the number of aborted passes. When decoys were deployed, they were attacked on 27 per cent of occasions.'[23] Calculations on individual target's chances of survival ranged from 9 to 38 per cent when CCD was not employed to between 42 and 90 per cent when they were. The average maximum aim point error similarly rose from 155 metres to 640 metres. 'The use of CCD also reduced the range at which aircrews could acquire and designate their targets, and altered the timing of critical events in the attack process.'[24]

Satellite imagery of the trial sites was also viewed by imagery analysts, who attempted to discern real targets from the background and decoys. In many cases the analysts identified incorrect targets, assigned incorrect targeting priorities or took longer to analyse each imagery set.[25]

COSTS OF CONCEALMENT AND DECEPTION

The employment of concealment and deception is not without cost. Depending upon the extent to which it is utilised and the nature of the object protected, CCD can entail a variety of costs. These can include:

- An initial set-up cost, including financial resources to purchase the stores and physical resources to set them up.
- An ongoing maintenance cost, again both financial and manpower.
- A logistic overhead as another group of items and stores requiring transport, storage and support.
- Some forms of CCD reduce the operating efficiency of the systems they protect. Camouflage systems may need to be dismantled before their parent platform can move or operate. The CCD may also impose an extra weight imposition or other obstruction, again reducing the potential capability of the employing platform.

[22] Hewis, M. and Sweetman, B., 'Hide and Seek', *Jane's International Defense Review*, April, 1997, p 27.
[23] *Ibid.*
[24] *Ibid.*
[25] *Ibid.*

METHODS OF DECEPTION

Employment of Concealment and Deception

Deception is achieved by an enormous variety of means. The advent of modern sensor technology and space based remote sensing systems does not eliminate the effectiveness of deception, it merely alters the degree to which deception may be effective. Deception operations can be based on the exploitation of bias, sensitivity and capacity vulnerabilities of human inference and perception.[26] Table 8.1 shows three deception principles, examples of counter-deception measures which may be employed and how objective decision support systems can reduce the effectiveness of some deception operations.

Deception Principle	Human Behaviours Exploited	Potential Counter-Deception Decision Aids
Reinforce the target's existing beliefs to achieve greater acceptance, while actual operations perform the unlikely.	Human decision making maintains biases that apply greater confidence and accept information that reinforces preconceived or pre-established beliefs, and places less confidence in or rejects information that it believes unlikely.	Provide objective quantitative assessment of all feasible possibilities. Display positive and negative evidence. Display long-term changes.
Condition (desensitise) the target over time to reduce sensitivity to subtle real indicators. Conditioning may include repeated false alarms prior to a real event.	Human inferential decision making is limited in terms of sensitivity. Sensitivity levels are established on the basis of baselines of belief established by repetition.	Detect possible conditioning activities.
Overload human inference capacity to bias the target to make decisions on the basis of a small incomplete set of facts.	Human inferential decision making is limited in terms of the capacity and perception may be biased to a small set of reinforcing data, rather than integrating a complete set including contradictory data.	Provide assessment support to reduce overload, allow human to focus on the most important information, not the most demanding data.

Table 8.1 Deception Principles, Exploited Human Behaviour and Counter-Deception Measures[27]

[26] Waltz, *Information Warfare: Principles and Operations*, p 212.
[27] *Ibid*, p 213.

Of importance in this table is the way in which human expectations are manipulated with deception operations. When developing airbase deceptive measures these factors should be applied rather than attempting to blatantly fool an adversary. By placing a false command post in a location where such a facility would normally be expected it is more likely to be accepted by the adversary. This is reinforcing their existing perceptions.

The basic forms of deception are concealment and fabrication. Concealment is used to deny the attacker knowledge of something that really exists, introduce ambiguity into their situational awareness or create uncertainty about the truth. Fabrication attempts to convince the attacker that something that doesn't exist actually does, it creates certainty about a falsehood.[28] During the 1991 Gulf War, deception proved to be a cheap and effective Iraqi tool. Simulated bomb damage and the camouflaging of real assets foiled many coalition attacks at little cost.[29]

With the advent of precision guided weapons accurate target position data is more critical than ever. During the 1991 Gulf War, targeting for the air campaign began in August, five months before offensive air operations actually began in the following January. A joint USAF and USN team was formed which compiled a strategic air target list, code named *Instant Thunder*. The plan included a comprehensive description of each target, the recommended weapons to be used and suitable offset aim points for attacking aircraft. One of the difficulties encountered during this meticulous planning process was the lack of accurate data on potential Iraqi targets. Extensive use was made of reconnaissance satellites to obtain target data.[30]

To be successful concealment and fabrication should be employed together. An airbase attacker with a modicum of pre-existing intelligence will be made suspicious if a recently obtained reconnaissance picture differs totally from what was expected. If a squadron of fighter aircraft are deployed to an airbase, it is better to conceal the real aircraft and replace them with decoys than merely to attempt to hide the real assets.

Deception refers to more than simply visual camouflage. A wide spectrum of emissions and activity can be used by a potential attacker to determine the presence and location of targets within the airbase. Deception should ideally be used equally to disguise all traceable signals and emissions from critical facilities and assets. It is not sufficient to camouflage a base headquarters so that it is invisible from the air visually if it presents a clear and unmasked infra-red signature at night or is a source of significant radio emissions.

[28] *Ibid.*, p 211.

[29] Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia*, Air Power Studies Centre, Canberra, 1992, p 158.

[30] Friedmand, N., *Desert Victory : The War for Kuwait*, Naval Institute Press, Annapolis, 1991, p 170.

The following are the principal emissions or characteristics that should be reduced or disguised to prevent acquisition or observation by modern sensors. Conversely, when constructing dummy targets these characteristics must be effectively mimicked or fabricated.

- **Infra-red.** Infra-red (or heat) energy is used in three main ways — passive near IR viewing, active near IR viewing and the viewing of radiated heat.

- **Radar.** Radar imagery from space or aircraft is being used more extensively to map large areas of land and locate targets. To prevent observation from these platforms airbase features should minimise their radar signature and present the radar with a variety of false returns.

- **Ultra-violet.** Present in sunlight, ultra-violet light is reflected in varying amounts from different surfaces. Snow and ice in particular have very high ultra-violet reflectance. Equipment used in this environment should be finished in a white colour that not only appears visually similar to snow, but also has a similarly high ultra-violet reflectance.

- **Surface texture.** In nature, there is very little glossy texture. Individual leaves may appear shiny; however, because of their different orientations they have no shine when viewed from a distance. Accordingly, it is important to ensure that all airbase features are treated in such a way as to prevent them from displaying any glossy texture. This can be achieved through the use of netting, matt paints, surface treatment panels, or hasty improvised coating such as mud.

- **Shape, shadow, silhouette.** The shape, shadow and silhouette of an object or facility will be the primary measure by which it is recognised. This is particularly important when the observer, such an attacking pilot, is operating under severe time and threat constraints. These three characteristics are best broken up by the use of vegetation, netting and improvised materials. This can be particularly important as some weapons use target shape data as part of their target acquisition process. Attention must be also payed to ensuring the item being hidden is done so at all viewing wavelengths.

- **Spacing or configuration.** When being viewed from a distance, the spacing and arrangement of vehicles or buildings is apparent before the details of the items themselves. Accordingly, when being deployed or built in this environment attention should be payed to randomising the layout or positioning of these items. The wide dispersal of equipment in random patterns also has advantages in that it prevents them from being attacked by a single weapon.

- **Radiated electromagnetic emissions.** Radiated electromagnetic emissions can come from an enormous number of sources on an airbase and all can be used to acquire and locate airbase features. Typical items which will radiate electromagnetic energy include on-base radio communications, external radio communications, mobile cellular phones, surveillance radars, weapon guidance radars and navigation and landing aids.

Balanced Stealth

One of the basic principles of CCD is that the target should be equally detectable in all viewing wavelengths. A target should be as visible (or preferably invisible) in all parts of the electro-magnetic spectrum. Deception measures should ideally apply equally to visible light, infra-red energy and radar cross section. It is likely that aerial attacks upon airbases will utilise the radio (both active, as in radar, and passively, homing in on airbase radio frequency emissions), visual and infra-red parts of the spectrum depending upon the attack parameters. Normally, a combination of these will be employed a typical attack run at night utilising radar to identify major features and then infra-red to locate and designate specific targets.

<table>
<tr><th></th><th>VISIBLE 0.4 to 0.7 microns</th><th>SWIR 0.7 to 2.0 microns</th><th>MWIR 3.0 to 5.0 microns</th><th>LWIR 8.0 to 12.0 microns</th><th>MMW 35-95 GHz</th></tr>
<tr><td rowspan="6">Signature Alteration</td><td colspan="2">Foliage</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Camouflage Paint</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Camouflage Nets</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Redirect Engine Exhaust</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Hot Spot Masking</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Radar Absorbant Materials</td></tr>
<tr><td rowspan="5">Decoys/ Deception</td><td colspan="2">Mockup/Replicas</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Smoke</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Heated plates/corner cubes</td></tr>
<tr><td></td><td></td><td colspan="2">Flares</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Chaff</td></tr>
<tr><td rowspan="4">Obscurants</td><td colspan="2">Fog/oil/smoke</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Phosphorus smoke/dust/burning oil</td><td></td></tr>
<tr><td colspan="5">Advanced smokes/aerosols</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Chaff</td></tr>
<tr><td rowspan="4">Directed Energy Weapons/ Jammers</td><td></td><td colspan="3">Hot Spot Beacons</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>RF Emitters</td></tr>
<tr><td colspan="2">Solid-state Lasers</td><td></td><td>CO2 Lasers</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">High Power Microwave</td></tr>
</table>

Table 8.2 Effective Spectral Range of some Typical CCD Measures

Varying CCD measures will be effective in different parts of the spectrum depending upon their design and employment. Table 8.2 illustrates the breadth of measures available and an indication over which parts of the threat spectrum they are effective.

Camouflage, Concealment and Signature Reduction

Camouflage and concealment are designed to prevent an enemy from observing the true disposition of forces within the airbase. Airbase features can be identified by the manner in which they reflect electromagnetic radiation (such as light) to produce a distinctive 'picture' or a detectable contrast with their background. Additionally, virtually all facilities and equipment produce a range of electromagnetic outputs that may be detected and used to detect, locate or target the object. These include visible light emissions, radio frequency energy and infra-red radiation. Five different techniques can be used to deal with the signature of an object. These are to eliminate, reduce, raise, change or copy the signature.[31]

'The scientific principle involved in all camouflage is to reduce as far as possible the contrast between a target and its background be the contrast in size, shape, movement, colour, heat emission or radar echo.'[32] The inability of visible light to penetrate solid objects makes its elimination relatively easy. Black-out conditions have been used since World War I to prevent observation at night from the air and ground. The reduction of other emissions or observable target characteristics is often not so easy.

In the airbase environment CCD is usually not intended to hide a vehicle, aircraft or facility from close observation. The size and complexity of these items typically precludes this without totally compromising the original purpose of the item. The primary aim of CCD is therefore to delay and complicate the process of target acquisition. Where air defences or other operational considerations have forced attacking aircraft to fly fast and low approach patterns even momentary delays in acquiring the correct target can foil correct weapon release. Similarly, a ground attack party infiltrating at night, utilising night vision equipment, under threat of detection from airbase defenders may be equally easily delayed, fooled or confused over their targets. This is particularly relevant when either aircraft or ground parties are on the look-out for secondary targets or targets of opportunity.

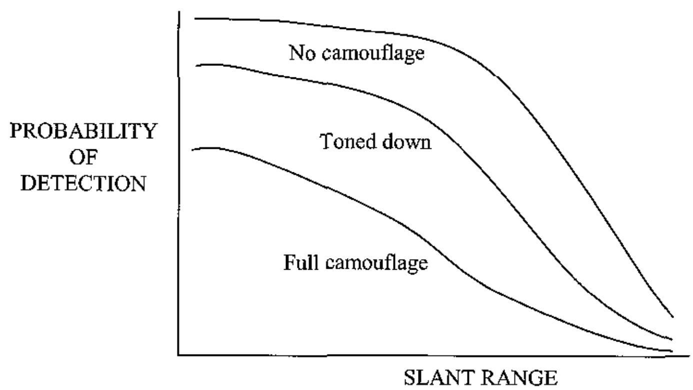

Figure 8.3 Cumulative Probability of Detection vs Slant Range[33]

Figure 8.3 illustrates the difference camouflage can make in the acquisition range of a typical airbase target feature. It demonstrates that CCD is not a 'black and white' issue and that the application of CCD will not simply either hide a target or fail to hide it.

[31] Atkinson, H.R., 'Modern Camouflage Technologies and Signature Management', *Miltech*, September, 2000, p 10.

[32] UK Ministry of Defence Technical Memorandum, Hartcup, G., *Camouflage*, p 147.

[33] Glover and Jackson, 'Camouflage, Concealment and Deception', p 284.

The probability of detection will depend on a broad range of variables, which certainly include the capabilities and opportunities of the acquiring platform.

Like any airbase operability technique a layered approach is more likely to succeed than the application of a single technique. Some of the wide variety of methods and systems that can be employed include the following.

Natural Vegetation

Natural vegetation such as trees provide an excellent source of obscuration for airbase facilities. Employed on a large scale they can complicate even the process of finding the airbase visually from low-level. On a more tactical level they can screen individual buildings or block the line-of-sight to ground based observers at a distance. 'Many airfields in Germany are situated amongst heavily wooded areas which can conceal even the hangers.'[34]

Figure 8.4 demonstrates the way in which trees can be used to hide airfield features at low viewing angles. This is important to not only block visual target acquisition by low altitude fast attack aircraft, but can also prevent laser designation of those targets. This may limit the ability of the attacking aircraft to use loft or toss deliveries from medium range at low altitude. Having to designate targets from either shorter range or higher altitude can expose those aircraft to airbase active surface-to-air defences or friendly fighter aircraft.

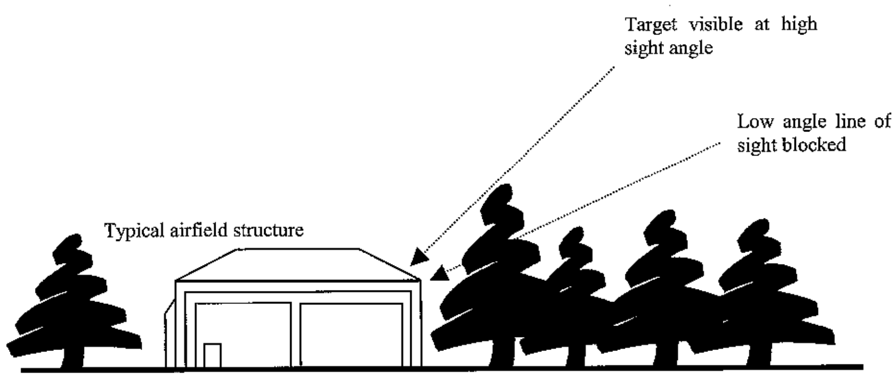

Figure 8.4 Use of Natural Vegetation to Block Low Angle Line of Sight

The extensive use of natural vegetation can also introduce difficulties into conventional airbase defence strategies. Ground forces can use vegetation to screen their approach to the base and provide concealment prior to or during an attack. Depending upon the nature of the trees and the construction of the airbase buildings this close forestation may increase the hazard from fires. Trees may be grown to supply camouflage, which have little or no foliage at ground level to provide

[34] Walker, J.R., *Air-to-Ground Operations*, Brassey's Defence Publishers, London, 1987, p 109.

concealment for personnel. Bands can also be cut into vegetation, parallel with the perimeter defences to provide fire-breaks and cleared fields of fire for defenders.[35]

Earth covered buildings are particularly effective when used in concert with natural vegetation plans. Their earth coverings have a reduced contrast with the surrounding vegetation, and can even be planted themselves with vegetation. They are also resilient to attack and are highly fire resistant.

Camouflage Nets

Camouflage nets have seen great use in every major conflict since World War I. They have been used to primarily prevent observation of ground assets from the air. Modern camouflage nets, or multispectral camouflage screen systems, are designed to reduce target observability in a broad range of media, providing obscuration in the visual, infra-red and radar bands. The nets present a realistic visual appearance in a scheme suitable for the current operating terrain whilst absorbing energy in the infra-red and radar bands. The new US Lightweight Camouflage Screen System (LCSS) is available in a variety of colour schemes and reduces the observability of the target in all three major bands.

Camouflage netting can provide three main functions:

- to prevent an observer from determining what has been placed under it;
- to prevent an observer from even identifying the presence of the material and netting; or
- although not a design function, camouflage netting can provide protection from the elements.

To achieve the first aim the netting must be capable of blocking the transmission of radiation in the three bands mentioned above — visual, infra-red and radar. To be utilised in the second role greater care must be taken to ensure the camouflage netting appears realistic. It must blend into the background and have a realistic natural shape. The netting must also be used consistently as gaps or periodic removal will expose its contents to waiting observers. In either case care must be taken to ensure that items outside the netting do not indicate its presence or the nature of its contents. Vehicle movement, tracks or piles of consumables or support equipment can all provide clues as to the existence or content of the hide.

Paints and Surface Modification Packs

Another method of reducing the visibility of facilities and vehicles are the use of textured panels attached to the surface of these objects. These mats reduce the radar signature of the bare metal surfaces, and present a realistic visual and infra-red

[35] Cooper, R.F., 'The Active and Passive Defence of the Northern Air Bases', in Waters, G. and Casagrande, R., (Eds), *Operational Support Workshop*, Air Power Studies Centre, Canberra, 1995, p 68.

appearance. When combined with advanced multispectral camouflage netting during a trial the use of textured panels was judged by 80 per cent of surveyed tank commanders as providing better visual protection than traditional camouflage netting systems.[36]

Paints have also received extensive development and promise to greatly aid in preventing detection by a range of sensors. Traditionally, paints have been used to reduce the contrast between an object and its surroundings. By combining appropriate colours and low gloss finishes they can still be very effective at this. However, recent developments have provided coatings that can be tailored to provide a wide range of protection. North Carolina-based Spectro Dynamic Systems (SDS) have developed a camouflage paint capable of providing electro-magnetic interference, radar absorption, infra-red absorption and infra-red masking.[37]

In the airbase environment surface modification packs would be on fixed or mobile airfield facilities, vehicles or services. The placement of textured surface matting on exposed surfaces would reduce their visibility in the visual and infra-red bands as well as their radar signature. Given the large numbers of potential radar visible objects on a modern airfield, including the pavement surfaces themselves, reducing the radar signature of fixed facilities may prove to be nugatory effort. However, by viewing the airbase through the eyes and sensors of strike aircraft aircrew, selected uses of signature reducing materials may become apparent. An example could include the masking of signatures from the ventilation stack emerging from an underground bunker.

Greater value may be found in reducing the radar signature of mobile airfield vehicles. As with all good defence a layered approach can be used to mask the presence and location of vehicles, plant and equipment.

- The use of ultra-low gloss camouflage paint incorporating significant grit content provides basic visual protection and blends the surface of the item into the low gloss vegetation background. This paint is also temperature colour matched to the chlorophyll in living vegetation to provide protection from thermal imagers.
- Thermal blankets can be placed over the engine compartments of stopped vehicles and stationary plant to reduce their heat signature. SDS have developed a pad-like blanket, referred to as the 'toaster cover' to be placed over hot vehicles to provide this form of protection.[38]
- Modern multi-spectral camouflage netting provide obscuration at visible, infra-red and radar wavelengths.
- Multispectral obscurant smoke can be used before and during an attack to provide point or broad area coverage.

[36] Hewis and Sweetman, 'Hide and Seek', p 30.
[37] Roos, J.G., 'Disappearing Act', *Armed Forces Journal International,* October, 1998, p 66.
[38] *Ibid.*, p 66.

In the past paints have been used to tone down or reduce the visibility of the airfield surfaces themselves. This was primarily undertaken to hinder the ability of attacking aircrew to acquire the airfields visually during attacks. The advent of radar assisted bombing has reduced the effectiveness of this technique and it may now be a considerable effort for little gain. Some utility may be gained however from attempting to disguise small areas of pavement which are particularly important or lead to a critical and otherwise well hidden facility.

Painting the aircraft themselves is a more fruitful exercise. Once the airfield has been found the attacker still needs to identify individual point targets for attack. This may be achieved using radar, infra-red sensors, visually or a combination of these. Painting the tops of aircraft to blend in with their surroundings has been effective in the past to delay or prevent them being visually identified as potential targets. The success of the Luftwaffe attacks on uncamouflaged US B-17s at Poltava during World War II compared to the far more limited results when RAF Harriers attacked camouflaged Argentine helicopters in the Falklands are good examples (refer to Chapter Two for details on both these incidents). When combined with other forms of CCD and active defences, this type of deception can be effective enough to delay target acquisition sufficiently to foil an attack.

Smoke or Obscurants

The use of smoke to prevent or hinder the enemy from being able to observe or target friendly forces has a very long history. Despite advances in target acquisition systems smoke can still be used in many ways to provide concealment for vital facilities and activities. Smoke generators can be placed in appropriate places (dependent upon prevailing weather conditions) and activated when the airbase comes under attack. If used carefully the smoke can obscure airbase targets from both ground and air observation and designation.

Modern developments have led to more advanced obscurants based upon aerosols and particulants. These are tailored to reduce visibility at specific or multiple wavelengths. The most common of these are designed to block visible and infra-red energy. Systems employed on modern armoured vehicles generate immediate obscurant clouds that prevent observation in both visible and infra-red wavelengths. The Buck Technologies ISG IR 76 millimetre systems provides multispectral coverage for not less than 50 seconds over an area 85 metres wide. A complimentary decoy module can be launched simultaneously which provides an infra-red energy source away from the real vehicle. The currently fielded US M81 smoke grenade also provides screening in these traditional wavelengths as well as the millimetre wave band to reduce the target's radar signature.[39]

[39] Hewis and Sweetman, 'Hide and Seek', p 32.

A similar system produced by the German company Buck Systems is designed to protect armoured vehicles from infra-red and laser guided munitions. When a threat is detected the smoke is ejected providing a multi-spectral screen for up to 60 seconds.[40] The system can be connected to a Laser Warning Receiver (LWR) to provide automated protection. It is possible that a derivative of this system could be placed on top of a critical airbase facility to provide automated protection against laser-guided weapons. It would be portable and could be deployed when and as required. Systems of this kind have been deployed on armoured vehicles since the early 1980s.[41]

An alternative system by Swedish company Hägglunds utilises a fine water fog to obscure the target from visual, infra-red and radar observation. Originally developed by the Swedish Defence Research Agency FOA the system is designed for mounting on armoured fighting vehicles, but could easily be modified to protect fixed high-value targets. A computer based electronic warfare system 'tunes' the water droplet size to match the appropriate current threat. Hägglands claim the aerosol is effective in the visual, 3–5 μm and 8–12 μm bands, and also gives a 15–30 per cent reduction in 94 GHz radar returns.[42]

Although in many launch scenarios the laser does not illuminate the target until just before impact the ability to launch fast-blooming obscurant clouds automatically on warning may sufficiently detract from weapon accuracy to ensure the survival of a hardened target. A network of detector-screening units could be placed around a facility, or group of facilities to provide more comprehensive protection. This would also reduce the ability of the attacker to use the laser to illuminate a spot nearby the protected facility and then 'walk' the designator spot onto the target at the last minute. During the 1991 Gulf War and 1999 NATO operations against Serbia many laser-guided bombs missed their targets when they were obscured by smoke.[43] This has always been a hazard when repeatedly attacking a single target; smoke and debris from the first bomb can conceal the target from following aircraft.

Smoke deployed in a wide screen can be used to block observation along a wide front. When deployed appropriately, considering the prevailing wind, smoke can be used to block observation lines of sight from fence or tree lines to aircraft operating areas. Fitted to a vehicle a continuous multispectral smoke dispenser can provide protection from visual and infra-red observation over a wide area for substantial periods of time. The US M56 system, which is installed on a wheeled utility vehicle, can produce multispectral obscurant for up to 60 minutes. Larger systems, such as the A/E32U-13 Multi-Spectral Smoke Generator use a gas turbine motor to provide obscuration of large static facilities such as airfields.

---

[40] Roos, 'Disappearing Act', p 64.

[41] Ogorkiewicz, R.M. and Hewish, M., 'Active Protection: Providing a Smarter Shield for AFVs', *Jane's International Defense Review*, 1 July 1999, http://defweb.cbr.defence.gov.au/jrl/janes/idr99/idr00420.htm accessed 13 September, 1999.

[42] 'Swedish Water Spray System can 'Tune In' to Tank Threats', *Jane's International Defense Review*, 11 November, 1999, p 11.

[43] Cook, N., 'UK RAF Cools Plans for LCDW Weapons', *Jane's Defence Weekly*, 31 March 1999, p 5.

Although modern infra-red sensors can generally see through ordinary smoke screens, designating lasers cannot. Multispectral obscurant smoke blocks even the infra-red observation. The deployment of multispectral smoke to envelop a target during an attack may prevent that target from being effectively viewed or designated from either the air or the ground. This will significantly reduce the accuracy of laser or command guided weapons, if they are indeed able to guide at all. If the target is hardened only relatively small miss distances must be caused before the attack is ineffective.

Smoke, however, can be a two edged sword. If not used carefully it can hinder the defender as much as the attacker. Smoke deployment is highly wind and atmospheric condition dependent and some forms of pyrotechnic smoke generator will only work for short periods before being exhausted. Accordingly, the placement and activation of the smoke generators is critical. Care must also be taken to ensure that the smoke does not interfere with other defence or aircraft operations, or present a health hazard to personnel enveloped by the chemicals.

Smoke also has a potential secondary deception role to indicate false targets. Particularly in the North of Australia smoke provides a very visible indication of ground activity. The lighting of smoky fires at random locations away from the airbase has the potential to attract attacking aircraft. This may be done in the hope that the smoke indicates damage from previous sorties or other ground incidents. However, as aircraft navigation systems become more accurate and reliable, this tactic becomes less rewarding.

Signage and Movement Indicators

One of the principal tools used to assess the importance of a facility under reconnaissance is the nature and volume of traffic entering it. By disguising, re-routing or otherwise concealing the traffic flows into important facilities they may appear to be less significant during the enemy's target analysis. In many cases during imagery analysis during Korea, Vietnam and the 1991 Gulf War facilities were well hidden but their security features, external connections and traffic flows gave them away.

Street and building signs are also important indicators to potential attackers who may not be entirely familiar with the airbase layout. These should be removed prior to hostilities commencing. Persons with bona fide reasons for being on the facility will be able to ask for directions and assistance from security and other base personnel. Terrorists or ground forces may not have a complete intelligence picture and may use signage to help identify or confirm targets or routes. During World War II travel in Southern England was made difficult because of either the absence of road signs or the deliberate use of wrong names or misleading directions.

Often innocuous seeming items can be used to indicate the presence of important or vulnerable assets. An example would be the sound of air conditioning units at a forward operating base indicating the presence of important personnel or critical electronic equipment. The presence of these forms of indirect indicators is an operations security issue and is dealt with in more detail in Chapter Seven.

Radar Signature Reduction

Whilst conducting operations against an airbase target, the attacking aircraft or missile may be dependent upon the interpretation of a radar image. This may be in the form of:

- Space based or airborne surveillance radars, possibly of a synthetic aperture design.
- The use of a radar in the attacking aircraft to acquire targets or offset points.
- A radar guidance system in a missile, either active or semi-active.

The ability to break-up this radar picture can be effective in preventing or delaying the acquisition of targets or offset points for attack. This can be done by emplacing radar decoys or by reducing the radar signature of real targets.

Starting in 1993, the US Department of Defence began investigating methods of protecting ground equipment and command and control facilities from detection and identification by airborne or space based high resolution radar. In response to this threat, the US Army Space and Strategic Defence Command (SSDC) at Huntsville, Alabama, began investigating the use of light weight shelters which could be quickly erected over important facilities or equipment and reduce their visibility at radar wavelengths.[44] The shelters are formed from complex shapes that provide no re-entrant geometry to reflect incident radar energy. The material covering these shelters is designed to break-up and absorb radar beams, reducing peak radar returns by as much as 20dB in tests against high resolution synthetic aperture radars.[45]

Other methods to reduce target visibility in radar wavelengths include special obscurants, camouflage nets, surface modification packs and active electronic jammers. These systems have already been described in detail.

Further Protection from Visual Observation

In addition to the use of netting, smoke, and vegetation, buildings can also be used to block observation, particularly from the air or space. This is one of the primary advantages of roofed aircraft parking areas. By having more shelters than aircraft the enemy will generally be unable to determine where the aircraft are parked at any given time, reducing their ability to destroy them successfully. If the shelters are hardened they can often continue to provide this protection after they have been attacked. The benefits of hardened aircraft shelters are discussed in detail in Chapter Nine.

Transportable shelters can also be used to protect parked aircraft from visual identification. Fabric covered shelters are available which can be transported to deployment locations and quickly erected to provide temporary aircraft hangars. They

---

[44] Fulghum, D.A., 'Stealth Structures Hide Critical Targets', *Aviation Week and Space Technology*, 21 February 1994, p 94.
[45] *Ibid.*, p 94.

are weather resistant and provide the required protection from aerial observation. One such product from Universal Fabric Structures claims to provide these benefits at low cost. The shelters can be thermally insulated and camouflaged.[46] When placed into pre-prepared dispersed revetments they are also protected against some of the effects of near misses. One such shelter is shown at Figure 8.5.

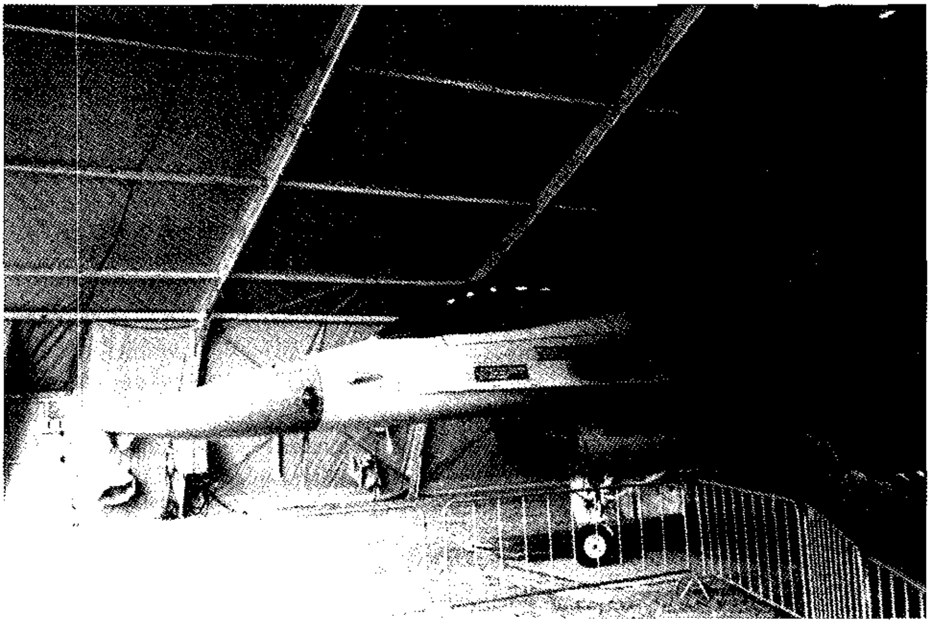

Figure 8.5 F-16 Aircraft Inside Transportable Hangar (Photograph courtesy Universal Fabric Structures)

Reductions in Electromagnetic Emissions

There are a large number of sources of electromagnetic radiation within the typical airbase. These can be used by an attacking force for a number of purposes:

- The source of the emission can be used to determine the location of critical facilities through the use of direction finding equipment.
- High power emissions can be used to guide passive anti-radiation weapons.
- The content of the signal can be interrogated to provide signals intelligence data. This can be in the form of communications intelligence, or comint, or non-communications signals such as radars, termed elint.

[46] Universal Fabric Structures web-site http://www.ufsinc.com/html/mss.htm accessed 5 November 1999.

Where ever possible buried land-line communications should be provided between all facilities on the airbase. Burial of cables reduces their probability of being damaged or interfered with during a ground or air attack. This form of cabling should also be provided between all planned or established defensive positions. Ideally, this cabling should be fibre-optic to maximise the bandwidth capacity, reduce the opportunity for covert interception and to provide electrical isolation.

Where radio communications are used, or other electromagnetic emissions are being generated, antennas and other emitting devices should not be co-located with critical facilities. This is a breach of good operations security principles and can immediately betray the location and/or nature of those facilities. Where it is feared that a remotely located antenna head may be susceptible to tampering or destruction a secondary antenna head can be provided close to the facility and activated when required.

Global Positioning System (GPS) Jamming

One weapon technology trend being extensively developed at present, is the use of GPS, or other Global Navigation Satellite Systems (GNSS), such as the Russian Glonass, to guide weapons to their targets. These systems promise the ability to attack geographically fixed targets with high accuracies and low costs. This form of guidance has many advantages over other popular forms as discussed in Chapter Three.

The principal disadvantage or vulnerability of GNSS guidance systems is their reliance upon the reception and interpretation of the relatively weak satellite signals. If these signals are blocked or jammed the navigation systems may not be able to determine its own current location accurately. This will generally force the weapon to use alternate guidance systems (where employed) such as inertial navigation, which may degrade its terminal accuracy.

With the GPS satellites located more than 17,700 kilometres from a terrestrial receiver it presently only takes a low power jamming signal to jam out the GPS signal. Jammers with a power output of one watt are currently commercially available which can block GPS signal acquisition in their vicinity. The two principal methods of avoiding this jamming are to modify the GPS receiver in the weapon or to modify the GPS satellites themselves. Presently, both these methods are being undertaken by the US military. The use of adaptive antennas and improvements to new GPS satellites will make GPS guided munitions more resistant to jamming. The final test of the Anti-jam GPS Technology Flight Test (AGTFT) test vehicle in a high power GPS jamming environment still resulted in a hit within six metres of the target.[47]

The USAF is also planning to make the GPS satellite network itself more robust and survivable. Plans are in place to improve the security of the new Block IIF series of GPS satellites due for launch from 2005. Issues being addressed include the security

[47] Richardson, D., *GPS in the Shadow of Navwar,* Armada International, April 1998, p 26.

and strength of the GPS signals and the vulnerability of the satellites themselves to attack.[48]

There are several further impediments to effective GPS jamming. Firstly, as GPS systems mature, and both receivers and the satellite network become more robust, it will take more power to jam the signal effectively. As the physical size and radiated power of these jammers increase they become targets in their own right, vulnerable to anti-radiation weapons. Secondly, back-up guidance systems such as inertial navigation provide weapons with the ability to strike targets despite loosing their GPS signal. This is particularly the case if the jammer is located close to the target and GPS signal loss occurs sufficiently late into the attack.

However, contrasting with this is the increasing sophistication and falling costs of GNSS jammers. These may soon be cheaply mass produced, allowing large numbers to be deployed on and around the airbase. They would then be resistent to cost-effective location and destruction and could be capable of preventing GNSS guidance out to a considerable distance. The placement of such jammers in Uninhabited Aerial Vehicles (UAVs) or balloons tethered over the airbase further increases their effectiveness. By placing the jammer physically above the receiver it is better able to penetrate directional antennae, producing a larger effective range with less radiated power. The use of any of these techniques could have a significant effect on weapon systems forced to rely on back-up guidance methods over large distances.

GNSS jamming also has potential applications to be used against enemy ground forces. Jamming may be used to prevent them from navigating by GNSS or accurately positioning stand-off weapons. Given that GNSS (and therefore GNSS jamming) signals only travel line-of-sight and the potential for the jamming to compromise friendly operations this methodology must be used with care.

Active Deception and Fabrication

Active deception is the technique of using overt methods to portray a target picture that is false or misleading. It relies upon the fabrication of false structures, features, aircraft, personnel, communications systems and movement.

Dummy Airfields

Dummy airfields have been used in the majority of wars fought during this century. Of note is the fact that more German bombs were dropped on dummy airfields than on actual operating airfields in Britain during World War II.[49] Two main types of dummy airfield were established by the British — 'K sites' and 'Q sites'. K sites were designed for daytime use and consisted of fake airfields complete with dummy fighters and bombers built by the British film industry. Q sites were designed for night-time use

[48] Bender, B., 'GPS Rethink Likely after Operation Allied Force', *Jane's Defence Weekly*, 28 April 1999, p 4.
[49] Glover and Jackson, 'Camouflage, Concealment and Deception', p 283.

and consisted of lights spread out to look like flare paths and circuit lights.[50] Following Luftwaffe attacks on these dummy fields fires would be lit, wrecked airframes layed out and canvas bomb craters positioned to encourage further attacks.[51]

The availability of high resolution satellite reconnaissance, precision navigation systems and the use of radar for target acquisition have made the use of dummy airfields less profitable, particularly given the potential cost of constructing them. Where satellite airfields have been constructed for use as diversionary or dispersal fields some utility may be gained by attempting to falsify the image the potential attacker has of the relative field usage patterns. Active deception may be employed to lure the attacker to strike the minor fields in preference to the main operating base.

Decoys

When employed correctly and realistically decoys have been shown to be effective in attracting enemy fire away from real targets. In both the Vietnam War and the 1991 Gulf War decoys were attacked regularly from the air. Soviet doctrine emphasises the use of deception and states that deceptive measures must be 'persuasive, plausible, timely, have continuity and that stereotypical or repetitive measures to conceal or deceive will not work'.[52] They further directed that 'decoys must look like the appropriate form and reflect light, heat and magnetic energy. They must also create the proper heat emissions, have magnetic fields around themselves, etc'.[53]

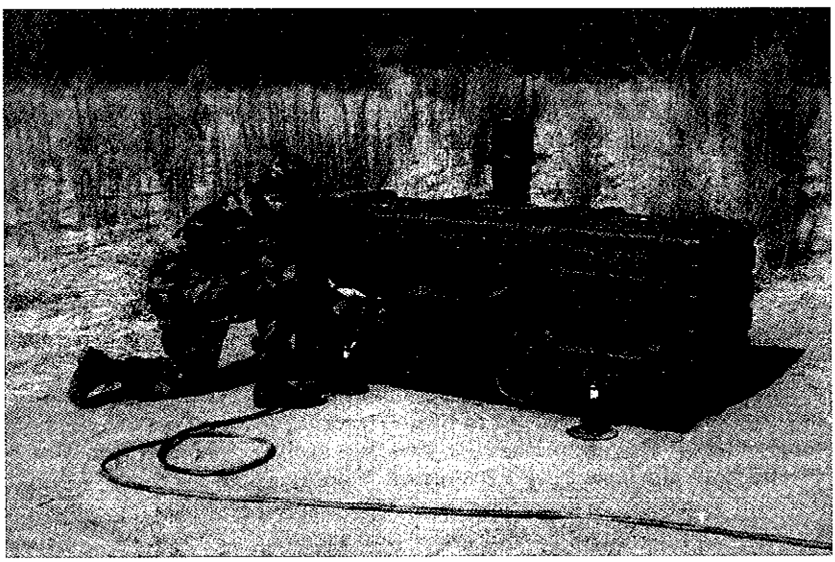

Figure 8.6 AN/TLQ-32 Active Radar Decoy (Photo courtesy ITT Gilfillan)

[50] Crabtree, J.D., *On Air Defence,* Praeger, Westport, 1994, p 60.
[51] Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987, p 14.
[52] Conley, H.P., *A History of Camouflage: Concealment and Deception,* p 37.
[53] *Ibid.,* p 36.

Modern aircraft decoys are available which can effectively simulate the appearance of actual aircraft in all observation media. They must be more easily acquired than the real thing, however, must also be placed in a realistic setting. Decoy aircraft, and to a lesser extent other airfield features, should possess the following characteristics:

- The dummy must be realistic enough to fool observers from a reasonable range, both from the air and ground.
- Dummies can be made more realistic by enhancing selected 'trigger points'.[54] These are the features of a parked aircraft that first cue an attacker to its presence or nature. These may include the presence of twin tails, a reflective bubble cockpit or the shadow under the aircraft.
- Features surrounding the dummy must be realistic. Parked combat aircraft are always surrounded by various items of ground support equipment and machinery. They also leave characteristic marks on the tarmac below them from fuel and oil stains and engine exhaust. These items and marks can be easily simulated from local materials.
- Dummy aircraft must be moved regularly — if they remain immobile for too long they will be recognised as dummies.
- Dummy aircraft must also be representative of the real thing in all parts of the viewing spectrum. They must appear visually like aircraft, contain a heat source and possess a realistic radar signature.
- The major components of the decoys must be capable of being disassembled or deflated and packed away. This will improve their transportability, reduce their storage overhead, and also allow them to be held in relative secrecy until they are required for use. The premature alerting of the enemy of the presence of active deception can greatly reduce its effectiveness.

Dummy aircraft have been employed in virtually every conflict in which airbases have been attacked. Perhaps the most recent use of this technique was by Serbian Forces during Operation *Allied Force* in 1999. Entering the conflict with a significantly inferior Air Force to NATO, the Serbians employed camouflage and concealment to a dramatic extent. Model makers from the Nova Pazova Model Club were tasked to construct very realistic mock-ups of MiG-29 aircraft for use as decoys. Obviously built with great skill, these mock-ups were very realistic looking, especially to an attack aircraft operating above 3,000 metres. When employed the decoys contained sufficient metal to present a radar signature and 'smoke boxes' were placed next to them to provide an infra-red source. These decoys were attacked on several occasions and according to one source were deliberately placed to entice NATO aircraft within range of surface-to-air weapons.[55] Figure 8.7 shows an F-18 aircraft dummy manufactured by Saab Barracuda AB.

---

[54] Glover and Jackson, 'Camouflage, Concealment and Deception', p 284.
[55] Stekovic, M., 'Yugoslavia's Wooden Fulcrums', *Air Forces Monthly*, November, 1999, pp 34-35.

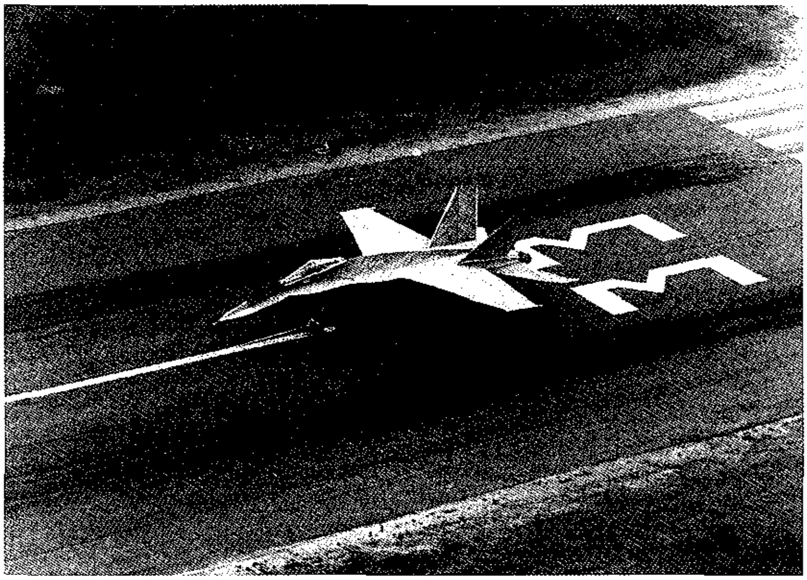

Figure 8.7 Commercially Manufactured F-18 Aircraft Decoy (Photo courtesy Saab Barracuda AB)

Decoys are also available which can simulate the presence of other airfield items such as air defence systems and logistics infrastructure. These may be sophisticated attempts to mimic radars, through to hasty improvised dummies constructed of local materials. Equipment such as the ITT Gilfillan AN/TLQ-32 electronic decoy can mimic the electronic signatures of high value targets such as air defence radars. The AN/TLQ-32 is a transportable decoy system designed to protect the AN/TPS-75 radar from attack by anti-radiation missiles.[56] It is shown at Figure 8.6.

Radar reflectors can also be placed around the airfield to present misleading radar returns. Normally, these reflectors will be pieces of sheet metal or aluminium honeycomb, shaped to present a high radar return using the corner reflector principle. Alternatively, long strips of sheet metal, bent into an 'L' shape along its length can be placed to simulate fence-lines, road edges and power cables. Figure 8.8 illustrates hows a piece of metal placed on the ground to produce a very strong linear target return. The placement of radar reflectors should be well considered and their placement designed to complement an overall deception plan. The effectiveness and positioning of these decoys is dependant upon a large number of factors including the radar signature of the real target, the overall deception plan and the resolution of the attacker's radar. The attacker's radar resolution will also determine how far away from the real target the decoy may be placed so that they will be viewed as separate and distinct targets.

[56] Hewis and Sweetman, 'Hide and Seek', p 31.

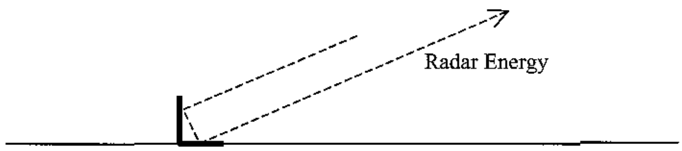

Figure 8.8 Use of Corner Reflector to Produce Strong Radar Return

Post-Attack Deception Techniques

'Gauging the effectiveness of the aerial attacks on Iraqi ground forces ultimately boiled down to battle damage assessment (BDA), a perennial problem in the application of air power.'[57] As this quote displays, the ability to determine the effectiveness of attacks is a critical component of the targeting cycle. Targets which have been struck, but which have not suffered a desired level of attrition, must be reattacked.

Where the target is an airbase, the determination of residual capability may be critical to the broader campaign. Subsequent air, land or sea operations may be planned which rely upon air power from that base being neutralised. The inability to determine to what extent this has been achieved may jeopardise those missions. The belief that an airbase has been neutralised, when in fact it is still capable of generating air missions, could lead to a nasty tactical surprise being inflicted by aircraft from that base. Deception is a very useful tool for complicating the BDA process.

The range of techniques that can be utilised to deceive BDA is as limitless as other deception techniques. An interesting summary of Iraqi BDA deception during the 1991 Gulf war states:

> Iraqi engineers tried to paint a false picture of the battlefield using decoys and other techniques. They deployed dummy Scud launchers, artillery pieces, tanks and SAM and Silkworm missile sites, and literally painted "holes" in airfield runways to simulate bomb damage. By night, they placed burning tires near the decoys to simulate heat signatures in order to fool FLIR sensors in allied aircraft. By day, they placed smoke canisters or containers of burning diesel oil on operational tanks to create the impression that they had already been hit.[58]

[57] Marolda, E.J. and Schneller, R.J., *Shield and Sword,* Naval Historical Centre, Washington, 1998, p 242.
[58] Marolda and Schneller, *Shield and Sword,* p 242.

Some post-attack BDA deception that may be effective in the airbase environment includes:

- The use of smoke to simulate damage and fires, particularly emanating from serviceable equipment or facilities.
- The use of paint or other materials to simulate crater damage to pavement surfaces etc. The principal limitation with artificial craters is their lack of shadow effect as the sun moves during the day. Depending upon the sophistication of the enemy intelligence services, this can be partially overcome by the use of moon shaped 'flat shadows' adjusted at regular intervals to fool aerial or space based reconnaissance.
- Spreading debris from the site of simulated bomb impacts to give the appearance of thrown spoil or secondary damage.

During the Korean War the North Koreans became increasingly adept at utilising camouflage and deception to fool UN bomb-damage assessment. On one occasion the false craters they painted on a runway were so realistic that a landing MiG-15 pilot was fooled, causing him to overshoot the apparently damaged area and crash.[59]

SELECTION OF DECEPTION TECHNIQUES

The secret in choosing which deception methodologies to employ (if at all) is the effective matching of a deception plan to the applicable threats and vulnerabilities. The utility of then employing CCD techniques can be assessed and the final decision can be decided on a cost-effectiveness basis. CCD does entail a cost and labour overhead and it may not be suitable in all situations. The selection planning process presented is shown at Figure 8.9.

- **Step 1.** Define the broad objective of the airbase CCD plan. How will it fit in with and complement any higher level deception plans in use in that theatre? The objectives of the plan should be realistic and take into consideration the range of reconnaissance capabilities available to the adversary.
- **Step 2.** Define the threat. This would include the adversary's reconnaissance and target acquisition systems and their ability to process and analyse this information.
    - Space, air or land based?
    - Stand-off or close reconnaissance capability?
    - Is the adversary undertaking this reconnaissance themselves or employing friends, allies, commercial organisations or proxies to assist?

[59] Kreis, J., *Air Warfare and Air Base Defence 1914-1973,* Office of Air Force History, Washington DC, 1988, p 277.

- How long has the adversary been accumulating data on the airbase? If the adversary has been building up an intelligence picture of the airbase for a long period this may negate the value of trying to hide some features suddenly.

- Sensors which the adversary may employ — IR, visible, ultra-violet, radio frequency, human intelligence.

- The technical capabilities and characteristics of these sensors.

- Do the adversary's platforms, people or systems have any weaknesses? Do they have any preconceived expectations that can be reinforced to the airbase's advantage?

* **Step 3.** Based upon the requirements of the CCD Plan (Step 1) define the airbase's visible target features and emissions or other indicators which must be concealed, modified or fabricated. Chapter Seven describes these features as information vulnerabilities.

* **Step 4.** Define additional considerations.

  - How is each target visible, both in reflected and emitted energy? Can it be seen in IR, visible light, ultra-violet or radio frequency wavelengths?

  - Are the potential airbase targets mobile? Do they have a requirement for rapid mobility? This may limit the CCD measures that can be employed as extensive camouflage may take some time to apply or remove.

  - To what extent are the media and public relations personnel involved in airbase operations? How will their efforts compromise or complement the planned CCD measures?

  - To what extent is the facility or asset critical? To what extent is the facility or asset vulnerable to damage or degradation? It may be possible to not apply CCD to some important features with the expectation that other operability enhancements such as active defence or hardening may protect them.

  - How long must the deception remain effective?

* **Step 5.** Determine potential effectiveness of each of the possible CCD measures and select the most effective and efficient method for each vulnerability.

  - What lead-time is available to develop or implement CCD measures?

  - What resources, in terms of money, labour and materiel are available for the development of CCD measures?

* **Step 6.** Implement CCD measures to create a complete deception 'story' based upon the initial objectives.

- **Step 7.** Constantly monitor the continuing effectiveness of the CCD measures and ensure they do not become predictable or compromised. 'Any perpetrator of deception will be in a much more vulnerable position if he assumes that his plan is working, whereas in reality his opponent is manipulating it to his own advantage.'[60]

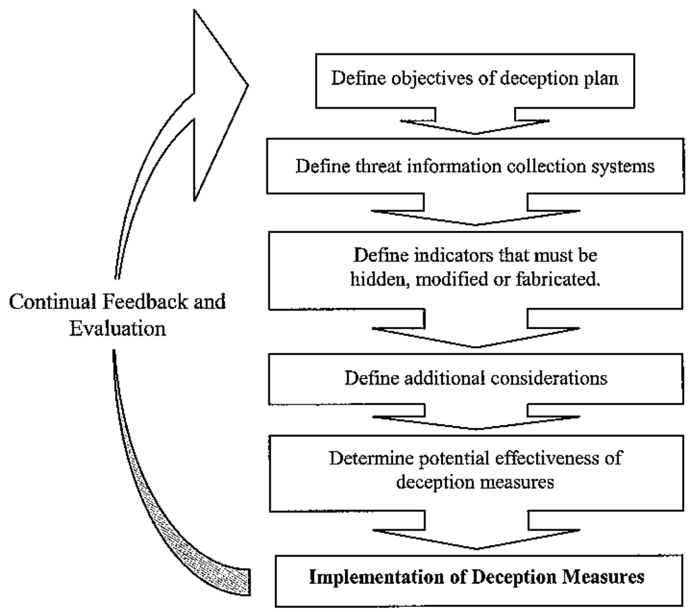

Figure 8.9 Selection of Deception Plan

SUMMARY

> It might be thought near impossible to fail to acquire an airfield, for example, but this has been done enough times in the past.[61]

Concealment and deception can play a very important role in airbase defence. The effective employment of CCD in airbase defence will act as a force multiplier and should be given a high priority. Unfortunately, whilst deception is often recognised as an important tool, there is no systematic way to teach the art. Although the basic mechanics of applying CCD to a task can be documented the skill of employing these

---

[60] Handel, *War, Strategy and Intelligence,* p 342.
[61] Walker, *Air-to-Ground Operations,* p 109.

methods into a seamless operational deception plan cannot. This requires imaginative lateral thinking, a clear understanding of the enemy's capabilities and, most importantly, a clear understanding of what is to be achieved by the deception plan.

Advances in technology have made the art of CCD more complex but certainly not redundant. Indeed, the greater range of sensor technologies available, and the variety of platforms they can be mounted on, makes the use of a comprehensive signature management plan more important than ever before. Modern CCD measures must now take into account the broad range of sensors available to an opposing force and present a balanced and comprehensive deception. Deception must also accommodate the reconnaissance and targeting decision support systems now available that combine advanced image processing algorithms and the ability to fuse multi-source data in near real time. This has dramatically increased the information that may be assimilated and analysed and commensurately increased the number of indicators that must be concealed. This vast information gathering and processing effort is a cornerstone of the so-called revolution in military affairs and can provide an opponent with dominant battlespace awareness and an obvious war winning edge. CCD is an essential tool in countering this threat.

Figure 8.10 A Crude Dummy Anti-Aircraft Gun Placed by the Japanese at Balikpapan, Borneo during World War II (AWM Photo 069482)

It may be unrealistic to attempt to hide the existence of an entire airbase, but great success may be achieved in delaying or preventing the acquisition of specific targets within that complex. Similarly, as weapons themselves become progressively smarter and utilise their own sensor suites to identify targets (and even specific aim-points on targets) CCD will become an increasingly important tactical counter-measure.

CCD can also be a very cost-effective method of improving operational effectiveness. The use of basic operations security procedures, and a limited range of well planned CCD measures such as decoys and multi-spectral smoke and nets has the ability to severely restrict enemy visibility of airbase operations and critical targets. 'Broadly speaking, the cost of applying a full suite of CCD measures to an average main operating base (MOB) should not exceed the cost of one current combat aircraft.'[62]

[62] Glover and Jackson, 'Camouflage, Concealment and Deception', p 285.

CHAPTER 9

Strength

Given a scenario in which an air defence command and control system can maintain its cohesion, and in which defending fighters and SAMs play a full role, the [Hardened Aircraft Shelter] HAS retains a valuable function in protecting air assets. It is not yet time to discard it.[1]

INTRODUCTION

A soft target is one that has little or no physical protection and can generally be easily destroyed by impact, fire or blast. Hardening or strength entails the protection of airbase facilities and assets from these terminal effects. Hardened targets must generally be attacked with special weapons that often have very specific deployment methods or parameters. They may also have reduced operational effectiveness and are usually substantially more expensive. Hardening reduces the options available to an attacker to achieve their desired mission outcome.

The availability of precision guided penetration weapons has meant that virtually any hard target can now be destroyed if attacked in the right way with the right weapon. The utility in hardening relies upon the fact that regardless of technology or the weight or nature of offensive fire power which can be brought to bear, it will always remain more difficult to destroy a hard target than a soft vulnerable one.

Strengthening or hardening of the airbase can be divided into two main forms — active and passive. Active defence entails seeking out the enemy and blunting their ability to inflict damage upon the airbase. The passive defence aspects of hardening are those measures designed to prevent the enemy from being able to inflict damage when they attempt to attack.

The aim of this chapter is to describe the active and passive features that can be incorporated into the airbase operability plan to provide resistance to attack. It emphasises the need for comprehensive plans and a layered approach.

Layering of Operability Enhancements

To be fully effective most operability enhancements or forms of defence (be they air or ground, active or passive) should ideally be layered. The two basic requirements of a layered defence is that it must possess depth and be multi-faceted.

---

[1] Spick, M., 'Hardened Aircraft Shelters – The Way to Go', *Asia Pacific Defence Review*, August 1994, p 35.

- Depth refers to the ability to sustain limited penetration by the enemy without them being able to immediately achieve their objectives.

- Multi-faceted refers to the ability of the defence to present numerous different counters to each threat presented.

Throughout the discussion of airbase defence it is important to ensure that wherever possible these two attributes of depth are utilised. Accordingly, the structure for the strengthening of airbase defences will be presented as shown in Figure 9.1. This Figure also gives some examples of how passive defences may be structured in a layered manner.

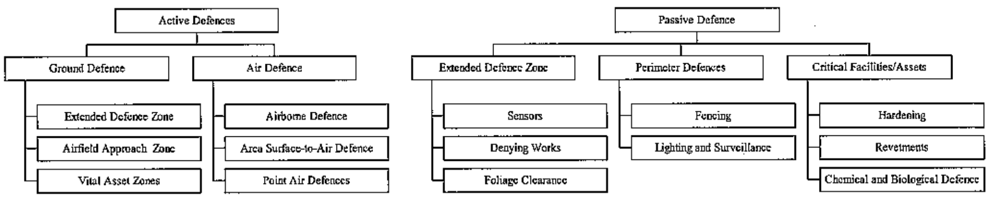

Figure 9.1 Airbase Defence Layers and Some Typical Inclusions

ACTIVE DEFENCE

Ground Defence Operations

The ground defence of an airbase is a unique operational requirement. The combination of large land areas, soft and strategically vital targets, and immovable infrastructure generate a distinctive ground defence situation. It may be seen as a vital asset protection task combining many high-value point targets dispersed over a wide area connected by vulnerable lines of communication. The extraordinary threat posed by stand-off and indirect fire weapons, as described in Chapter Four, further extend the amount of ground that must be denied the enemy.

Also, unlike many traditional infantry defensive formations the defenders do not get to select the ground they will defend; this is already defined and provides little flexibility. However, the permanent nature of all but the most austere forward operating strip provide a good opportunity to develop a good defensive appreciation and to implement those measures.

Given these unique requirements, ground defence of airbases requires a layered approach. Noting particularly the damage which may be inflicted by ground forces from outside the base perimeter, both in terms of stand-off weapons attacks and other less overt means, active ground defence must be prepared to operate outside the perimeter fence.

Like most topics of military doctrine there are many different opinions on the deployment of ground forces in defence of airbases. These range from the establishment of hard perimeters with watchtowers and heavy weapons (eg. Vung Tau airbase during the Vietnam War) to the use of open bases with lots of vegetation, flexible boundaries and very active hunter-seeker style ground defenders.

Division of the Airbase into Zones

To define the application and implementation of airbase operability features further it is necessary to break the airbase and its surrounds into zones. There are many ways of doing this, but most are oriented towards one particular form of defensive operation such as ground defence. Most air forces utilise some form of zoning and each have their own terminology to describe the various areas. For the purposes of this book the airbase and its surrounds have been divided into three main zones. Referred to by different names the world over, here they will be referred to as the Extended Defence Zone (EDZ), the Airfield Approach Zone (AAZ) and the Vital Asset Zone or zones (VAZ).[2] These divisions will often be arbitrary and there is certainly no one correct method of defining them. The division and establishment of these zones will vary enormously depending upon the nature, size and terrain of the particular airbase. Figure 9.2 details typical zone divisions for a representative airbase.

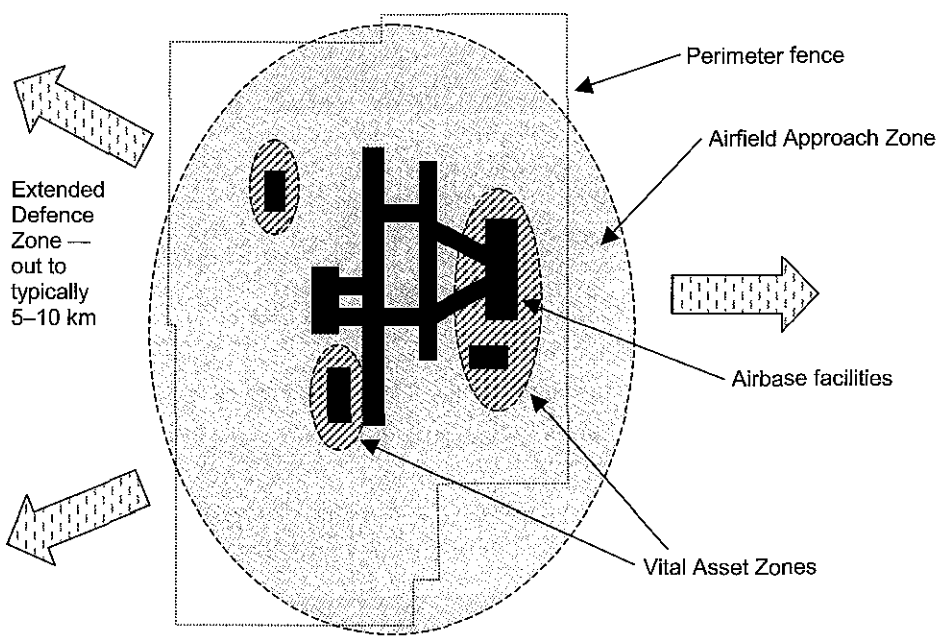

Figure 9.2 Indicative Airfield Approach and Vital Asset Zones

[2] Within the RAAF the areas corresponding roughly with these divisions are respectively the Patrol and Surveillance Area (PSA), the Close Approach Area (CAA) and the Close Defence Area (CDA).

Extended Defence Zone

In terms of the effective ranges of modern weapon systems, the typical airbase is quite a small area. A heavy machine gun, sniper rifle or anti-armour weapon, given an appropriate line of sight, can place fire relatively accurately on virtually any part of the typical airbase. Indirect fire weapons such as mortars or rockets are even more effective at laying fire onto the airbase from outside the perimeter fence. Shoulder launched Surface-to-Air Missiles (SAMs) may be used to attack aircraft taking off or landing at considerable distances along their flight paths away from the airbase.

Accordingly, to prevent the effective use of these weapons against airbase assets, the airbase defence must extend beyond the normal airbase perimeter. The failure to prevent enemy exploitation of land surrounding the airbase may make it extremely vulnerable to attacks launched from and through that land. The degree of depth of the defence is most heavily dependent upon the threats that the airbase may face. Defence of the EDZ may be divided between neighbouring manoeuvre forces and locally commanded organic or specialist airbase defenders.

Actions to be undertaken by ground defence forces in the EDZ include:

- Surveillance, reconnaissance, denial and patrolling of likely stand-off weapon launch points, including SAM launch points.
- Surveillance, reconnaissance, patrolling and denial of likely reconnaissance vantage points, hides or communications relay points.
- Patrolling and protection of dispersed assets such as mobile surface-to-air weapons and sensors, communications relays, power and water supplies, and main resupply or movement routes.
- Detection, patrolling and denial of likely infiltration routes of enemy ground parties.
- Psychological and civil affairs operations within local communities.
- Establishing and maintaining liaison and connection with neighbouring allied units and formations. Ensuring that the boundaries between defined areas of responsibility are effectively controlled (tied up) and responsibility for any buffer or boundary zone is established.

Defence of this region involves the coverage of large tracts of land. For example an area of land of more than 200 square kilometres is involved assuming a minimal EDZ which merely encompasses the area around the airbase from which man-portable mortars could be fired (a six km deep belt around a 16 km^2 airbase). A more effective EDZ encompassing likely observation vantage points, infiltration routes, and out-stationed vital assets is going to be much larger than this. Effectively denying this ground will require a large patrolling force with a high degree of mobility. Given that sufficient ground forces are unlikely to be available to blanket this area sufficiently the extensive use of force multipliers will be required. Technologies available today, or under investigation include, inter-alia, the use Uninhabited Aerial Vehicles (UAV), night vision equipment, dogs and counter-battery systems. These and other options are considered later in this chapter.

Ultimately, the surest means of preventing the enemy exploiting the EDZ may be for the defence to dominate this zone themselves. Aggressive patrolling and vigorous prosecution of potential infiltrations is the most effective manner in which to achieve this.[3] The use of small, rapidly moving teams, with unpredictable patrol patterns can ensure that maximum coverage of this area is achieved. Not only does this methodology provide tangible results in terms of the results achieved but it also provides an important psychological benefit. Aggressive patrolling instils and displays an aggressive defensive mindset, boosting morale and helping to prevent the inevitable degradation of preparedness which can accompany long periods of inaction. Effective communication and well drilled command and control procedures will enable the rapid concentration of these patrolling elements to counter attempts to penetrate by force. Force multipliers such as UGS and aerial platforms assist in this task, but carry a significant resource cost and should not detract from the principal aim of patrolling and denying this ground.

The Airfield Approach Zone

The AAZ generally encompasses the area from which direct fire may be aimed at airbase assets. It will normally incorporate the base perimeter fence where one exists. On large undeveloped airbases the AAZ will usually also incorporate areas within the heart of the airbase that break up the dispersed important facilities and assets. Defenders in this zone will be a combination of static defence positions, patrols and mobile reaction forces. This area should form a defended locality containing individual key points (VAZs) and mutually supporting defensive positions.

The reaction or counter-penetration force, normally termed the Rapid or Quick Reaction Force (RRF), is responsible for responding to probable incursions and sightings and providing firepower to counter attempted infiltration and raids. The effective use of RRF allows the airbase defender to match the local force superiority that an attacker can achieve through the use of surprise. Normal perimeter or area defences will be by necessity spread quite thinly. Through the use of stealth or rapid movement an enemy ground party may be able to place large numbers of attackers against a single point in the perimeter or vital asset. The RRF are used to counter this hostile local force superiority. It should also be noted that if the resting locations and routes used by the RRF become predictable, a competent airbase attacker might seek to ambush them as they respond to the main attack. The key features of an effective RRF are mobility, responsiveness, protection, flexibility and firepower.

THE KEY FEATURES OF AN EFFECTIVE RRF ARE MOBILITY, RESPONSIVENESS, PROTECTION, FLEXIBILITY AND FIREPOWER.

[3] Interview with HQ AFDW staff, 9 Jun 99.

Defenders in the AAZ are responsible for:

- Reconnaissance, patrolling and denial of likely direct fire weapon and reconnaissance vantage points.
- Patrol and monitoring of perimeter defences and approach routes.
- Providing a mobile counter penetration capability to respond to and defeat potential threats.
- Detection, interception and destruction of infiltration parties before they can bring direct fire weapons to bear on vital assets.
- Security of internal routes of communication, including internal roadways, aircraft operating surfaces and communication links.

Vital Asset Zones

A VAZ is a tightly defended locality surrounding an important or vital asset, such as a large fuel tank or a command centre. Defence of a VAZ is normally accomplished by a combination of passive defences (such as hardened facilities or camouflage), static key-point defensive positions and a mobile RRF. Depending upon a variety of factors each airbase may have a number of VAZs or a single larger one. The greater the ratio of potential threats to the number of defenders the smaller each zone of defence around each vital asset is likely to be. Where the threat force levels are high and defending assets limited, the VAZs may be small compact areas surrounding particularly crucial facilities and assets only.

Not all VAZs will be within the recognisable perimeter of the airbase proper. Remotely located facilities such as radar heads may require protection as key points and accordingly will be defined within a VAZ. Where a traditional 'man-proof' perimeter fence is provided for peacetime security purposes, this line should not be used to define the VAZs. The location of these zones should be based upon the key assets they protect, the resources available to defend them and sound tactical principles such as the development of mutually supporting fields of fire.

Defenders assigned to VAZs are responsible for:

- Static point defence of vital assets.
- Developing passive defences for facilities or assets incorporated into their zone.
- Physical security of buildings and facilities. Ensuring that all personnel who seek entry to vital facilities are appropriately authorised and positively identified in accordance with the extant security plan.
- Damage control, survey and emergency response actions during and following attack.

- Providing intelligence and situational reports to the base command post for actions and incidents inside their assigned areas.

Ensuring that control systems are in place to prevent fratricide and firing upon friendly units patrolling and working in the AAZ and enclosed working areas.

Ground Defence Force Multipliers

Airborne reconnaissance. Some form of airborne reconnaissance capability — UAVs may be highly suitable for this role. These platforms, particularly if equipped with thermal imaging night vision equipment are very effective at locating vehicle hides and moving personnel. Airbases are the ideal location from which to support and launch UAV operations. During July 1998 the USAF tested a rotary-winged Austrian manufactured UAV equipped with a television camera, thermal imager, and real-time video downlink. The UAV was used to patrol around a mock airbase finding enemy positions, surface-to-air threats and avenues of approach to defended areas.[4]

Dogs. Dogs provide a significant enhancement to patrolling elements. Traditionally deployed in the AAZ or around key points, dogs have the capability to accompany more extended patrolling elements to detect infiltrating parties more effectively than personnel alone. Dogs have special considerations such as limited endurance, which must be considered when being employed in this role.

Vehicles. High mobility transportation. The ability to effectively patrol and move over such a large area will require assigned forces to possess a high degree of integral mobility. Although they present substantial logistic problems, horses also have the potential to provide long range transport that is virtually silent. Motorcycles, quad bikes and other less conventional forms of transport also provide flexibility to the defenders.

Unattended ground sensors. Unattended remote Ground Sensors (UGS) can be used to detect the passage of personnel or equipment. These devices can provide benefits when appropriately sited and utilised. However, if not sited well, they can generate unacceptably high false alarm rates because of the movement of wildlife or vegetation. UGS can also be expensive to purchase and maintain which can be to the detriment of other capabilities. UGS are discussed in more detail later in this chapter.

Night fighting equipment. Night fighting equipment such as thermal imagers and low-light weapons sights. History has shown that ground attacks on airbases have occurred predominantly at night. High quality attackers such as Special Forces (SF) will normally operate at night and will certainly be equipped with this equipment themselves.

Communications. Effective secure communications links with the airbase command posts and other friendly units in the area.

---

[4] Hewish, M., 'The Last Line of Defence', *Jane's International Defense Review*, October, 1999, p 30.

Firepower. High firepower weapons that are capable of destroying a potentially well trained and equipped SF unit or assault force. As they are defending a static target airbase personnel are limited in their ability to use manoeuvre or withdrawal when they contact a superior enemy force. Accordingly, they should be equipped to the maximum extent feasible to employ firepower to engage and destroy or drive off attackers as they are discovered. Given limited manpower resources this can be achieved by the allocation of generous quantities of mobile unit support weapons. Units in the EDZ should be equipped and trained for the establishment of hasty ambushes and the emplacement of a range of defensive aids such command detonated mines, field fortifications and booby-traps. When contacted, SF will likely attempt to withdraw. Accordingly, the ability to engage, and more specifically, place fire onto them quickly is of great importance. Where the terrain around the airbase is suitable, light, highly mobile armour would provide mobility, firepower and night fighting capability in a single platform.

Counter-battery capability. Where an airbase is established in an area with potential threat from indirect fire weapons, a counter-battery detection and engagement capability should be emplaced. This was critical during the Vietnam War where US counter-battery radar and artillery was used to locate and engage attacking Viet Cong mortar and rocket teams. Particularly in restrictive terrain it will often take too long to locate the firing point and deploy personnel there to catch the attacking force before it can move away. In some cases indirect fire weapons have been fired by improvised timers, allowing the firing party to escape before the attack has even begun. The additional weight that even a modest organic indirect fire capability can provide an airbase defence cannot be under estimated. In addition to providing a counter-battery capability, modern fire control procedures and terminally guided projectiles give the indirect fire team the ability to multiply defensive firepower at critical points and even defeat heavy threats such as armour. 'With modern artillery and air support, a pair of eyes backed up by an unjammable radio and perhaps a thermal imager becomes the equivalent of at least a (company) combat team, perhaps a battle group.'[5] In other situations the mortar team can be used to fire signal flares, illumination or smoke rounds as required or directed.

A MODEST INDIRECT ORGANIC INDIRECT FIRE CAPABILITY BACKED UP BY AN EFFECTIVE COUNTER-BATTERY, FIRE CONTROL AND DIRECTION SYSTEM PROVIDES A VERY STRONG CAPABILITY TO DELIVER HIGH FIREPOWER AROUND THE AIRBASE AT CRITICAL PLACES AND TIMES.

[5] Simpkin, R.E., *Race to the Swift Thoughts on Twenty-First Century Warfare,* Brassey's Defence, London, 1985, p 169.

Acoustic sniper and mortar location systems. Acoustic and radar based artillery and mortar locating systems can also be used to detect the location of snipers. Acoustic systems such as the Siemens Plessey Hostile Artillery Location (HALO) detector utilise arrays of microphones to locate artillery and small arms fire accurately. Extensively trialed by British Forces in Bosnia during 1995 HALO is claimed to be ideal for detecting both direct and indirect fire directed at an airbase. Six clusters of microphones deployed within the perimeter fence would be capable of detecting mortar and heavy-calibre sniper fire out to their maximum effective ranges with an accuracy of the order of 25 square metres. This would certainly enable the effective direction of a quick reaction team to eliminate a sniper or the use of counter-battery fire to engage indirect fire weapons.[6]

Resonance weapon recognition. Another concept under investigation is the use of elctromagnetic resonance to detect rifle and gun barrels from considerable distances. This is the same basic principle used by retailers to prevent shoplifting who conceal tiny metal wires or fibres in goods that are then detected by a low-power microwave radar system at the door of the store. Miltary systems were trialled during the Vietnam War, but the technology available at the time was not adequate to provide an operationally useful tool. By radiating wide-band microwave energy from the airbase and applying doppler processing to resonant returns it may be possible to detect and approximately locate any object resembling a weapon barrel moving in the airbase surrounds. Such technology is still under development and considerable work may be required before it is safe and useful, but it could provide an enormously powerful knowledge edge tool for airbase defence.[7]

Organisation and Source of Airbase Ground Defence Personnel

Historical studies have demonstrated that when an airbase has been dependant on third parties or other services for primary ground defence problems have occurred. The British forces in Crete, the Luftwaffe in North Africa and the USAF in Vietnam all relied upon other Services or allied forces for much of their ground defence.[8] Some of the problems this created included:

- Ground forces assigned to defend the airbase, unless organic to that facility, could be reassigned to other tasks as the area or theatre commander saw fit.

- Airbase defenders not commanded by the airbase itself sometimes failed to appreciate the absolute importance of defending the airbase. Unlike other terrain, to retreat from the airbase with the hope of recapturing it later is not satisfactory.

---

[6] Pengelley, R., 'Counter-Battery Systems', *Jane's International Defense Review,* August, 1997, pp 39-41.

[7] Birkler, J., Neu, C.R. and Kent, G., *Gaining New Military Capability,* RAND Corporation, Santa Monica, 1998, pp 61-69.

[8] Shlapak, D.A. and Vick, A., *Check Six Begins on the Ground',* RAND Corporation, Santa Monica, 1995, p 36.

This is absolutely critical if the intention of the attacker is to seize the airbase for use as an insertion point or air-head for larger follow-on forces.

- Ground forces operating close to the airfield must understand this unique environment. Specific rules exist to ensure safe and effective airfield operations and these must be understood and complied with for the safety of the ground forces and aircraft operations.

- Even when commanded by the airbase the forces must be embedded in the theatre command chain and not controlled by an external (out of theatre) agency. This will ensure that linkages between the airbase defenders and other forces in the theatre are maintained and that breakdowns in communication and coordination are avoided.

- As the majority of airbases are located in rear areas away from the frontline or immediate fighting low quality forces have often been assigned to defend them. A theatre commander may assign the best troops and formations to the ground fighting and less trained, equipped or experienced units to rear area (including airbases) security. This phenomenon was a contributing factor in successful ground attacks on airbases in World War II and Vietnam.[9]

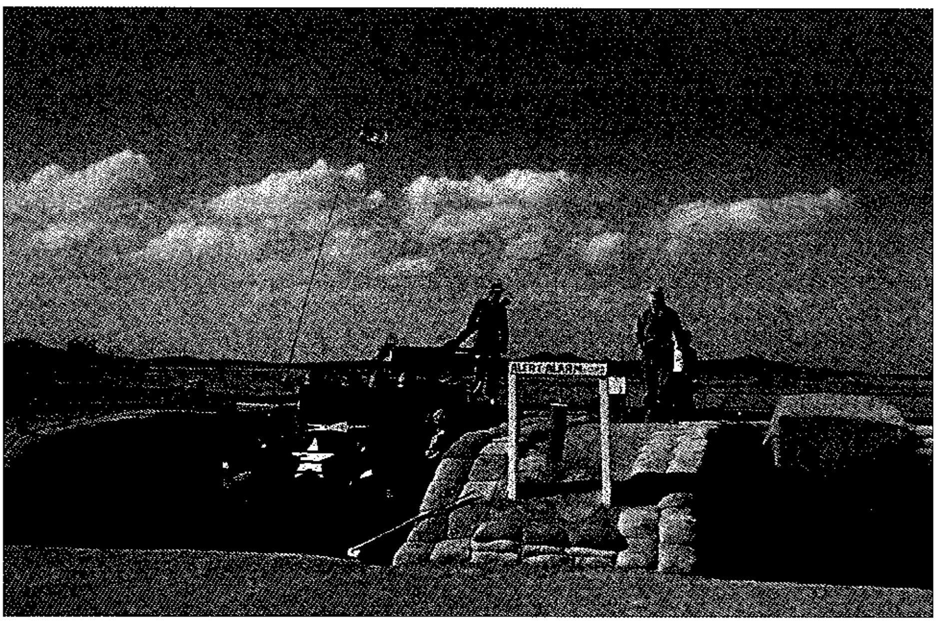

Figure 9.3 Airfield Defence Post, Kimpo Airbase, Korea, 1951
(AWM Photograph P0675/127/123)

---

[9] Vick, A., *Snakes in the Eagle's Nest,* RAND Corporation, Santa Monica, 1995, p 63 and 102.

Use of Airbase Support Personnel to Undertake Airbase Defence Tasks

The use of airbase staff other than dedicated full-time ground defence personnel to undertake active defence duties is a difficult choice. Defence of airbase VAZs is often assigned to the maintenance, administration and logistics personnel who work in those areas. This is dictated in RAAF air power doctrine at the highest level — 'Air power depends on airbases which must be protected. All RAAF personnel have operational ground defence and security responsibilities.'[10]

Modern aircraft operations and support require highly trained and experienced personnel. These personnel are critical to the generation of air power from that airbase and accordingly should be regarded as critical assets. The loss of key maintenance or operations staff can be as crippling to the generation of air missions as the loss of aircrew. It is essential that these personnel are protected and are able to fulfil their primary tasks to the fullest extent of their capabilities. Fatigue factors, for example, will make delicate and vital aircraft maintenance and support operations hazardous and jeopardise safe flying operations. Fatigue will be a major factor in the safe conduct of airbase ground operations and primary employment combined with excessive ground defence duties and additional assigned miscellaneous tasks such as sand-bagging will likely result in accidents.

Ground combat operations require the personnel involved to be trained in a range of skills, including weapons handling, tactical movement and coordination of fire. These skills take time to learn and develop. With the increasing complexity of aircraft systems and the trend towards multi-skilling, technical and logistics support personnel are required to devote large amounts of time to the professional mastery of their own fields. They may not have sufficient time to acquire even moderate levels of proficiency in these ground combat competencies. To provide them with this training and expertise can impact upon their ability to perform their primary task — generating and supporting air missions.

The reliance for airbase defence on these part-time personnel as 'barely trained' ground combatants may be the result of wishful thinking when they are simply outfought by an attacking force, perhaps also unnecessarily incurring heavy casualties. Indeed, by deliberately raiding a perimeter defended by essential operations, logistic and technical support personnel and inflicting casualties the enemy may effectively hinder the airbase's ability to support subsequent air operations.

Accordingly, airbase operations should not be mounted in moderate to high risk ground environments without sufficient numbers of dedicated and trained full-time ground defence personnel. These personnel should, in addition to basic infantry skills, have additional training in the protection of vital assets and airbases. These skills are presently available within organisations such as the RAAF Airfield Defence Wing, the RAF Regiment and the USAF Security Police. The employment of technical and support personnel in these roles in anything other than the most static vital asset

[10] Royal Australian Air Force, *The Air Power Manual, 3rd Edn,* p 48.

defence can detract from safe and effective air operations and waste highly trained personnel assets.

This is certainly not to say that airbase support personnel need not be capable of self-defence or effectively buffering the airbase defences in time of dire need. However, the reliance on support personnel to provide this ground defence function is potentially dangerous. The deployment of air forces to areas of potential ground threat should be accompanied by sufficient numbers of fully trained and equipped ground combatants, be they soldiers or airmen. To not deploy them on the assumption that the support personnel can do the job can compromise the operability of that airbase. This is a simple recognition of the high strategic value of those aircraft and their inherent vulnerability to ground attack.

AIRBASE OPERATIONS SHOULD NOT BE MOUNTED IN MODERATE TO HIGH RISK GROUND ENVIRONMENTS WITHOUT SUFFICIENT NUMBERS OF DEDICATED AND TRAINED FULL-TIME GROUND DEFENCE PERSONNEL.

Similarly, full-time ground combat staff should not be used to undertake the tasks for which specialists are normally employed. This is often a temptation when an initial airhead is established in a non-benign environment and early manning levels are tightly constrained by available transport assets. Air terminal operations, explosive ordnance reconnaissance and disposal, communications, intelligence functions and logistic support operations are all normally undertaken by specialists for good reason. Using ground defence personnel in these roles is likely to cause accidents and to reduce the ability of the airbase to operate as required.

Active Air Defence

'There are two things that make air defence necessary — something to defend and an airborne threat.'[11] This dual requirement is particularly important to remember when the aircraft is attacking a critical target such as an airbase because, after the weapon has been released, the destruction of the aircraft is generally of secondary importance. Airbases certainly provide something to defend, and they must also be defended economically in terms of the assets required. An air force entirely devoted to defending its own bases and support infrastructure has no capability left to contribute to the greater strategic objectives of the broader campaign.

[11] Elsam, M.B., *Air Defence,* Brasseys, London, 1989, p ix.

Active air defence is a vital component of airbase operability. History has demonstrated that where an attacking air force has had uncontested control of the air over an airbase that no amount of resiliency can prevent it from being destroyed or damaged. This has been seen in Korea, Vietnam and Iraq. Surface-to-air weapons and airborne interceptor aircraft have two roles in airbase defence. Ideally, they prevent attacking enemy aircraft from reaching the target airbase, or if this cannot be achieved by limiting the weapons and attack methods which can be employed. They restrict the choices available to the attacker and force them to use options perhaps not as conducive to achieving their mission.

Active air defence should be layered; it must provide depth and be multi-faceted. Depth can normally best be provided by having three main defence layers. The outer layer is provided by defending fighter aircraft, supported by Airborne Early Warning and Control (AEW&C) aircraft and air-to-air refuelling tankers, and defends against stand-off weapons attacks. The middle layer is covered by area or theatre SAMs. In a dense air defence environment these may be placed in belts or zones or may be provided by naval vessels off-shore.

From an air attack perspective the typical airbase can be seen as a collection of point targets. Traditionally, the third layer of air defence would be provided by point defence weapons such as short range SAM systems, shoulder fired SAMs and guns located on the airbase itself. 'If fixed high-value objects such as air bases, C^4I nodes, oil refineries, power plants or bridges are to be protected, they must be defended by a dedicated [low-level air defence system] capable of stopping lethal threats as small as a [precision guided munition].'[12]

However, the use of short range air defences placed only on the airbase itself (particularly where area or theatre SAMs are not available) can make the airbase vulnerable to increasingly effective stand-off weapons. To reduce this threat surface-to-air weapons should be positioned away from the airbase itself, ideally on identified air attack approach routes. These weapons should be kept mobile, well camouflaged and make every effort to avoid detection by electronic intelligence assets. If well positioned these systems may deter or defeat the launch of stand-off weapons, laser designation, stand-off reconnaissance or interfere with the approach runs of conventional attack aircraft.

In this manner the potential air attacker must penetrate many layers before being able to prosecute direct attacks on the airfield. To avoid some of these defence layers, they may choose to use tactics that can lead to higher costs-per-sortie or reduced terminal accuracy or effectiveness.

In this way the defence is also multi-faceted, in that it presents a variety of defensive weapons to the attacker. The combination of airborne fighter weapons, radar and infra-red guided SAMs and guns decreases the probability that the attacker will be able to determine, counter and therefore penetrate the defence.

[12] Lok, J.J., 'Protecting High-Value Assets Against Threat From the Skies', *Jane's International Defense Review,* November, 1999, p 29.

Airborne Defence

The first defensive screen a potential airborne airbase attacker may encounter are airborne air defence aircraft. Ideally, these will be supported by AEW&C aircraft and airborne refuelling aircraft. The use of these force multipliers will greatly increase the flexibility and effectiveness of the airbase air defence capability. They will provide advance warning of attacks and where possible deter or destroy the attacking aircraft before they are able to launch stand-off weapons at the airbase.

Surface-To-Air Missiles and Guns

'The purpose of air defence is not to destroy aircraft. The purpose of air defence is to keep the enemy from destroying you, and the effectiveness of air defence needs to be judged on that basis.'[13] The scale of the forces assigned to an airbase for anti-aircraft defence will depend on the threat posed and the value of the assets staged there. However, one assessment has stated that as a minimum 'each base requires a battery of Rapier (or equivalent) with an all weather day/night capability, supplemented by at least one air defence troop of four detachments equipped with shoulder-fired VLLAD [Very Low-level Air Defence] weapons.'[14]

Detailed discussion of the relative merits and employment options for land based air defence is beyond the scope of this book. However the following comments can be made about the employment of these assets.

Anti-Aircraft Artillery (AAA). AAA has low kill probabilities against high-speed attack aircraft and must be deployed in excessive numbers to cause significant attacker attrition. However, the employment of a limited number of advanced, mechanised, radar directed rapid-fire guns at each major airbase, in conjunction with other surface-to-air weapon systems could limit an attacker's ability to undertake low-level attacks with impunity. Modern AAA is particularly effective against helicopters and other low-altitude low-speed aircraft. Mechanised armoured rapid-fire guns placed in positions affording good visibility of the airfield will effectively prevent enemy insertion of ground forces by air or the use of small low-speed low-level cruise missiles. By using visible tracer ammunition guns can also provide a visual deterrent to low-level attack aircraft, distracting them from their primary task of target acquisition or weapons release. This was demonstrated during the Falklands War when three British Harriers were shot down and nearly every single other British aircraft sustained some level of damage from AAA.[15] Argentine AAA even shot down one of their own aircraft, a damaged Mirage being brought down near Stanley on 1 May 1982, the pilot not escaping.[16]

[13] McCoy, T.W., 'Task One: Airbase Operability', *Armed Forces Journal International,* September 1987, p 54.

[14] Bishop, R.B., 'The Defence of Airbases' in Ball, D., (Ed), *Air Power: Global Developments and Australian Perspectives,* Pergamon Press, Sydney, 1988, p 547.

[15] Harbison, I., 'Airfield Defence Systems', *Defence Today,* December, 1985, p 541.

[16] Middlebrook, M., *The Fight for the Malvinas,* Viking Books, London, 1989, pp 90-94.

Shoulder Fired Infra-Red Guided Missiles. These weapons are typically shoulder launched, man-portable systems employing passive infra-red guidance. Redeye, Stinger and SA-7 are examples of these weapons. They provide an excellent supplement to the defence of an airfield against low flying attackers. They have the following characteristics.

- Prior to launch they do not produce any signature to alert the target aircraft or attract suppressive fire.
- They are highly mobile and can be repositioned easily. If small teams equipped with these weapons are dispersed to vantage points in land surrounding the airbase, they can cause considerable distraction to aircraft flying past at low-level.
- They are cheap to purchase and have low maintenance overheads.
- They are ineffective against aircraft above an altitude of approximately 3,000 metres.
- They can be susceptible to countermeasures.
- Whereas it is possible to equip personnel patrolling the EDZ with these weapons, it is preferable that the anti-air role be made a specific task. The weight of shoulder launched SAMs is considerable and when added to an already significant patrol load may reduce the effectiveness or endurance of the patrolling force. Additionally, although many of these weapons are advertised as 'point and shoot', to be used effectively their operators must receive special training. Time constraints may limit the degree to which normal ground defence personnel can receive this training.
- Unless provided with electronic friend or foe identification systems these weapons can pose a significant risk to friendly aircraft.

Mobile Radar Guided Missile Systems. These weapons are in common use throughout the world. Systems deployed by western nations tend to be point defence weapons that have low minimum engagement altitudes and relatively short ranges. Systems are also available that provide true area coverage to high altitudes. The characteristics of these systems include:

- They can be susceptible to attack by anti-radiation defence suppression weapons.
- They may have more flexible engagement envelopes, with longer range and higher maximum altitudes. This is essential for engaging attacking aircraft employing guided stand-off weapons such as laser guided bombs.
- They can be relatively mobile and can be repositioned or redeployed easily.
- If designed as such they can provide protection from ballistic or cruise missiles.

The airspace control issue of surface-to-air missiles can be difficult to solve, particularly at an airbase. Destruction of friendly aircraft by surface-to-air weapons has been commonplace in history. RAF Regiment Rapier missile batteries deployed to the 1991 Gulf War spent weeks en route at Akrotiri practicing command, control and communication and airspace management with allied aircraft.[17]

Point defence of airfield targets is important despite probable local air superiority. Air superiority is not a black and white issue and can be present in degrees. Syrian helicopters were able to attack Israeli Army units in Lebanon during 1982 despite Israeli air superiority, because these units lacked point defence weapons.[18]

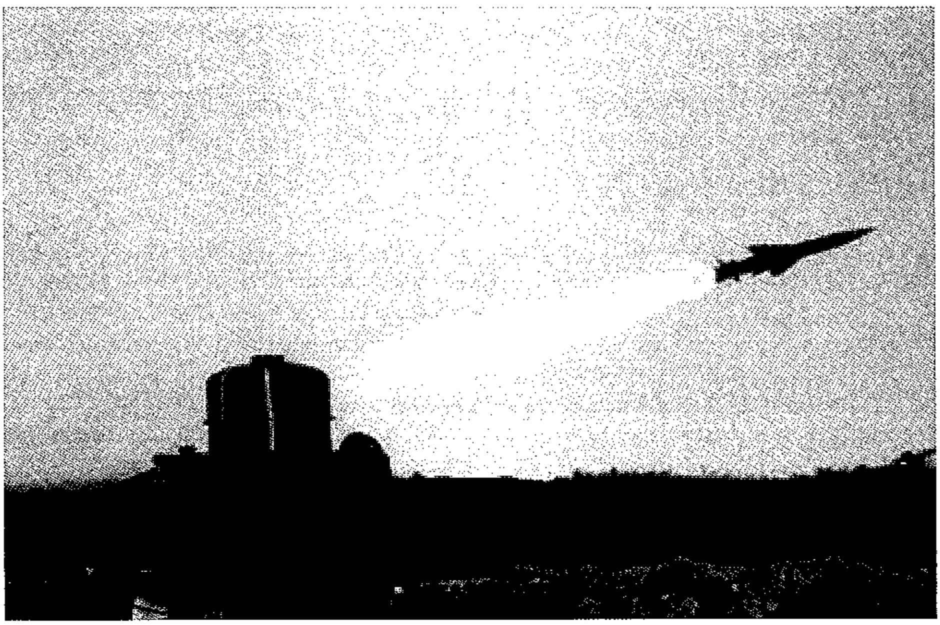

Figure 9.4 Rapier Surface-to-Air Missile System

Surface-to-air weapons systems will never provide total protection for an airbase when deployed alone. This was clearly demonstrated during Korea, Vietnam and the Persian Gulf. In each case the defence was preponderantly surface-to-air and in each case airbase attacks were successfully and repeatedly prosecuted. However, they may force the attacker to divert resources to undertake defence suppression missions, increase bombing altitude which may reduce accuracy, restrict the attackers flexibility in choosing attack profiles, prevent airborne assaults on the airbase and, potentially, shoot down some cruise missiles.

[17] Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia,* Air Power Studies Centre, Canberra, 1992, p 157.
[18] *Ibid.*, p 157.

The placement of these surface-to-air systems some distance from the airfield itself can be more effective than placing them centrally. Most strike aircraft will be capable of some form of limited stand-off attack such as toss bombing. Mobile surface-to-air defences placed in unpredictable locations in the region surrounding the airfield can complicate this process, particularly if laser guided weapons are used. The placement of mobile short-range surface-to-air weapons around the airfield can force the attacker to use stand-off techniques. When using these kind of attacks, guided weapons are required if the airbase has been designed with hardened facilities. The placement of surface-to-air weapons at unpredictable locations away from the airfield at distances where the attacker is likely to be attempting to pop up, to bomb toss or to designate with a laser can be highly effective.

Considerable research is presently being undertaken into advanced integrated air defence systems for high value point and area targets. These systems are designed to be survivable, flexible and effective against a wide range of airborne threats. Traditional fixed Integrated Air Defence Systems (IADS) were shown to be vulnerable to destruction or suppression in both the 1991 Gulf War and also Operation *Allied Force*. The new systems rely on advanced radars, high-speed data links, cooperative engagement and the use of mixed guns and missiles to provide maximum lethality against the broadest possible range of airborne threats. The use of tactically mobile and armoured components increases their survivability and reduces the ability of a potential attacker to determine the disposition of the air defences prior to attack.[19]

Air Defence against Missile Threats

Conventional Missiles and Bombs

Active defence against missile and bomb threats is a vital component of many modern warships. A combination of interlinked sensors, guns and missiles is used to provide layered protection against small, fast and agile weapons. Evolved versions of the proven Phalanx Close-In Weapons System (CIWS) such as the Phalanx Block 1B and the Sea RAM provide increasingly capable defences against these threats.

Slowly this research is being applied to protect landbased infrastructure. Hughes and Rafael have teamed up to develop the ADAMS mobile point defence system for high-value targets. ADAMS combines the Phalanx radar and gun, and the Barak vertically launched missile system on a cross-country vehicle. It is claimed to provide robust defence against missiles, helicopters, aircraft, and remotely piloted vehicles from ranges of 100 metres to 12 kilometres.[20]

In addition to these naval inspired point defence weapons, armoured forces are beginning to utilise even closer range active defensive aids suites to stop incoming weapons. These systems employ miniature phased array radars that detect incoming

[19] Lok, 'Protecting High-Value Assets Against Threat From the Skies', pp 29-33.
[20] Jane's Land Based Air Defense, 1997/98, pp 60-61.

chemical or kinetic energy rounds and fire explosively forged projectiles or small grenades to strike them. This impact is sufficient to prevent the incoming weapon from penetrating the tank's armour. Other systems use laser weapons to automatically locate and destroy electro-optical or laser systems attempting to target the tank. All of these concepts could be seen to have utility in protecting high-value airbase assets.

Ballistic Missile Threats

Ballistic missiles present a specific threat against airbases and any defence against them requires special capabilities. As they proliferate, ballistic missile defence is an increasingly important consideration when conducting operations from fixed installations such as airfields. One recommended method of defeating the ballistic missile threat is to rely upon four 'pillars of protection'.[21]

- The first pillar is command and control, which provides an integrated system to identify and plot all missile threats in a theatre and disseminate this intelligence in a timely fashion to likely targets as well as to forces capable of attacking the launch sites.

- The second pillar is a conventional counter-force capability to strike back at the state or organisation launching the missiles. This can be undertaken to destroy the missile capability or as a punitive or deterrent action to prevent further launches.

- The third pillar is passive defence. This employs hardening and protective measures against the warheads of the missile threats, including potential nuclear, chemical or biological threats. Passive defences such as hardened facilities can be particularly effective against TBMs due to their limited accuracy.

- The fourth pillar is active point defence of the airbase targets to act as an umbrella shield against incoming ballistic missiles.

PASSIVE DEFENCE

Passive defence entails the use of constructed or naturally occurring features to limit the ability of the enemy to undertake or prosecute attacks against the airbase. Like all defensive operations good airbase passive defence measures should be layered. This chapter discusses those passive defence features that provide strength to airbase features as opposed to those that provide concealment or redundancy.

For the purposes of this analysis passive defences are divided into three layers:

- **Passive Defences in the EDZ.** Beginning with the stand-off footprint or EDZ, the principal passive defence measures that may be incorporated are works designed

[21] Cook, N., 'Europe's Missing Shield', *Jane's Defence Weekly*, 28 April 1999, p 25.

to prevent infiltration into and operations within this area. These works deny and detect movement out as far as practicable from the airbase or at least to the maximum effective range of any indirect fire threat.

- **Passive Defences in the AAZ.** The next level is the AAZ, the principal passive defence feature of which is normally the perimeter defences. These may incorporate a traditional chain-mesh fence about which all other perimeter defences are aligned or it may represent a more flexible line about which the inner defences give way to the extended zone.

- **Passive Defences in the VAZ.** Finally, passive defence measures are applied to the assets and facilities within the airbase itself. As far as hardening is concerned, this entails the protection of vital assets, personnel and equipment from the effects of attacks or weapon systems. The use of protective revetments, or walls, around important facilities is an example of this form of passive defence in the VAZ.

Passive Defences in the Extended Defence Zone

Passive defences are generally designed to support the operation of defenders assigned to that zone. Typically, passive defences in the EDZ will have the following aims:

- Detection of enemy forces operating in the EDZ. The construction of cleared areas, defensive strong-points and the emplacement of UGS to detect movement are typical.

- Denial to the enemy of important locations such as good firing positions for direct or indirect fire weapons.

- Physical security of remotely located important assets, and systems to alert the airbase in case of interference or tampering.

- Works to improve the mobility and effectiveness of defenders assigned to this zone.

Passive Defences in the Airfield Approach Zone

Within the AAZ the attacker will encounter the airbase perimeter defences. This combination of active and passive defences provides the defence with its best opportunity to deter or thwart attacks that have penetrated the EDZ. The use of the term perimeter defence must not be taken literally as the existence of a single delineable line without any depth. As with all defences, the AAZ is a zone of defence and effectively provide a shield for the VAZs.

Perimeter defences must be consistent in quality throughout their length. Potential attackers will be aware of the defences and will try to find weak points. If one point of the perimeter is defended to the exception of all else the attacker will avoid it, and penetration attempted elsewhere. An example is the fortification of main gate vehicle check-points without consideration of the vulnerability of the rest of the fence line.

Vehicle bombs can be driven through fences and over lawns as easily as they can be through gate booms.

Each airbase will have its own unique topography and tactical requirements; however, in general the AAZ should provide the following defensive features:

- It should form a visible deterrent to attack or intrusion.
- It should be designed so that penetration of the zone (or attempts to do so) will be detected or exposed, by night or day.
- It should be conducive to patrolling and surveillance.
- It should provide a physical barrier to prevent direct weapons fire or observation and to delay or prevent penetration through it.

The main passive defence features in the AAZ are fence lines (including features designed to block line-of-sight and/or direct fire), cleared open areas, lighting, intruder detection and surveillance systems and the recognised base entry point/s.

Fencing

Fences are vital and traditional components of airbase security. Fences will not prevent the eventual infiltration of either combat ground forces, irregular forces or civilian non-combatants. However, they will deter, hinder or delay progress and may indicate that a penetration has occurred.

To be effective fences should:

- Be regularly patrolled to detect signs of tampering or breaching. Fences, irrespective of their construction method, can be crossed or breached. A standard 'man-proof' chain link fence can be crossed in 7–8 seconds and penetrated in 18–19 seconds.[22]
- Be covered by intruder or tampering detection equipment. Ideally, this may be electronic, however, simple noise makers such as tin cans can be utilised if monitored by nearby defensive positions.
- Depending upon the illumination plan, the fence line may be lit.
- Where possible, protected positions should cover the fence line and be able to place effective weapons fire onto intruders detected there. These positions should have two-way communications links back to the ground defence command post to enable immediate notification of enemy contacts.

[22] Quadripartite Advisory Publication 65, *Physical Protection of Key Installations*, p 39.

- Fences must be constructed in a manner commensurate with their task. Where possible concrete should be laid along the fence base to deter and delay intruders digging under the fence. The fences must also be high enough and of sufficiently strong construction to prevent them being pushed over by crowds of protestors. Obvious base entry points such as front gates should be reinforced and strengthened, as they are likely focuses for mass protest activity.

Where vehicle bombs and/or vehicle mounted assaults are a potential threat the vulnerability of the entire fence line to this form of penetration must be assessed. The use of ditches, retaining walls, bollards (real ones, not ornamental), heavy barriers or suitable stands of trees can prevent vehicles penetrating the perimeter.

Figure 9.5 Perimeter Defences Bulon Valley, Korea (AWM Photograph SHA/65/0097/VN)

Heavy gauge chain link fences also have a limited ability to detonate the warheads of rocket propelled grenades which may be fired at them.[23] This is particularly useful when protecting vital assets from the effects of these armour-piercing weapons. The detonation of the warhead at the fence line will prevent it from having a penetrating effect on the target. Fences may also be covered with opaque cloth, hessian or plastic to block line of sight. This is again useful where potential targets inside the fence line are exposed to direct fire from outside the perimeter fence.

At forward operating bases or in combat areas concertina wire may be utilised as an effective fencing tool or as a physical barrier. Multiple rolls of wire, appropriately covered by weapon arcs will be effective in blocking, delaying or channelling enemy penetrations.

In rear echelon locations dense thorn bearing vegetation can be used to supplement existing fence lines and vehicle barriers. This will hinder penetration, block lines of sight and provide a more aesthetically pleasing facade to the base perimeter.

Lighting and Surveillance

Lighting of facilities and areas is very much a two edged sword. Light can reveal and deter intruders. However, it can also blind defenders and reveal vital or vulnerable facilities. Where it is not used around primary or critical facilities for this reason, illumination may still be useful around secondary facilities or to cover approach routes.

Ideally, defenders should be equipped with night vision devices and trained in their use. This will enable them to compete on equal terms with attackers who will most likely be provided with these late 20th century military staples. If however, this is not the case, lighting must be designed and used to provide maximum benefit for the defender and maximum disadvantage for the attacker. Defenders must always be positioned in the shadows and the lighting angled outwards to illuminate and hopefully glare any outside attacker. Any internal building lighting must be subdued red light to ensure that people leaving the building, either routinely or in an emergency, are not night-blind. Ultimately, the individual tactical situation at each airbase will determine the requirement for defensive illumination.

Lighting can also be activated by remote sensors, however, this has the disadvantage of regularly turning the lights on and off as the sensors invariably generate false alarms. This warns potential attackers of the presence of the sensors and dulls the defenders to the potential for genuine incursions. Where defensive illumination is desirable it is often better to have the lighting permanently illuminated and have any remote sensors connected to watch keeper alarms.

[23] Ryan, S., 'Security and Personnel Protection', *Asian Defence Journal*, No 2, February 1995, p 51.

Even in an age of advanced night vision sensors the lighting of a facility will make it more susceptible to effective attack from the air. During the 1986 US air raid on Libya, the attack on military aircraft parked at Tripoli international airport was aided by runway and tarmac lighting which remain illuminated throughout the attack. Where lighting is employed, it must be capable of being immediately extinguished upon command.

The following general principles should be considered when developing an integrated operational airbase illumination plan:

- Are the locations of primary or vital facilities betrayed by the employment of lighting?
- Are any defensive positions illuminated or blinded by lighting?
- Where approach routes, fence lines or open areas are illuminated is the level of lighting appropriate and are there any shadow zones that could be exploited by an attacker.
- Is the airbase conducive to being operated whilst under blackout conditions or by personnel employing night vision devices?
- Where applicable, especially inside buildings, is the lighting capable of operating as red light to reduce night-blindness of people moving in and out of illuminated areas?
- Can the lighting be effectively controlled to illuminate or extinguish it quickly if required?
- Is the lighting power supplies or control circuitry vulnerable to tampering, sabotage or damage?

Intruder Detection Systems and Unattended Ground Sensors

Intruder Detection Systems (IDS) or UGS can be used in many ways around fixed installations such as airbases. They have evolved from an understanding that fixed defensive features such as fences can always be penetrated and that reducing manpower levels have made detection of intruders more difficult.

IDS can use a variety of methods to detect people or vehicles. The more common methods are radar, infra-red imagery or detectors and beam type systems. Beam systems employ lasers or active infra-red and can be used to detect intruders crossing specific lines and are designed so that small animals or moving tree limbs will not trigger the alarm.

Detectors that combine radar, infra-red and visible light systems are also available. The Advanced Exterior Sensor (AES) under development in the US combines these three detection medium with advanced computer processing to provide a low cost deployable IDS. Images from infra-red and visible light sensors are combined with range data from the radar to produce an accurate picture at ranges up to 1,500 metres from the sensor. Computer processing then reduces the false alarm rate, even when viewing a complicated or obstructed area. Multiple AES sensor units can be located around a large facility and linked to a central monitoring station.[24]

Perimeter Access Points

The following general considerations should be applied to access points into an airbase:

- **Minimal Access Points.** The number of access points to the base should be limited to an absolute minimum.
- **Vehicle/foot Traffic Separation.** People wanting access to the airbase on foot should have a different entrance to those entering in vehicles. This allows better control of both entry points and reduces the potential for confusion or mistakes. In high threat environments personal searches or security systems such as those employed in civil airports can be used to vet personnel entering the airbase.
- **Traffic Separation.** Entering and exiting traffic should be separated and be independently controllable.
- **Protection.** Personnel manning the entry points should be able to do so without exposing themselves to observation or fire from outside. It should not be easily possible to determine the full strength of the entry point guard by external observation.

The use of vehicles to take bombs onto facilities such as airbases has caused considerable damage and casualties in the last 20 years. The US Marine barracks in Beirut, Khobar Towers, and the Oklahoma Tax Department bombing are all examples of the use of car or truck bombs. Vehicles may also be used to smuggle infiltrators into the airbase, or equally, smuggle sensitive information or valuable equipment out.

Accordingly, most airbases are equipped with Vehicle Check Points (VCP), which regulate the flow of vehicles in and out of the airbase. They range from simple main gate arrangements at rear echelon bases to fortified bastions at facilities in places such as Sri Lanka or Northern Ireland. Vehicle check points and entry ways must not be hardened at the exclusion of the rest of the perimeter. As detailed above it is possible to bypass a heavily defended VCP and drive a truck bomb through a chain link fence to achieve the same effect.

A typical VCP will use a series of obstacles to prevent vehicles 'running' the checkpoint allowing guards to check identification and perform vehicle searches if desired. The features of a good VCP include:

- Solid barriers to prevent vehicles, including heavy trucks, bypassing the VCP.
- A protected position to the rear of the VCP with good visibility over the approaches to provide effective covering fire with a heavy weapon.

[24] Hewish, 'The Last Line of Defence', p 34.

- An initial questioning and quarantine area where vehicles are stopped for the first time as far forward of the VCP as practicable.

- An area where people and vehicles can be searched if required.

- Reliable and secure communications with the airbase ground defence/security command post. Where command posts and VCPs are well established, or their location is planned in advance, landline communications should be provided.

- Particularly in urban areas where a terrorist threat may be prevalent, the VCP must be capable of quickly processing the peak staff traffic expected each morning. Queues of airbase staff in stopped cars outside the main gate every morning at the same time are a highly vulnerable target for terror attacks such as bombings or 'hit and run' shootings. An alternative preventative measure is the use of stagger shifts or varied start/finish times to reduce peak traffic flows.

- Regular patrolling of the vantage points overlooking the VCP and/or the placement of remote sensors may be used to prevent observation of the VCP by potential infiltrators or intelligence collectors.

- Alternate entry points should be available in case the primary VCP is rendered unusable. This may occur if a vehicle bomb is stopped at the VCP and abandoned there. Until Explosive Ordnance Disposal personnel can clear the device and scene (which may take some time) the VCP will need to be cordoned and will be unusable.

- The gate should be provided with closable and lockable high mesh fences. This is an effective method of preventing non-violent protestors from entering the airbase. A well planned 'assault' by a large number of non-violent demonstrators will overwhelm the smaller number of VCP staff allowing them to penetrate into the airbase. A high mesh fence with barbed or razor wire on top will hinder their progress and, if backed up by dog teams inside the wire, is a highly effective deterrent. These techniques even if not totally effective in preventing infiltration will certainly delay the protestors allowing the deployment of large numbers of base personnel or alternative counter-measures.

- The use of closed circuit video cameras to directly monitor VCP activity from the ground defence/security command post can be very useful. This enables the commander instant access to real time information on activity there. At bare bases the cabling and mounting hardware for such systems should be permanently installed with the video equipment connected when the base is activated.

- A large truck or bus can be positioned near the VCP to be used as an additional roadblock. The truck or bus can be used to reduce the vehicle access path to a size that will not accommodate anything larger than a normal light commercial vehicle. If a larger vehicle desires access the blocking truck or bus can be quickly moved out of the way. Alternatively, the truck or bus can be used to quickly block the entire entryway in high threat situations. Care must be taken to ensure the use of this technique does not block the visibility of the VCP crew.

Passive Defences in the Inner Defence Zones and Protection of Critical Facilities

Air power theory and doctrine details the facilities and assets on airbases that may be targeted in priority order during an offensive counter air campaign. It is critical to use this planning information in reverse to determine the priority by which airbase assets should be afforded close physical protection.

Aircraft, facilities such as command and control centres, communication nodes, essential operational and support personnel and essential infrastructure would be priority targets during airbase attacks. These targets must be protected by dispersal, camouflage and where possible, they should be hardened against the effects of the weapons that may be directed against them.

Hardening can not provide unlimited protection. The 1991 Gulf War demonstrated the vulnerability of hardened and semi-hardened facilities where the attacker had the following capabilities:

- Detailed information on the nature and exact location of the facility, normally obtained from multiple intelligence sources.
- Sufficient numbers of precision guided penetrating weapons.
- Sufficient control of the battle space above the targeted airbase to allow these weapons to be deployed effectively onto their targets.
- Suitable resources to conduct effective post-attack bomb damage assessment.

However, where the potential attacker does not have all of the above in quantity the use of hardening, combined with other resiliency features, makes the job of attacking the airbase considerably more difficult. It makes the achievement of a desired level of damage technically more difficult, require a larger commitment of resources and entails potentially higher casualties amongst the attackers.

As again demonstrated during the 1991 Gulf War and subsequent air operations, attackers, be they from the ground or air, are for a variety of reasons often unable to locate, identify, or reach their primary target. Normally, they may have a list of alternate targets that can be attacked if this occurs. Hardening of facilities generally prevents their exploitation as targets of opportunity as they will be largely immune to attacks from non-specialist weapons.

It can also be very difficult to determine to what extent hardened facilities have been damaged following an attack. 'It was almost impossible to confirm destruction of dug-in targets until coalition ground forces arrived to see for themselves. Accordingly, the allies missed some targets and hit others that were already destroyed.'[25]

[25] Marolda, E.J. and Schneller, R.J., *Shield and Sword,* p 243.

Hardened Aircraft Shelters

Much press has been given to the perceived vulnerability of aircraft protected by Hardened Aircraft Shelters (HAS). The use of precision guided penetrating weapons has been claimed to have made the HAS or its various derivatives obsolete. Many of the graphic images released during the gulf war showed laser-guided munitions penetrating and destroying Iraqi HAS, Figures 1.3, 2.7, and 9.6 are examples. However, despite total air supremacy and access to the most advanced air power available it required 3,000 dedicated airbase attack sorties to destroy 141 Iraqi aircraft in their HAS during 1991.[26] This can be compared with the over 400 Egyptian aircraft destroyed by less than 1,000 Israeli Air Force sorties during June 1967.[27] It was in fact following the destruction of so many Egyptian aircraft in this attack that HAS first began to appear, initially in Europe, on both sides of the Iron Curtain.

The HAS can protect the aircraft placed inside from a number of threats depending upon the nature of its construction. Typically a shelter may be designed to protect against:

- Near misses by large unitary warheads and direct hits by sub-munitions. The heavy construction of the HAS can protect the contents from the primary damage mechanisms of high explosive bombs and missiles — blast and fragmentation. Generally the only method by which modern HAS can be breached are direct hits by precision guided penetrating bombs or missiles. However, the employment of precision guided weapons does not guarantee destruction of assets in hardened facilities. During the June 1993 US attack on Iraq, 23 Tomahawk land attack missiles (Block II) were fired at Iraqi targets. Of these one was unaccounted for, 16 hit the desired point of impact and six (that is 27 per cent of the warheads which reached the target area) missed.[28] This is for a weapon with a published accuracy of five metres CEP.[29] Given the relatively small warhead size of most precision guided missiles, had these targets been aircraft in quality HASs they possibly would have survived.

- Attacks by ground fired indirect and direct fired weapons. The heavy earth covering featured by most HAS will protect them against attack from virtually all ground fired weapons including direct fired anti-armour weapons.

[26] Centner, C.M., 'Ignorance is Risk', *Airpower Journal*, Vol 6, No 2, p 33.
[27] Mason, R.A., 'Air Power as a National Instrument: The Arab-Israeli Wars' in Stephens A., (Ed) *The War in the Air 1914-1994*, Air Power Studies Centre, Canberra, 1994, p 188.
[28] Presentation by Air Commodore A. Vallance (RAF), Chief of Staff, ACE Reaction Forces Air Staff during Precision Guided Munitions Conference, Cumberland Hotel, London 12/13 November, 1998.
[29] Sengupta, P.K., 'Cruise Missiles for Asia-Pacific', *Asian Defence Journal*, Jan/Feb 1999, p 38.

Figure 9.6 A group of Iraqi hardened aircraft shelters. The extent to which they are damaged internally is very difficult to determine.

- Observation of the contents of the HAS by ground, air or space based reconnaissance sensors. This can severely complicate the targeting, planning or bomb damage assessment task of the attacking force. The placement of a number of aircraft in a greater number of HAS (as part of an integrated deception plan) can force the enemy to target all the HAS simultaneously in order to guarantee destruction of the aircraft fleet. If the attacker has only limited numbers of attacking platforms, the uncertainty over exactly where the target aircraft are may be sufficient to deter the attack. Penetrating weapons are designed to penetrate the HAS roof, leaving a small hole, and detonate inside, destroying the contents and often blowing off the doors. By clearing out the rubble inside, serviceable aircraft can be placed in a 'destroyed' HAS requiring them to be struck again. The attacker will not know which HAS contain intact aircraft. Unless the attacker can simultaneously target all the HAS on a single base, unscathed aircraft can be moved around from shelter to shelter. This is sometimes referred to as 'playing the shell game'. 'Bomb damage assessment was often virtually impossible. We will probably never know just how many Iraqi airplanes were killed in their shelters.'[30]

- HAS are particularly effective in protecting aircraft and their ground support equipment from cyclones and destructive weather. This can protect the assets inside in the event of an unexpected weather front and remove the requirement to evacuate aircraft when destructive weather is forecast.

[30] Friedman, N., *Desert Victory: The War for Kuwait,* Naval Institute Press, Annapolis, 1991, p 253.

- Due to their earth covering HAS provide protection to aircraft, supporting equipment and staff from extreme heat or cold. This can alleviate human fatigue factors and reduce the aircraft equipment maintenance burden.

- They provide protection for the aircraft, personnel, associated equipment, and ordnance inside from the accidental detonation of explosives nearby. The use of HAS can greatly reduce the safety distances required by peacetime operating rules for the handling of high explosive ordnance.

- They can protect against attack by chemical or biological weapons. As explained in Chapter Three, airbases are very lucrative targets for chemical and biological weapons. HAS may be designed and built employing features which enable them to be sealed against the effects of these weapons.

Accordingly, the protection of tactical combat aircraft in HAS dramatically complicates the mission of an aggressor who wishes to begin their air campaign by attacking air assets on the ground. 'Destruction of HASs witnessed during the [1991 Gulf] War does not mean that HASs have become obsolete; the sophisticated systems needed to place weapons platforms overhead and the smart weapons required to actually hit the HAS, placed extraordinary demands on the attacker.'[31] The extensive construction of HAS by Arab air forces following their destruction by Israeli air power in 1967 prompted a dramatic change in Israeli tactics during the 1973 war. During the former conflict Arab aircraft were parked undispersed in the open and were virtually completely destroyed by the Israeli attacks. With the Arab aircraft now well protected Israeli pilots resorted to runway attacks in 1973, with a greatly reduced effect upon the enemy.[32]

Even relatively modest HAS can provide high levels of protection against ground launched attacks and many aerially delivered weapons. In Vietnam rocket attacks by the Viet Cong and North Vietnamese Army prompted the construction of roofed revetments within which to park fighter sized aircraft. In March 1969 one of these revetments received a direct hit from a Soviet made 140 millimetre rocket. The aircraft inside remained unharmed.[33] These roofed revetments will be considered in more detail later.

HAS also have several disadvantages:

- HAS are expensive and their construction will require considerable investment, possibly resulting in trade-offs of other capabilities.

- HAS have long construction times and must be built in the right places prior to a conflict erupting. HAS built in the wrong location, or left too late, are ineffective.

---

[31] Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia*, p 151.
[32] Centner, 'Ignorance is Risk', p 26.
[33] Vick, *Snakes in the Eagle's Nest*, p 88.

- HAS are difficult to conceal in open terrain and make obvious and tempting targets.

- Protecting the aircraft from the effects of attack does not protect the personnel and equipment supporting or operating them. Providing hardened facilities for all support equipment and personnel would be even more expensive.

- Aircraft larger than a typical fighter/bomber cannot be economically protected by existing HAS designs. These aircraft are physically too large.

Threat weapon	Nature of Aircraft Protection			
	Unprotected aircraft	**Open revetment**	**Hard roofed revetment**	**HAS**
Small arms	minor/major	nil	nil	nil
Mortars, artillery and Anti-tank weapons	major/total	minor	nil	nil
Sub-munition attack	major	major	nil/minor	nil
General purpose bomb fused for airburst.	major	major	minor	nil
Strafing attack	major	minor/major	minor	nil
Mk 84 2,000 lb bomb at 50m miss distance	minor	nil	nil	nil
Mk 84 2,000 lb bomb at 5m miss distance	total	major	minor/major	nil
Fuel-Air Weapon at 30m miss distance	total	total	total	total/nil
Mk 84 2,000 lb bomb at 0m miss distance	total	total	major	minor
BLU-109 2,000 lb penetrating bomb at 0m miss distance	total	total	total	total

Table 9.1 Likely Aircraft Damage Comparison[34]

As a method of comparison Table 9.1 demonstrates the degree of damage which aircraft would be likely to suffer when attacked with a variety of weapons whilst in varying levels of shelter.

[34] Adapted from Hammond, O., 'Iraq's Preparation for the Gulf War – Lessons for RAAF Operational Facilities Planning' in Waters, G., (Ed), *Line Honours – Logistics Lessons of the Gulf War,* Air Power Studies Centre, Canberra, 1992, p 73.

Developments in other forms of precision guided munitions are also changing the vulnerability picture of HASs. The introduction of affordable GPS guided penetrating munitions with high accuracies such as the US Joint Direct Attack Munition (JDAM) has negated many of the advantages of HAS. The use of these weapons allows geographically fixed facilities to be attacked accurately without the need for real time target designation. This reduces the vulnerability of the strike platform and reduces the weapons susceptibility to counter-measures such as smoke. The high accuracies and ability to be fitted with penetrating warheads ideally suits these weapons to this attack role. One method of potentially defeating these weapons is through the use of GPS jammers near critical facilities. These measures are discussed in detail in Chapter Eight.

Use of Protective Revetments

Revetments are protective walls placed around important assets or facilities. They provide protection against low angle high velocity fragments projected from nearby explosions. This also has utility in preventing an explosion in one revetment causing sympathetic explosions in neighbouring revetments. Revetments normally do not normally have a roof, although a light weather protection cover can be incorporated. Accordingly, aircraft parked in revetments will be vulnerable to precision guided weapons, area weapons and unitary bombs fused for air burst.

Revetments can be constructed from a variety of materials, and designed to provide protection from varying levels of attack. Many of the advantages of HAS can be obtained by using covered and revetted parking areas. They provide protection from observation as well as a degree of protection from near misses. Where provided with an easily replaceable light roof they may confer the capability to move around surviving air assets to confound enemy post-attack damage assessment and targeting.

Revetments can also be used as a visual and physical barrier around the airfield itself. They can be used to screen operating areas from potential enemy vantage points and provide protection from direct fire weapons and observation of indirect weapons fire. Likely places where revetments can be used are around taxiways and large aircraft parking aprons. The mounding of earth against one of both side of the revetment can increase its protective strength and reduce its observability. Native vegetation can be planted on the revetment to further improve its camouflage, particularly against aerial radar or visual observation. When carefully sited, revetments can also protect assets from the effects of friendly direct fire, potentially improving the areas over which defensive fire can be applied. If built from earthen mounds they can be used as sites for elevated observation posts or firing points.

Figure 9.7 Aerial View of Tan Son Nhut Airport Showing Revetments, Saigon 1965 (AWM Photograph P01975.001)

Improvised revetments. Where resources and time permit revetment walls should be constructed as earthen berms or reinforced concrete walls. However, where this is not possible revetments can be constructed from a variety of improvised or locally available materials. These materials have low costs and can be stockpiled in large quantities prior to any conflict. Some examples of these include:

- 205 litre, or smaller, fuel drums filled with concrete or local materials. By placing horizontal steel bars through the drums, protruding out each side, prior to filling with the concrete they can be easily moved by fork-lift.

- Large shipping containers can be positioned and filled with local earth to form large heavy revetments. Formed in to open rectangles they can be used to provide improvised revetted shelters for individual aircraft.

- Wooden box sections, or empty ammunition containers filled with concrete or local materials.

- Precast concrete sections similar to those used as roadside barriers can be stockpiled at the airbase and deployed as required. Concrete culvert sections, normally used for bridge making are ideal for making the core of pre-positioned key point defences.

Curtain revetments. Where resources or time are insufficient for the construction of physically substantial revetment walls, curtain revetments can be constructed. These are insubstantial barriers purely designed to block line of sight. They may be constructed from sheet metal, suspended hessian, commercial shade-cloth or other such locally obtained materials. Curtain revetments can prevent or hinder weapons fire (both direct and indirect) by blocking the line-of-sight between the firer and the target. They also can prevent observation of critical facilities and operations. Curtain revetments, by nature of their insubstantial construction are fragile and can be removed by physical damage, destructive weather or enemy action.

Heavy roofed revetments. The placement of a concrete roof on a revetted area can confer many of the advantages of a HAS at a greatly reduced cost. Table 9.1 shows the protection which can be afforded a parked aircraft by a roofed HAS as opposed to other forms of protection. It can be seen that the roofed revetment can provide a large degree of the protection offered by a HAS. This option is particularly attractive in lower threat environments when the precision guided munitions needed to destroy them may not be available or deliverable in sufficient quantity. Roofed revetments provide a high-level of protection from ground fire, sub-munitions, near misses and air burst bombs. Roofed revetments also provide protection from aerial or space based reconnaissance. If the construction of a heavy roof is initially too expensive, the design of a light metal roof capable of supporting later enhancement may be considered. This can be achieved by spreading concrete, earth or sandbags over the original roof when the threat situation warrants.

HEAVY ROOFED REVETMENTS PROVIDE A HIGH-LEVEL OF PROTECTION FROM UNGUIDED WEAPONS, AREA WEAPONS, GROUND-FIRED MUNITIONS, THE ENVIRONMENT AND OVERHEAD RECONNAISSANCE AT A LOWER COST THAN HEAVIER HARDENED AIRCRAFT SHELTERS

It is important to note that when damaged by enemy fire, parked aircraft become themselves a hazard. This includes the dangers posed by burning fuel or ordnance cook-offs (explosive ordnance which is burnt or heated to detonation). Burning fuel is particularly important as a typical aircraft has a large fuel capacity and these tanks are easily punctured by fragment strikes. This fuel will then flow downhill until contained. If this fuel is burning it presents a great hazard and can easily spread the fire to aircraft nearby. During the Vietnam War Phan Rang airbase was attacked with mortar fire on the night of 25–26 January 1969. One of the rounds scored a direct hit on an F-100 Super Sabre aircraft parked in a revetment. Burning fuel from this aircraft flowed into the revetment opposite and set fire to an another aircraft. Both aircraft were completely destroyed; the ensuing explosion hurling munitions around the surrounding area.[35] So although the revetments protected the second aircraft from the mortar attack itself, burning fuel destroyed it.

The provision of many light or heavy roofed revetments in dispersed locations around the airbase can provide ready-made protection for aircraft, personnel or stores. Maximum concealment can made by leaving tall native vegetation around them for

[35] Coulthard-Clark, C.D., *The RAAF in Vietnam,* Allen & Unwin, St Leonards, 1995, p 232.

camouflage. By utilising a heavy concrete roof and revetment walls, a large amount of protection can be obtained from near misses and enemy observation. If sufficient shelters are built, it will greatly complicate an enemy's targeting strategy.

Protection of Critical Facilities

Command, control and other essential facilities such as communications nodes should be afforded levels of protection commensurate to the impact that their destruction would cause. Traditionally, these facilities have been placed in buried bunkers, relying upon hardening and to a lesser extent concealment to prevent air and ground attacks.

Despite the recent developments in deep penetration weapons, burial under metres of concrete and earth can provide considerable protection. The current generation of penetrating warheads are limited to only a few metres of reinforced concrete and overburden. The BLU-109 warhead is claimed by different sources to be capable of penetrating 1.8[36] to 2.4 metres of reinforced concrete.[37] The 5,000 pound BLU-113A/B is credited with being able to penetrate 30 metres of earth or 6 metres of reinforced concrete.[38] However, the weight of this weapon precludes its effective delivery from many platforms, particularly the smaller aircraft available to less advanced air powers.

Although the US continues to develop smaller deep penetration weapons, 2.5 metres of concrete seems to be the present limit of penetration that can be achieved from the 2,000 pound class weapons available. Accordingly, deep burial of critical facilities can still afford considerable protection from aerially delivered weapons. To attack deeply buried facilities successfully requires an aggressor to apply precision accuracy and deep penetration simultaneously and have the ability to accurately locate the facility. This may be a difficult task unless resources on a scale available only to a major power are committed.

A principal vulnerability of deeply buried facilities is their connections with the outside world. This includes entry points, supply of services and communications links. Care must be taken when designing these facilities to ensure that these potential weaknesses are not exploitable.

Deep burial of critical facilities can be very expensive and, ultimately, it may be feasible to attack buried facilities irrespective of how deeply they are built. A potentially more cost effective solution is the use of a large number of conventionally or moderately hardened facilities placed in dispersed locations around the airfield. By regularly moving critical operations between these facilities, the enemy may be unable to determine which ones to strike. They may not have the resources to strike them all simultaneously, making a high-risk mission with such an unreliable outcome very unattractive. Shelters not currently being used by the critical functions provide

[36] Starr, B. and Evers, S., 'US Aims to Penetrate Subterranean Centres', *Jane's Defence Weekly*, 26 February, 1997, p 35.
[37] Jane's Air Launched Weapons, Issue 28
[38] Jane's Air Launched Weapons, Issue 28

convenient places for personnel to rest and recuperate in relative comfort, or for the conduct of less critical activities.

> THE PROVISION OF A SINGLE HARDENED FACILITY FOR CRITICAL BASE FUNCTIONS SUCH AS COMMAND AND CONTROL IS DANGEROUS AND COUNTER-PRODUCTIVE. SPACE BASED REMOTE SENSING TECHNOLOGY WILL HAVE LONG REVEALED ITS LOCATION AND MODERN PRECISION GUIDED PENETRATING WEAPONS ARE CAPABLE OF DESTROYING SUCH FACILITIES WITH EASE.

Active Protection of Critical Facilities

In the last 30 years there has been considerable development in protective devices for armoured vehicles. These systems use a combination of active and passive means to detect and defeat threats to the vehicle. Some of these systems are designed to engage the firing platform, whilst others engage the attacking weapon directly employing a variety of soft and hard kill methods.

This research has a great deal of potential application to the protection of critical facilities at installations such as airbases. Many of the same technologies used to defeat threats to armoured vehicles could be modified to detect and defeat threats to hardened airbase facilities.

These systems incorporate laser detectors, ultra-violet missile detectors and a variety of radars. Incoming threats are then neutralised by a combination of obscurants, laser jammers, and infra-red decoys and jammers. Hard kill systems that can be employed include small missiles and rockets, explosively forged projectiles, intelligent reactive armour, linear explosive charges and electromagnetically launched projectiles. These hard kill systems have been used to intercept and destroy incoming anti-tank missiles, and gun-launched kinetic energy penetrators and chemical energy shaped-charge warheads.[39] It would not seem too difficult a challenge technologically to adapt this form of defence for defeating typical threats against airbase hardened targets.

Protection of Personnel and Other Facilities

In addition to the hardening of aircraft parking and critical support facilities, such as fuel and ordnance storage, personnel accommodation and work areas should also be

[39] Ogorkiewicz, R.M. and Hewish, M., 'Active Protection: Providing a Smarter Shield for AFVs', *Jane's International Defense Review,* 1 July 1999, http://defweb.cbr.defence.gov.au/jrl/janes/idr99/idr00420.htm accessed 13 September 1999.

protected from the effects of weapons. The principal causes of fatalities and injuries from attacks result from the following:

- Direct impact from high speed primary fragmentation;
- Impact from secondary fragmentation.
- Direct blast effects and the damaging effects of translational type injuries (where the body is thrown against an immovable object).
- Heat and fire effects.
- Effects of toxic chemical agents.

These damage mechanisms normally result from the detonation of high explosive or the direct impact of a projectile such as a bullet. A degree of protection against these damage mechanisms can be provided by the use of relatively low revetment walls around important facilities. Protection should also be available to personnel who are caught in the open during attacks. Given a typical 2,000 pound class general purpose bomb can throw lethal fragments in excess of 1,500 metres an attack on any part of the airbase can endanger all exposed and unprotected personnel.

Other base facilities may be too large to protect adequately with low revetment walls and may be susceptible to critical damage by fragment strikes. Above ground fuel storage tanks are an excellent example. Ideally, fuel storage at an operational airbase should be built in underground tanks or provided from transportable bladders that can be hidden and protected by a variety of means. However, if the base is dependent upon a limited number of above-ground thin-skinned metal tanks, procedures should be in place to prevent loss of fuel by tank puncture. This could include the provision of excess tank capacity to enable fuel to be moved quickly from damaged tanks to the physical protection of the tanks by light armour. However, these techniques are obviously expensive and provide nowhere near the protection afforded by purpose designed infrastructure.

MISCELLANEOUS HARDENING ISSUES

Hardening of Electricity Supply and Other Essential Services

It can be expected that any concerted attack on an airbase or any attempt to prevent air operations from that airbase may target infrastructure and services for that base. This may include electricity supply, communications links and water. Accordingly, these services must be capable of surviving attacks.

Protecting these services requires the same application of operability theory as other airbase features. They must be hidden, protected and redundant to a level commensurate with the disruption their degradation would cause.

One means by which this can be done is to bury these services. This will hide them from view and protect them from attack. Elevated cables and wires, apart from being vulnerable, may also provide very visible radar returns, which can be used to find targets from the air. They can also be a hazard to personnel if they are damaged or brought down by attack or destructive weather.

Design of Fighting Positions

Defence of airbase vital assets and selected positions in the AAZ can be improved by the establishment of hardened fighting positions. These are protective works from which defenders can maintain surveillance and direct fire whilst remaining relatively protected. Fighting positions can also be distributed around the airbase to provide hasty protection for personnel during surprise air or ground attack. Depending upon their design and intended use fighting positions can provide their occupants with protection from:

- Direct fired weapons, possibly including light anti-armour weapons.
- Fragments from indirect fired weapons, including air-burst munitions. This requires all-round protection including over-head.
- Observation by the enemy either on the ground or in the air or space.
- The debilitating effects of the sun and weather.

These fighting positions should be pre-constructed and placed in accordance with a comprehensive ground defence plan. This plan would consider many factors such as arcs of fire and mutual support. Construction of such positions during contingency is manpower intensive and can compromise the primary tasks of personnel who have been deployed for reasons other than ground defence. Pre-cast concrete sections, surrounded by dirt mounds provide high levels of protection. Some additional consideration when designing and employing fighting positions include:

- A high water table or high rainfall patterns may cause excavated positions to fill with water. In this environment these positions should be constructed above ground.
- The provision of protection to the rear of the position can protect the occupants from the effect of indirect fire weapons detonating behind them. However, if captured this can enable the position to be used by an adversary to fire into the airbase.
- Provision can be made to enable entry and exit from the position whilst under fire. This will enable evacuation or reinforcement to be undertaken with some protection if required.
- Communications links, preferably land-line, can be provided to improve command and control and warning procedures.

- Camouflage of the position will hinder the ability of the enemy to locate it or determine its construction or manning.

During the Australian involvement in Vietnam protective revetments were built for personnel to protect them from mortar fire. Throughout the domestic and working areas improvised sand-bag positions were constructed with steel matting and sand-bag roofs. Although these required considerable maintenance they provided significant protection for RAAF personnel. As the threat from indirect fire weapons increased so did the scale of protective works designed to defeat them. In the second half of 1968 many of the sand-bag positions at Phan Rang were replaced by structures built of 200 litre fuel drums and earth mounds. They were larger than the existing structures and required less maintenance.[40]

Protection from Terrorist Attacks

Overt terrorist attacks against airbases will normally consist of the following threats:

- Direct attacks using either direct or indirect fire weapons.
- The physical destruction of important assets by vandalism, theft or fire.
- The use of improvised explosive devices delivered either by vehicle or through a parcel or package.
- The introduction of contaminants into the air, water or fuel supply.
- The use of techniques such as kidnapping or hostage taking.
- Hoaxes threatening the use of any of the above.

In additional to the normal operability measures that apply in all threat scenarios the following additional measures can be taken to deter and prevent these forms of attacks.

- During high threat periods, ensure all vehicles, including those driven by staff are searched at the base entry point. Staff may have had bombs placed in or under their vehicles either without their knowledge or under duress.
- Locate vehicle parking areas away from important facilities to provide stand-off protection from blast effects. Under building car parks allow vehicle bombs to be placed for maximum possible damage effects and effective vehicle barriers should be placed to prevent entry to these. Ideally, important facilities will not feature car parking under or close to the facility. Similarly, open foyer areas or large areas of glazing should be protected from 'ram-raid' style vehicle attacks.

---

[40] Coulthard-Clark, *The RAAF in Vietnam,* pp 230-231.

- Provide layered security measures so that the more critical a facility the further into the defensive structure of the airbase it is placed.

- Ensure that all buildings and facilities are designed to prevent covert entry or tampering. This means fitment of appropriate physical security intruder detection devices to important buildings and services. Access man-hole covers must similarly be protected.

- Ensure that garbage receptacles and other containers are not located next to important facilities or personnel concentrations. These make ideal places to hide bombs.

- Screen recreation or gathering areas from off base view. This reduces the potential for direct fire weapon attacks from outside the perimeter.

- Movement routes throughout the airbase should be restricted and controlled. Ideally this should be done with mobile, vehicle-proof road-blocks. These can be used to channel and deny routes to infiltrators who penetrate the airbase perimeter. They can provide an information edge to defenders who will know where these mobile blocks are, but if moved regularly, not the terrorists. In the event that an attack has rendered some internal roads unusable the roadblocks can be removed entirely to provide redundant movement routes. These barriers can also be used to prevent vehicle access to vulnerable areas whilst allowing access by pedestrians with suitable credentials.

- In high risk environments personnel and vehicles that seek to enter the airbase should be searched for weapons, explosives or intelligence gathering equipment. An area should be set aside for the purpose of conducting these activities. This area should be secure and be remote from any vital facility or traffic route. In the event that a suspicious item is found during a search a cordon may need to be established around this location which should not unnecessarily hinder other base operations. This principle also applies to the handling of enemy casualties, prisoners or prisoners-of-war. Prisoner-of-war and enemy casualty processing and holding facilities should be established where they or their equipment cannot compromise airbase assets or operations.

- Appropriate protection may need to be provided to dependants who may be valid targets for an enemy employing asymmetric strategies.

Hardened, earth covered or buried facilities also provide excellent protection against ground force or terrorist attack. They provide physical protection from the effects of weapons and explosives and generally have highly limited access. Appropriate security at the entry points and protection of external connections and services are required to complement these facilities. Services such as air intakes and communications conduit ducting are the vulnerable points in these hardened facilities and should be given appropriate protection.

Prevention of Airborne or Aircraft Borne Assaults

Airborne (parachute) or aircraft borne assault troops have been used to capture or attack airfields many times in the past. Airborne assaults have been used by the Germans in Belgium and Crete and by the Americans in Grenada and Panama. Aircraft or glider-borne troops have been inserted onto airfields by the Germans in both the Netherlands and Crete, and by Israel at Entebbe.

A more unconventional assault of this type occurred on 24 May 1945 on the Pacific island of Okinawa, at the recently American occupied Yontan airfield. On that evening five twin engine Japanese bombers were spotted approaching Yontan from the direction of a nearby Japanese held airfield. Four were shot down but the fifth was able to complete a wheels-up landing on the airfield. Ten heavily armed Japanese leapt from the aircraft and began throwing grenades and incendiaries at surrounding parked aircraft. Before they could be killed, these suicide troops destroyed seven planes and damaged a further twenty-six. They were also able to destroy 70,000 gallons of fuel stored in the airfield fuel dump.[41]

These types of assaults utilised either the airbases own runway or the large amount of open flat space present at most airbases. Methods of preventing such force insertions include:

- The use of tactical air defence radar or remote observers to provide warning of aircraft approaches. These aircraft may be flying very low or may attempt to mimic commercial or friendly aircraft traffic.

- To deter airborne assaults the airbase should have as little as possible open flat ground. This can be achieved by leaving natural vegetation in place, particularly tall trees, which can effectively prevent parachute-borne or helicopter insertions.

- Those defences that also overlook open areas inside the airbase should be capable of directing fire onto those areas. This means providing those positions with all round protection and sufficient firepower to impose heavy casualties at medium to long range. Care must be taken when doing this that fratricide is avoided. The positioning of a sustained fire machine gun capable of placing accurate fire onto the aircraft operating surfaces will deter these kind of attacks.

- Point defence anti-aircraft weapons will deter landings or low-level over-flights in transport aircraft.

- Runways may be blocked when not in use. This can be done with vehicles that can be moved quickly to allow friendly air operations.

[41] Gailey, H.A., *The War in the Pacific: From Pearl Harbor to Tokyo Bay,* Presidio Press, Novato, 1995, pp 442-443.

CHEMICAL AND BIOLOGICAL DEFENCE

Chemical and Biological (CB) weapons have unique characteristics and accordingly an unique set of defensive measures need to be adopted against them. Modern CB agents can be deployed by air or ground weapons and are described in detail in Chapter Three.

The proliferation of these weapons make them a viable threat in virtually any expeditionary operations conducted by ADF air forces. 'In the aftermath of the Gulf War, the United States has concluded that the threat of [Weapons of Mass Destruction] WMD use is likely in future warfare. In places where the United States has deployed forces such as the Middle East, potential adversaries possess WMD and may seek to counter U.S. conventional superiority through the use of these types of weapons. Consequently, U.S. forces must today train and be equipped to operate in a potential WMD theater.'[42]

An important secondary utility of an effective CB defence is its inherent deterrent value. CB weapons have markedly reduced effect when deployed against units that have a well developed capability to operate in this environment. 'In terms of a deterrent, any potential opponent seeing a well trained, well equipped force will be less likely to consider the use of NBC agents.'[43]

There are six main elements to an effective airbase chemical and biological defence capability. These are:

- A system for detecting and identifying CB agents and providing immediate local warning.

- A system for assessing the potential impact of CB agents and for receiving and promulgating warning of their use to neighbouring units and commands.

- A system for decontaminating personnel, equipment and facilities which have been exposed to CB agents.

- Medical systems which are capable of treating CB and conventional casualties in a contaminated environment. This includes a capability to treat and move incapacitated personnel who may not be able to wear normal Individual Protective Ensemble (IPE). This capability would also include the inoculation of all personnel against likely biological agents, and naturally occurring endemic diseases, prior to their deployment to the airbase.

- A system of individual and collective protection for base personnel and critical equipment.

---

[42] Hajjar, S.G., *Security Implications of the Proliferation of Weapons of Mass Destruction in the Middle East,* US Strategic Studies Institute, Carlisle, 1998, p 5.

[43] Tusa, F., 'The Danger of Asymmetric Threats, Asian Military Review', 9 November, 1998, p 26.

- Personnel trained and equipped to conduct explosive ordnance disposal procedures on unexploded CB weapons.

Once CB defence and decontamination systems are in place, and personnel are trained in the use, the level of readiness at which the protection is maintained will be the primary determinant of how severely they impact airbase operations. A high-level of preparedness will provide high protection from surprise CB attacks, however, can detract from the ability of the airbase personnel to perform their primary functions.

It is also important to note how easily chemical contamination can be maintained over an airbase sized target. Once initially contaminated, it would only require one VX agent warhead tactical ballistic missile per day to land on or near the airbase to maintain lethal levels of coverage over large areas. Once personnel are aware of the chemical threat, they will begin to use protective equipment and the ongoing contamination is unlikely to cause further casualties, but will dramatically effect the sortie generation rate of the airbase. Accordingly, the ability to sustain operations in a CB environment for an extended period is important.[44]

CB Detection Systems

Systems to detect and identify CB agents are available with widely varying costs, complexity and capability. They are generally divided into individually portable equipment sets, either chemically or electronically based, and larger sets to provide area coverage and greater sensitivity.

For the detection of a range of biological agents US forces have begun deploying their Portashield system.[45] This is a network of detection and communication technologies to provide alerts for fixed sites such as airfields. The system can detect eight different types of agents in 15–25 minutes and has a low false-alarm rate. More portable systems, such as the US Army Biological Integrated Detection System (BIDS), use commercially available detection systems and are self-contained on the back of a high-mobility vehicle. The BIDS system has been deployed in US service since 1996.[46]

Inoculation Regimes

The majority of accepted biological agents can be countered by immunisation. The US Department of Defence has begun a program of vaccinating all US service personnel against anthrax. Immunisations against another 14 biological agents is also being planned.[47] The difficulty of immunisation is the variety of agents that must be inoculated against. 'An effective vaccine is one of the best defences you can employ,

---

[44] Chow, B.G., Jones, G.S., Lachow, I., Stillion, J., Wilkening, D. and Yee, H., *Air Force Operations in a Chemical and Biological Environment,* RAND Corporation, Santa Monica, 1998, p 25.
[45] Beal, C., 'Facing the Invisible Enemy', Jane's Defence Weekly, 4 November, 1998, p 24.
[46] Beal, 'Facing the Invisible Enemy', p 24.
[47] Beal, 'Facing the Invisible Enemy', p 24.

but you can never be sure you have the right vaccine or that it will protect against altered agents or if those closest to the agent will have sufficient protection.'[48]

Individual Protective Ensemble

IPE is the term used for clothing designed to provide the wearer with protection from CB agents. IPE will normally consist of the following components:

- Respirator mask and disposable filtration canisters;
- Permeable CB suit, and
- Impermeable gloves and over boots.

These items have finite shelf lives and limited protective qualities once unpacked. When exposed to chemical agent the suit has a short useful life and must be replaced. The useful life of this equipment depends upon the design of the equipment and the nature and concentration of the chemical agent to which it is exposed. Lightweight overgarments are presently available which can be laundered and re-used.[49]

In some situations impermeable IPE may be worn. This is done when the wearer may come into contact with liquid or gross contamination. This may occur during chemical decontamination or CB explosive ordnance disposal operations.

One of the principal impacts of having to wear chemical IPE is the degradation it causes on the operational efficiency of the individual. 'Having to work and fight in full NBC [Nuclear, Biological and Chemical] suit, boots, gloves and respirator is very draining, and troops' capability is hit by 50 per cent straight away. As time goes on, it also affects the combat efficiency of units to a massive extent.'[50] Hot, humid environments exacerbate this situation. This degradation may be alleviated to an extent by providing facilities where personnel can eat, rest and perform some work tasks in a CB clean environment. Such facilities are termed collective protection.

Collective Protection

Collective protection, or colpro, provides protection for groups of personnel from CB agents, alleviating the requirement for them to wear their individual ensemble whilst inside these facilities. Prolonged wearing of the CB IPE causes degradation in the operational performance and endurance of the individual. This degradation may be alleviated to a degree by providing adequate facilities where individuals can obtain temporary relief by removing their IPE.

[48] *Ibid.*, p 24.
[49] *Ibid.*, p 24.
[50] Tusa, 'The Danger of Asymmetric Threats', p 25.

Collective protection should be available for the following airbase facilities:

- Command posts;
- Communications facilities;
- Air Traffic Control facilities;
- Medical facilities;
- Air crew briefing/readiness facilities;
- Technical repair facilities;
- Some administrative facilities, and
- Rest, recuperation and recovery facilities for all staff.

When deciding on how much colpro should be provided, and in what priority order, the following must be considered:

- How long can the unit expect to be exposed to CB agents? This will be determined by the magnitude of the CB threat compared to the capability of the unit to conduct decontamination operations.
- To what extent will the operation be hampered by the wearing of IPE? Some technical maintenance and medical procedures are almost impossible to perform whilst wearing IPE.
- Can the unit move out of the contaminated area and resume operations?

Airbases are geographically fixed sites and once contaminated with an appropriate agent will remain so until decontaminated. Personnel cannot move to an uncontaminated area to seek relief whilst continuing to support the airbase mission. The nature of the activities conducted in support of air operations such as aircraft maintenance and preparation are highly delicate tasks and difficult to undertake whilst wearing IPE. Accordingly, by considering these three factors, colpro is particularly important at airbases.

ONCE CONTAMINATED WITH CHEMICAL OR BIOLOGICAL AGENT AIRBASES CANNOT BE USED AND WILL REMAIN UNUSABLE UNTIL EFFECTIVELY DECONTAMINATED. ACCORDINGLY, THE ABILITY TO SUPPORT AIR OPERATIONS IN A CONTAMINATED ENVIRONMENT FOR AN EXTENDED PERIOD AND TO UNDERTAKE DECONTAMINATION OPERATIONS IS CRITICAL.

There are two basic categories of colpro, which vary significantly in cost and capability. These are sealed shelters without air filtration and positive pressure shelters.

Sealed Shelters Without Air Filtration

These shelters rely upon uncontaminated air trapped inside the shelter to provide an agent free environment. These types of shelters are cheap and simply require the ability to be sealed when CB agent use is suspected. The main limitations of these types of shelter are:

- Once sealed, the shelter cannot be opened until the CB threat is gone without compromising its protective properties. Personnel inside the shelter are therefore trapped inside and may be temporarily combat non-effective.

- Carbon dioxide build up will limit the stay time inside the shelter. Other factors being equal, CO_2 will accumulate to uninhabitable levels before the available oxygen is depleted. As a rough planning figure, each cubic metre of air per person allows a stay time of 75 minutes. It may be possible though in some circumstances to remove CO_2 from the air chemically to extend this period.

Because of these limitations sealed shelters have highly limited application in the airbase environment and should be considered an emergency only capability.

Positive Pressure Shelters

These types of shelter rely upon the air pressure inside the shelter being higher than the outside ambient pressure to prevent ingress of contaminated air. Air for the shelter's inhabitants is drawn in through a filtration and purification system. These systems allow for longer-term use than sealed types and should possess the following features:

- These shelters must contain at least one air lock to allow entry and exit of personnel. Personnel entering must be decontaminated and their contaminated IPE or equipment not allowed inside the colpro.

- A positive pressure system for drawing in and decontaminating the air must be included. This should also incorporate a system for controlling the humidity of the shelter air.

- The shelter should incorporate entry and exit points for cabling and other services.

- The shelter should incorporate a system for detecting and warning of contamination within the facility.

These features should ideally be incorporated into hardened facilities during their initial construction phase. The retro-fit of these capabilities into existing structures, particularly hardened ones, is expensive and often compromises the original design intent of the facility. At a very minimum these capabilities should be factored into the initial design or master planning process and space reserved.

SUMMARY

A wide variety of active and passive defences can be employed to protect airbase targets. Like any other single airbase operability enhancement these will not provide immunity from all attacks when applied in isolation. However, when employed as part of a comprehensive plan, strength can significantly reduce the options available to forces wishing to attack the airbase. Some specialist requirements such as chemical and biological protection can take many forms and pre-planning is required to determine the most effective manner in which to employ this protection.

The battle between armour and warhead has been ongoing since the longbow was first used to dispatch the armoured knight. Armoured fighting vehicles have revolutionised warfare since World War I and continue to be effective despite means of penetrating their armour being found almost immediately. The same thought process should be applied to the hardening of airbase facilities. No amount of concrete or steel will make a shelter invulnerable, just like no modern tank is invulnerable.

The use of hardened or semi-hardened facilities on the airbase can significantly reduce the flexibility available to a potential attacker. By requiring them to use precision guided and/or penetrating weapons the risk and cost of the airbase attack is greatly increased. This is particularly so if the facilities are duplicated and concealment and deception is used to prevent the enemy from determining which ones actually house critical assets. These facilities also provide environmental benefits for equipment and staff alike and can be designed to allow chemical and biological protection to be incorporated if later required. Obviously though, the cost of hardened facilities is the primary disadvantage, particularly given their demonstrated vulnerability to some modern weapons. However, there are a range of levels of protection available and the most effective solution may be a combination of hardening and duplication.

Defending an area target like an airfield is extremely difficult. Damage to or destruction of any one of a large number of vital installations could paralyse or cripple the operational capability of the airfield. The fact of the matter is that the stand-off capability that modern air forces (and some maritime surface and sub-surface forces) possess is far superior to the air defences that can be effectively deployed currently.[51]

However, the considered use of hardening, in concert with a well developed active and passive defensive aids suite provided on a scale commensurate with the adversary's capabilities can still provide excellent protection to mission critical capabilities. State-of-the-art defensive systems, thoughtfully employed, can provide an effective deterrent against all but the strongest air campaign.

[51] Kainikara, S., 'Ground Based Air Defence – Keeping Pace with Threat Perceptions', *Asia-Pacific Defence Reporter*, December, 1999, p 23.

CHAPTER 10

Redundancy and Dispersal

The Gulf War confirmed that redundancy is a successful passive defence measure.[1]

INTRODUCTION

Ultimately, despite deception and hardening, airbase facilities and assets may still be vulnerable to attack if sufficient effort is expended to this end. Also, even when not exposed to enemy fire, personnel can be injured and systems can fail depriving the airbase of their services.

Given that airbases will always be vital centres of gravity additional measures will need to be taken to ensure that the base continues to performs its functions. These measures include employing redundancy and dispersal. This is achieved by having more than one of each of the airbase's critical systems, facilities or people and ensuring that they are kept far enough apart that a single attack or system failure cannot destroy all simultaneously.

The aim of this chapter is to describe the methods by which redundancy and dispersal can be employed in the airbase environment.

REDUNDANCY

Redundancy is that characteristic in a structure which enables it to perform its primary functions even when elements of the structure have failed or been destroyed. It is an important airbase characteristic that can greatly reduce its vulnerability to capability degradation, which can occur through enemy action, equipment unserviceability, shortage of critical resources or unexpectedly high demands exhausting or overloading the primary supply.

There are two basic forms of redundancy: parallel and hierarchical.

[1] Hammond, O., 'Iraq's Preparation for the Gulf War – Lessons for RAAF Operational Facilities Planning' in Waters, G., (Ed), *Line Honours – Logistics Lessons of the Gulf War,* Air Power Studies Centre, Canberra, 1992, p 71.

Parallel redundancy. Parallel redundancy is provided when the primary and alternate systems have the same operational capabilities. In its purest form the parallel redundant system has no primary and alternate, with all systems being used under normal operation, and transfer between them being seamless and unnoticed by the customer. Properly designed parallel redundant systems should not suffer from the change-over problems that occur when switching from one source of supply to another with different characteristics.

Hierarchical redundancy. Systems which have a primary system and a back-up are known as hierarchically redundant. Under normal circumstances the primary component operates, with the back-up being activated when the primary fails, or is damaged. The secondary source is normally not as capable or efficient as the primary. The system may have a number of cascading back-ups, each successive component taking over from the previous in the event of its failure.

Redundancy can be applied effectively to many airbase features. The use of duplicate runways, redundant fuel and electricity supplies, and dispersed ammunition storage points all provide the airbase with redundancy. Redundancy can also be applied to people as well, ensuring that there is never only a single person capable of providing a critical service or knowledge on the airbase.

Critical airbase capabilities that should be provided with redundancy include:

- Petrol, oils and lubricants;
- Electricity Supply;
- Water supply;
- Ammunition storage;
- Aircraft Operating Surfaces (AOS);
- Medical, rations and other essential personnel support services
- Command, control, communications and information systems; and
- Airfield support services.

Petrol, Oils and Lubricants

Aircraft operations use copious quantities of fuel. With a typical jet fighter/bomber squadron using approximately 750,000 pounds of aviation fuel per week of operations, resupply of fuel will be constant and potentially highly vulnerable. Aircraft and ground operations will likely cease without sufficient supplies of Petrol, Oils and Lubricants (POL).

Accordingly, to protect this important resource both aviation and ground POL can be stored in redundant hardened facilities. The base operability plan should identify the POL supply flow from when it enters the area of operations until it is pumped into the user machinery or aircraft. This will enable the identification of vulnerable points and potential alternative methods and supplies. Every opportunity should then be taken to protect supplies from interruption, and to buffer operational stocks in case interruption occurs.

When used within the airbase mobile fuel tankers are high profile and vulnerable targets. They should be kept full at all times to disperse fuel holdings and positive control maintained over their movement to prevent their grouping as a single target.[2] Given the inherent physical vulnerability of fuel tankers, aviation fuel should ideally be supplied directly to hardstands and dispersal points by underground piping. This improves refuelling efficiency and reduces the vulnerability of these easily attacked vehicles. Fuel tankers should still be available to cater for unusual refuelling tasks or as an independent back-up to the underground reticulation system. The more widely dispersed the aircraft parking and operating areas are, including off base operation, the more expensive it may be to supply them with underground fuel reticulation.

One alternative method of providing bulk contingency fuel storage is the use of transportable collapsible bladders. These can be pre-positioned into purpose-built, revetted and bunded areas constructed for them. By placing the bladders inside the revetments they provide inexpensive, rapidly established and dispersed fuel storage.

Where it is possible to containerise motor transport fuel this should be done and dispersed around the base. A single refuelling point for all ground vehicles is a vulnerable and attractive target.

Use of Airborne Refuelling Tankers

One option for the provision of fuel to forward operating aircraft is the use of airborne aerial refuelling tankers. These aircraft would normally be flown from rear bases to orbits in the desired area providing fuel to aircraft requiring it. An alternative method is to fly fully fuelled tankers or large transport aircraft into the forward operating base and down-load as much fuel as possible into storage tanks.

While aerial refuelling tankers are an attractive alternative source of supply of aviation fuel, the following disadvantages should be noted:

- Airborne refuelling may complicate command and control arrangements and mission planning.

- The requirement to use of airborne refuelling can make tactical aircraft operations more predictable.[3] Once it becomes apparent to the adversary that aircraft must

[2] Cooper, R.F., 'The Active and Passive Ground Defence of the Northern Airbases', in Waters, G. and Casagrande, R., (Eds), *Operational Support Workshop,* Air Power Studies Centre, Canberra, 1995, p 70.
[3] Bingham, P.T., *Operational Art and Aircraft Runway Requirements,* http://www.airpower.maxwell.af.mil/airchronicles/apj/apj88/bingham.html accessed 21 January 1991, p 2.

refuel airborne immediately after take-off foreseeable patterns can established which may make both the combat aircraft and the tankers vulnerable. The inability to refuel on the ground may force aircraft to land with sufficient fuel reserves to enable them to take-off and immediately refuel airborne. Therefore, unless very large numbers of tankers are available to enable refuelling before landing this requirement will ultimately reduce the combat radius of those aircraft.

- The tanker aircraft themselves require significant logistic support and may entail an additional operating cost.

- The tanker aircraft may be vulnerable to enemy action.

- Where limited numbers of tankers are available, their use to provide fuel to an airbase, particularly one with an ongoing air defence commitment, can monopolise their tasking. Higher priority missions may subsequently deprive the airbase of this fuel supply.

Electricity Supply

Modern airbase operations depend entirely on electrical power. Electrical power should ideally be provided with a quadruple redundancy system as follows.

- Firstly, there should be not less than two main generation supplies or facilities, both of which are capable of running essential services independently for an extended period. Only one of these supplies should rely upon external off-base generation. Each should be independent to the extent that battle damage to a few vital points should not impact both supplies. The main reticulation circuit around the base should be in the form of a ring, so that multiple cuts are required to block supply.

- Secondly, each operationally critical electricity dependent facility should have its own integral back-up generator capable of sustaining operations.

- Thirdly, mobile generators should be available to supplement requirements and to take over from damaged or unserviceable local supplies. Operationally critical electricity drawing facilities should be built with plug-in points to accept mobile generator supplies.

- Finally, all operationally critical equipment should be provided with Uninteruptable Power Supplies (UPS) and power supply conditioners to allow smooth transitions between supply sources. Most back-up sources of supply will require a period of time to come on-line. This is particularly critical with micro-processor based equipment which must be protected against momentary power outages or voltage spikes.

Electricity generating equipment and reticulation systems require specialist maintenance. Dependence upon portable electricity generating equipment for long periods can induce high maintenance overheads.

Water Supply

Water is critical to life and will be consumed in large quantities by both personnel and operations at an airbase. Operations in a typical airbase will consume not less than 20 litres of water per person per day, even when living in field conditions. An airbase complement of 250 personnel may therefore consume not less than 5,000 litres of potable water per day. When operating from a hot or tropical location this requirement will increase.

Some airfields may utilise off base water supplies either pipe-lines or bore water, with the bore fields being located off the airbase. These pipes, bore heads and pumping stations are often extremely vulnerable to damage by enemy ground forces and, unless back up supplies are available, water shortage may make base operation untenable. These water supplies may be damaged or destroyed by Special Forces units or by local irregulars in an attempt to disrupt base operations. It may also be possible to poison or pollute the water supply. As a counter it may be possible to sink bores within the defended base perimeter to provide reliable supplies in time of contingency.

These activities may occur as either a planned attack or when the water source is encountered as a target of opportunity.

Ammunition Storage

Ammunition storage poses a unique dispersal problem in that it must not only be protected from the effects of enemy fire, it must also be protected from its own destructive forces. For this reason strict rules are normally applied in peacetime to the types and quantities of explosive ordnance that may be stored together and the minimum distance by which these must be separated from other explosives and personnel.

These distances are often quite significant and depend greatly upon the physical protection accorded the ordnance in their storage buildings. Often to meet these safety requirements a dedicated ordnance storage compound may be established a significant distance from the rest of the airfield facilities. The storage buildings themselves are also usually revetted or earth-covered. Therefore dispersal of ordnance stocks is normally not a particular problem. However, two other difficulties can be encountered with ordnance storage facilities. Firstly, as the ordnance storage area is usually well outside the normal defended area of the airbase it can be difficult to secure from ground attack. Secondly, it is very rare for sufficient storage space to be built to cater for wartime ordnance loads. This then forces the use of improvised or field storage areas that do not meet normal requirements. Overcrowding may occur, providing a lucrative target that may be difficult to protect or disperse.

Aircraft Operating Surfaces

To allow take-off and landing fixed-wing aircraft generally require a large amount of smooth hard pavement. The minimum length, width and quality of this pavement will depend upon the type of aircraft, its loading, and the prevailing atmospheric and environmental conditions. In most circumstances this requirement, termed the Minimum Operating Strip (MOS), will be of the order of 5,000 feet in length and 50 feet in width. Accordingly, modern airbases with 10,000 feet by 200 feet main runways, plus additional runways and taxiways generally provide many different possible MOSs. To support operations from the MOS additional pavement is also required to allow taxiing and parking. The MOS plus this additional pavement is referred to as the Minimum Aircraft Operating Surface (MAOS).

The capability to relocate the actual area of pavement utilised as the MOS provides significant redundancy in capability. This redundancy provides the following operational benefits:[4]

- It provides a deterrent against pavement denial attacks.
- It magnifies the difficulties of neutralising the airfields, and reduces the effectiveness of area denial weapons.
- It increases the probability of maintaining continuous operations.

To be successfully used as an alternate MOS a piece of pavement should possess the following characteristics:

- The pavement must have sufficient shear and load bearing strength for its assigned aircraft, aircraft loading and role.
- There must be safe and timely access for aircraft to the MOS from parking, arming and fuelling areas. (A complete MAOS)
- Sufficient clearance must be provided at either end of the MOAS and to each side of it to allow for safe aircraft operations.
- The surface and shoulders of the MOAS must be sufficiently clean, so as not to present a Foreign Object Damage (FOD) hazard.
- Portable aircraft arrester systems can add great flexibility to the choices of MOS available. As detailed below the pavement requirements of combat aircraft during landing are commonly the most demanding. To be able to utilise portable arrester systems requires the placement of hard-stands or foundation blocks and other support infrastructure at predetermined locations.
- The chosen pavement should have an acceptable level of slope or camber.

In addition to the use of existing AOS for aircraft operations, specially prepared roadways can be used as emergency runways and taxiways if constructed to an appropriate standard. The roadways can either be within the airbase or outside it. If

[4] Hammond, 'Iraq's Preparation for the Gulf War – Lessons for RAAF Operational Facilities Planning', p 71.

built to the required standard during initial construction the additional cost will be minimised.

In addition to the normal runways and taxi-ways there should be additional areas of pavement to cater for damaged aircraft and aircraft with damaged weapons. A belly-landing strip should be provided to enable aircraft with damaged landing-gear to land without the risk of damaging the primary runway or blocking it with wreckage. Aircraft that have been damaged by enemy fire may return to the airbase with unjettisonable weapons that will require examination and possible explosive ordnance disposal attention before they can be considered safe. Although this situation may seem unlikely, parking areas should be available for these aircraft where they can be examined without endangering other operations.

Reducing the Aircraft Operating Surface Requirement

So far this chapter has concentrated on what measures can be taken by the airbase to minimise the effect on air operations by attack. Later in the book methods will be discussed for the repair and regeneration of an airbase which has been subject to a successful attack. However, there are steps that can be taken by the aircraft themselves to assist the resilience and recovery operations of the airbase. These include modification to the aircraft design that will enable the aircraft to operate from degraded or lower standard airfields. Although little can be done to reduce this requirement once an aircraft type has been introduced into service, airbase support, including pavement requirements, should be a consideration during the selection process.

Soviet planners have long understood that smooth long runways may not always be available, particularly following an enemy offensive counter air campaign. Where runway repair organisations are available these will often struggle to repair operating surfaces to the quality required by modern western jet aircraft. For example the MiG-29 aircraft incorporates several features to make it less demanding on runway quality. Firstly, large, low ground pressure tyres allow the aircraft to operate on surfaces that are rougher and softer than comparative Western designs. Secondly the engine intake duct geometry is such that is reduces the potential for foreign objects to be ingested by the engines during ground movement. On damaged and hastily repaired surfaces this factor could be critical. Prior to the collapse of the Soviet Union, the Commander or the Soviet Air Force Marshall of Aviation Aleksandr Yefimov emphasised that 'the operations of the VVS [Soviet Air Force] should not be affected by damage to the runways'.[5]

The F-86F Sabre is a good example of how the performance of the aircraft in the air was given preference over its suitability to operate from the airfields available in the theatre. Previous models of the F-86 had slats on the wing leading edges to improve lift at lower landing speeds. However, this modification also reduced the performance of the aircraft at high speed. So, despite the difficulties already being encountered in

[5] 'A New Generation of Combat Aircraft Expected', *Jane's Defence Weekly,* 13 February 1988, p 279.

the theatre with lack of suitable pavements the F-86F was modified to have a solid leading edge. This increased its landing speed and therefore the length of runway required.[6]

An experimental version of the US F-15 fighter — the Short take-off and landing and Manoeuvring Technology Demonstrator (SMTD) has been designed and tested with runway length and quality requirement reductions in mind. This aircraft features enhanced manoeuvrability and greater aerodynamic lift allowing it to fly slower and accordingly take off and land on shorter pavements. These modifications allow the aircraft to take off from a runway with only 1,500 available feet. This compares with the 2,100 feet required by the conventional F-15C. These tests were conducted with a typical air-to-air mission load with approximately 6,000 pounds of external fuel and stores.[7] Both aircraft compare favourably against older fighter aircraft such as the F-4 Phantom, which required 3,180 feet for take-off.[8] A typical modern military airfield will have a 9,000 or 10,000 foot main runway. This additional runway length provides the ability to abort take-offs when required, or to land with less than full braking capability. Barrier and wire systems can also be used to assist this.

The SMTD F-15 will also incorporate modified landing gear capable of operation on rougher airfield surfaces, such as may be encountered following attacks and hasty repairs. The new landing gear can handle higher sink rates allowing steeper approaches, which reduce the aircraft's exposure to ground fire whilst landing. The new gear can also handle rougher surfaces and can tolerate bumps of up to 4.5 inches at speed. During testing bumps of up to 7.5 inches were tolerable. The SMTD will also feature modified bias-ply tyres, which will again better tolerate a hastily repaired runway surface.

An alternative approach to airbase operability is to eliminate the dependence of the combat aircraft on airbases entirely. This is most commonly proposed by the use of Short Take-Off Vertical Landing (STOVL) aircraft such as the Harrier family. Although it demonstrated itself ably in the 1982 Falklands War STOVL aircraft have some considerable limitations:

- When hovering for vertical landing there is no forward airflow so large intakes are required to provide sufficient air for the engines. Combined with a large radar this can give the aircraft a very sizeable frontal area.

- The requirement to vector the jet exhaust downwards limits the maximum thrust that can be developed from each engine. The Pegasus engine used in the Harrier can develop approximately 11,000 kilograms of thrust, sufficient for a maximum aircraft weight of 8,000 kilograms. STOVL aircraft are currently limited to using a single engine as the requirement to match exactly the thrust on both sides of the

[6] Cooling, B.F., *Case Studies in the Achievement of Air Superiority,* Centre for Air Force History, Washington DC, 1994, p 491.
[7] Rhodes, J.P., 'Landing on Less', *Air Force Magazine*, April, 1987, pp 74-76.
[8] Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987, p 4.

aircraft during hover cannot be presently achieved using two engines. Given that a modern twin-engine fighter typically weighs up to 20,000–25,000 kilograms, considerable mission capabilities will need to be sacrificed to meet this requirement.

The combination of large frontal area and low all-up weight greatly limit the roles that can presently be allotted STOVL aircraft. The Falklands War demonstrated the superb operational flexibility of the Harrier family but also some of the practical limitations imposed by the theoretical considerations above. Principal amongst these was the highly limited radar capability and small weapon load. The requirement for the Harriers to employ STOVL limited the physical cross-section of the radar they could employ and the loads they could carry.[9]

Accordingly, unless some significant technological breakthroughs can remove these restrictions, STOVL is unlikely to reverse the requirement for large airbases. One possible alternative technology which may make this feasible is the continuing development of Uninhabited Combat Aerial Vehicles (UCAV). Current research into these systems has led to Boeing being selected by the USAF to develop a demonstration aircraft. The stealthy UCAV is designed to carry multiple advanced precision guided munitions and fulfil a range of roles. The aircraft is expected to have a maximum take-off weight of 6,818 kilograms, well within the weight limit for a foreseeable STOVL design.[10] The combination of UCAV and STOVL technologies has the potential to reduce the dependence of air power on traditional air bases.

THE COMBINATION OF UCAV AND STOVL TECHNOLOGIES HAS THE POTENTIAL TO PROVIDE EFFECTIVE MULTI-ROLE COMBAT AIR POWER WITHOUT A REQUIREMENT FOR TRADITIONAL AIRFIELDS.

Command, Control, Communications and Information Systems

Command, Control, Communications and Information (C3Inf) systems are crucial to the effective operation of modern military forces including airbases. The aim of many military strikes may be to destroy or disrupt these capabilities. It is often more efficient to 'decapitate' fighting forces by separating them from their C3Inf links than to attempt to destroy them by the direct application of force. 'Destruction or isolation of any level of command may have a serious — and perhaps fatal — impact on the unit or units subordinate to it. Clearly, command, with its necessarily associated

[9] Walker, J.R., *STOVL: Another View, Jane's Defence Weekly*, 4 October, 1986, pp 735-741

[10] Bender, B., 'Boeing Chosen for UCAV Demonstration', *Jane's Defence Weekly*, 31 March, 1999, p 10.

communications and intelligence gathering functions, is an obvious centre of gravity, and has been from the earliest times.'[11]

Accordingly these services and links must be protected and survivable. Clearly, the principles of effective military information systems described in Chapter Seven must be applied to them. These principles include survivability, robustness, adaptive response and distribution and variability. These properties are most effectively provided by ensuring these services are dispersed and exhibit redundancy.

In practice this can be achieved by ensuring that single point vulnerabilities are removed at every stage of the C3Inf chain. This should be applied to:

People. No single person should be crucial to the airbase. Essential skills sets should be passed on and individual competencies replaced by corporate competencies. Groups of individuals with unique skills should not be vulnerable to a single attack or accident. Where possible they should use separate transport and not share accommodation etc. Back-up personnel with specific skills vital to the airbase should be identified to enable their rapid acquisition in case of airbase casualties.

> AN AIR FORCE ORGANISATION THAT ENCOURAGES INDIVIDUALS TO ACQUIRE EXPERTISE, RATHER THAN BUILDING CORPORATE OR SYSTEM KNOWLEDGE MAKES ITSELF VULNERABLE TO THE LOSS OF THOSE INDIVIDUALS.

Command Centres. Individual command centres are high priority targets, representing a concentration of the C3Inf assets on an airbase. Every effort should be made to hide command centres and fully functional alternate centres should be available. Transfer of command to the alternate command centre should be rehearsed and seamless.

Communications Links. Communication links should be robust, survivable and resistant to tampering or interference. A variety of different systems (such as high-frequency sky-wave, satellite, microwave, courier, land-line) should be available to provide further resistance to enemy interference. Links between the airbase and the rear areas should be particularly diverse. Within the airbase itself, redundant and dispersed linkages should be available. Single point vulnerabilities such as common switch-boards should be provided with effective redundant services or avoided altogether.

---

[11] Warden, J.A., *The Air Campaign*, National Defence University Press, Washington DC, 1988, p 51.

Information Systems. Information systems comprise a diverse range of people, systems and links as described in Chapter Seven. The storage, analysis, dissemination and transfer of information is vital to the successful operation of the modern airbase. Any system that performs any of these functions should be provided with tested redundancy. Operations using back-up systems should be well briefed and rehearsed. Single point vulnerabilities should be analysed and eliminated wherever possible.

Airfield Services

Airfields provide many operational flight support services to their customer aircraft. These services may include:

- Landing and movement support services and systems such as:
  - Instrument Landing Systems (ILS).
  - Navigational aids.
  - Air Traffic Control (ATC) services, including Ground Controlled Approach (GCA) assistance.
- Terminal and ground movement support systems and services such as:
  - Air movements, personnel and cargo handling services.
  - Aircraft refuelling and flight preparations services.
  - Maintenance services.
- Operational flight and mission planning facilities, services and communication links.

DISPERSAL

Closely tied to the concept of redundancy (essentially a subset of it) is the principle of dispersal. Dispersal implies the placement of assets such that a single successful attack or single weapon will destroy the minimum amount of any airbase or air power resource. Dispersal has been assessed as one the most effective means of passive defence. As T.W. McCoy notes 'Perhaps the most effective means of survivability is dispersal. The fewer targets there are in any one place, and the harder they are to find, the less effective each enemy attack will be.'[12] The transformation of one large target into many smaller dispersed ones magnifies the targeting problem. Targeting is made

[12] McCoy, T.W., 'Task One: Airbase Operability', *Armed Forces Journal International*, September, 1987, p 54.

even more difficult as dispersal may reduce the visual, infra-red or radar signature of this target set.

> The object of dispersal is to present the enemy commander with a situation containing, in his mind, a considerable amount of uncertainty regarding his ability to suppress [airpower]. Dispersal, therefore, should help deter conflict in the first place or, failing that, should tend to cause the enemy commander to ignore airbases as a profitable target set.[13]

Dispersal is one of the few passive defence measures that cannot normally be overcome by the simple application of a weapon designed to do so. Hardened facilities can be destroyed by the application of precision guided penetrating weapons. Dispersed facilities can only be destroyed by the application of multiple weapons or multiple attacks.

Another advantage of dispersal is that it does not always require the expenditure of additional resources to develop or construct infrastructure. This can result in lower construction costs and may be conducive to flexibility, as developed infrastructure such as hardened facilities may be inappropriate unless there is a degree of certainty in advance as to where the war will be fought. The protection of parked aircraft by hardening, for example, requires a substantial additional construction cost and if the aircraft are then required to be deployed away from these facilities that expenditure may have been wasted.

Dispersal also has potential disadvantages, foremost among them is that it will often dilute defensive forces. This is particularly important when defending air assets from ground attack. The dispersal of aircraft and vital facilities around a large airfield greatly increases the number of personnel required to defend them effectively. The placement of US aircraft at Wheeler and Hickam fields in Hawaii in tight rows as an anti-sabotage precaution before the Pearl Harbor attacks contributed to their mass destruction during the air attacks. Figure 10.1 shows the flight line at Serbia's Batajnica Airbase prior to NATO air strikes during Operation *Allied Force* in 1999.

Another disadvantage of dispersal is the additional operating costs incurred. This includes the additional logistic burden of supporting dispersed operations and the reduced economies of scale that can be enjoyed. This effect can be manifested in one of two ways, either an increase in the overall cost of supporting air operations, or if support resources are fixed, a decrease in the number of sorties that can be generated.

A factor significantly affecting the ability of aircraft to disperse is their tactical mobility. Aircraft tied to extensive ground support suites have less flexibility in choosing an operating location. They may also take longer to make the move to the new base, and require greater support in doing so. Once aircraft are dispersed there is considerable benefit in continuing to vary their locations. Camouflage, concealment and deception make it difficult for an enemy to locate dispersed aircraft. Continual

[13] Halliday, *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations*, p 8. The original referred specifically to 'US airpower'.

mobility can then be utilised to make any information the enemy might acquire perishable. This increases their requirement for reconnaissance operations and may further reduce any certainty they may have in being able to target aircraft on the ground and their mobile support assets.

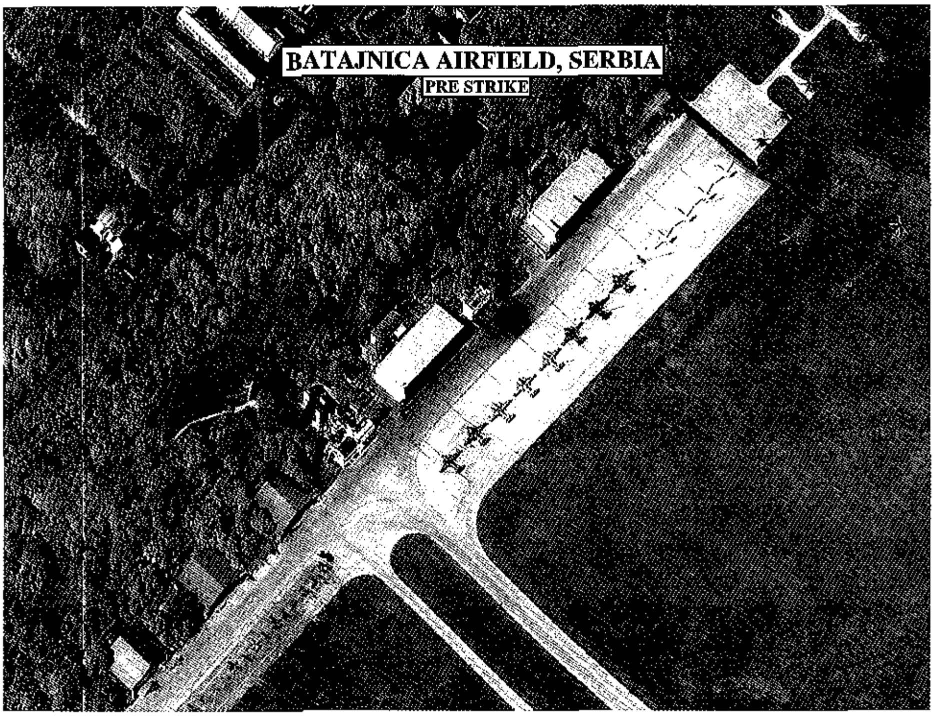

Figure 10.1 Batajnica Airfield, Serbia, Showing Undispersed Aircraft (NATO Photograph)

There are four basic forms of dispersal: rearward dispersal, horizontal dispersal, on-base dispersal and mixed force dispersal.

Rearward Dispersal

Rearward dispersal (also called vertical dispersal) entails keeping as many assets out of the forward theatre as possible. As a general rule, only those aircraft and support assets that must be placed in vulnerable locations should be. Placing these assets in safer rear echelon locations reduces their exposure to attack and reduces the defence requirement of the airbase.

Rearward dispersal can be most easily applied to larger aircraft with long range. Aerial refuelling tankers, airborne early warning and control platforms and transport and maritime patrol aircraft can all be rearward based and should spend the minimum possible time on the ground in forward locations.

The primary disadvantage of rearward dispersal is that it places the aircraft further from the operating areas, reducing their responsiveness to tasking and their mission endurance once they reach the battle space. During July of 1950, General Timberlake, Deputy Commander of the US Fifth Air Force in Korea noted that '[o]ne F-51 adequately supported and fought from Taegu Airfield [Korea] is equivalent to four F-80s based on Kyushu [Japan]'.[14] The F-80 was obviously technically superior to the Mustang, but in the absence of suitable airfields on the peninsula it was better to have F-51s nearby.

Rearward basing of aircraft has two other disadvantages, reduced sortie rates and increased wear-and-tear on aircraft. Operating from a rearward Main Operating Base (MOB) will obviously increase the transit times to and from the area of operations, ultimately reducing the number of missions that can be flown in any given period. This increased flying time can also increase the amount of maintenance that must be performed between missions, further reducing potential sortie rates. In some ways this may be offset by the generally superior level of support services that can be made available in a rearward MOB.

Despite these disadvantages US forces commonly rearward disperse valuable and vulnerable aircraft. During the Vietnam war large aircraft were based in Guam and Loas, during Korea they flew from Japan, and during the 1991 Gulf War aircraft were flown from England, Turkey, Diego Garcia, and the Continental USA.

Horizontal Dispersal

Horizontal dispersal entails the distribution of air power assets from a single or a few MOBs to a larger number of airbases within the same theatre. These can either be a number of MOBs, or a number of MOBs each supported by several dispersed operating locations.

The aim of horizontal dispersal is to increases the number of airbases the enemy must attack to destroy a given number of aircraft. By reducing the number of friendly aircraft on each base it also reduces the benefit (in terms of assets destroyed) which the enemy can hope to achieve from each individual attack. This reduces the attractiveness of the attack and can dissuade the enemy from attempting it. Going back to the principles of active air defence — the aim is not to destroy enemy aircraft but to prevent damage to your own capability. Dissuading the enemy from attacking at all can be seen as the ultimate success of any defence measure.

Horizontal dispersal to a number of airbases within a theatre provides benefits in that each airbase can benefit from the mutual support provided by the others. Defensive assets from nearby supporting bases may be employed to counter attacks on neighbouring bases. Additionally, without highly effective real time intelligence it is difficult for the potential attacker to predict accurately what will be found to target on each attack.

[14] Futrell, Robert F., *The United States Air Force in Korea,* Duell, Sloan and Pearce, New York, 1961, p 89.

There is one major potential flaw with dispersal, horizontal dispersal in particular. By spreading air assets over a number of bases not only are the number of bases that the enemy must attack increased, so are the number of bases that require defence. This can be expensive and through dilution of defences may actually be to the attacker's advantage in some scenarios.

Horizontal dispersal can also cause many logistics problems. Spreading aircraft over the theatre of operations can make logistic support very difficult, particularly if the distances between the operating bases are large. The requirement to provide specialist logistic, maintenance and personnel support to these dispersed locations may heavily tax in-theatre transport assets. Similarly, the ability to deliver the right types and quantities of ordnance, technical spares and specialist equipment to the dispersed locations will require a very capable logistic support system.[15]

During times of peace, when cost minimisation is paramount, many air forces will tend to aggregate their aircraft onto a small number of MOBs to reduce support costs. An alternative to the permanent use of dispersed operating locations is the establishment of full MOBs in the rear and a number or austere operating airfields closer to the area of operations. Aircraft would be based at the MOB in the rear, relatively safe from enemy attack, and attended by a full range of support services. During each combat period (day or night) these aircraft would stage from the forward location, using it only for re-arming, re-fuelling and crew rest and rebriefing. This system has the potential to provide increased sortie rates compared to operations strictly from a rearward location. However, the forward airfield will still require defence and support, although it does provide another option.

Dispersing aircraft of the same type, or from the same units to different bases can also complicate operational planning. Mission planning and coordination of strike groups composed of aircraft from different locations can be difficult and again require a very capable command and control system. This system would need to support remote mission planning, mission briefing, intelligence dissemination and remote debriefing.

Three major factors affect the ability of air forces to employ horizontal dispersal:

- The design of the aircraft themselves. Some aircraft require significant ground support, whilst others are more suited to operations from austere dispersed locations.

- Dispersed operations are expensive in terms of support equipment requirements, manpower and logistic support. Only air forces with suitable quantities of this equipment and a large multi-skilled support force can support sustained dispersed operations. Ground defence requirements need to be considered here as well.

- The availability of suitable airfields to which forces can be dispersed.

[15] Stillion, J. and Orletsky, D., *Airbase Vulnerability to Conventional Cruise Missile and Ballistic Missile Attacks,* RAND Corporation, Santa Monica, 1999, pp 39-40.

A modification of the horizontal dispersal theory is the launch-on-warning concept whereby all serviceable aircraft are launched when a potential attack on that airbase is detected. This method can reduce the ongoing costs of dispersal in the period prior to the conflict, but once joined can entail significant costs and difficulties. The short warning times prior to attack provided by modern attack aircraft, or the use of long range stand-off weapons, make this method difficult to implement and such high levels of aircraft and crew readiness are expensive to sustain for any period of time.

On-Base Dispersal

On-base dispersal provides many of the advantages of horizontal dispersal and can avoid some of the pitfalls. On base dispersal entails the distribution of critical assets so that single weapon strikes, even area cluster type weapons, will not inflict damage on more that one asset at a time. Further to this, the dispersal should ideally be done in a manner which will prevent a single attacking aircraft or ground party from being able to direct weapons against any more than the fewest possible assets.

On base dispersal should be applied to more than aircraft. All assets important to the conduct of airbase operations should be protectively dispersed.

Perhaps the ultimate form of on-base dispersal is the creation of individual aircraft support stations. These are hardened positions dispersed around the airbase, each holding an individual aircraft or pair of aircraft. In addition to each aircraft each weapon support station has facility to:

- Store sufficient ordnance and fuel for the next weapon load.
- Communicate securely with the relevant command centres.
- Perform an appropriate level of first line maintenance.
- Generate its own electricity requirements.
- Provide protective accommodation for the crew and support personnel assigned to that aircraft.
- Provide close protective positions for ground defence to be manned by either permanent ground defence personnel or the positions own staff.

The principal disadvantage of on-base dispersal is the increased support and ground defence requirement. Where aircraft and other critical assets are placed together, such as on the traditional aircraft 'flight line', communication and movement between aircraft is easy, and Ground Support Equipment (GSE) can be moved quickly from aircraft to aircraft. By spreading aircraft out over a large area it makes this more difficult and imposes a considerable overhead in terms of extra GSE, transport, on-base communications and, as already stated, ground defence. For this reason it is important that assets are dispersed in a well thought out manner, with consideration given to the weapons the dispersal is designed to protect against. Ad-hoc dispersal during conflict can also create difficulties unless the additional infrastructure and stocks of support equipment are available prior to the decision to disperse being made. This lack of preparation caused considerable difficulties for the RAF Fighter Command as they implemented a hasty dispersal program during the Battle of Britain to protect their aircraft on the ground.[16] They lacked bulldozers to create dispersed revetments, vehicles to drive crews around large open bases and communications equipment to link these physically separated facilities. Although, in contemporary and future conflicts the physical requirements of a dispersal program may be different the challenges for the unprepared commander will be no less.[17]

Figure 10.2 A Typical Deployable Shelter
(Photograph courtesy Universal Fabric Structures)

Dispersal may be best achieved when it is well planned in advance. The construction of as many revetted areas as possible around the airbase provide the Commander with flexibility when determining where to place aircraft and personnel. The creation of these revetments early in the construction phase of the airbase will also allow the best use to be made of natural vegetation to provide camouflage from aerial or space-based reconnaissance. If desired, the shelters can also be fitted with a heavy or light roof, or deployable shelters can be pre-positioned for erection when required. Each revetted position can then be equipped with land-line communications, some form of lighting

[16] Cooling, *Case Studies in the Achievement of Air Superiority*, p 140.
[17] *Ibid.*, p 620.

and power, ablutions making them available for a wide variety of uses. If covered by some form of roof and well protected by appropriate vegetation some can be used as hangars, others as storage, accommodation, command centres or left empty and it will be very difficult for an adversary to know which is which. This would dramatically complicate the targeting process. Figure 10.2 shows a typical deployable shelter, which could be quickly erected in pre-built revetments to form multi-purpose dispersed work areas or aircraft hangars.

Scale of Dispersal

The principal aim of dispersal is to ensure the minimum number of important assets can be targeted or destroyed with a given number of weapons. As discussed above, dispersal can also have disadvantages, including dilution of defences and increases in construction and support costs. Accordingly, where assets are to be dispersed, this should be done in a manner which maximises the advantages whilst minimising the disadvantages.

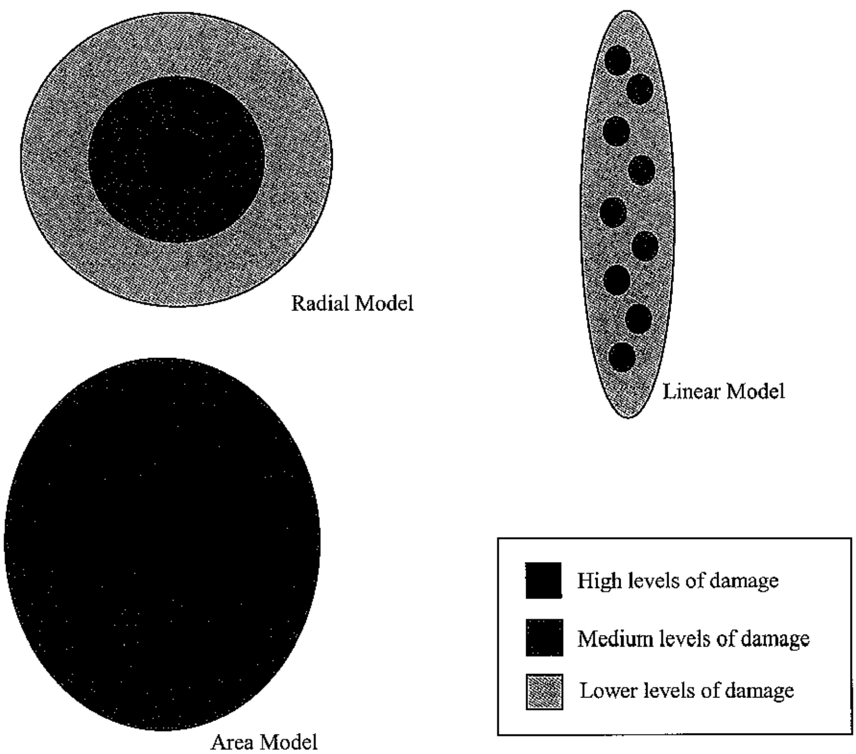

Figure 10.3 Simple Template Models used to Simulate Warhead Types

The first step in achieving this aim is to identify the characteristics of the threat weapon systems and identify the appropriate damage templates. Assets are then positioned so that the minimum number can be covered by a single weapon template. Three principal template models can be used to undertake this design process — the radial, the linear and the area template. Figure 10.3 shows these templates diagrammatically.

The Radial Model. The radial model is used to simulate point warheads such as unitary bombs and missiles. It is characterised by a circular blast and fragmentation template, with the level of damage decreasing with distance from the impact point.

The Linear Model. The linear model is used to simulate sticks of bombs or aircraft strafing attacks. It is characterised by a pattern of damage in line with the attack path. Within the damage template may be individual warhead detonation points. Linear warhead templates can be characterised by their length and width. Accordingly, assets to be protected from this threat should be arranged so that no more that three assets can be covered by a single template. (Given the length of some weapon templates, it would normally be unfeasible to prevent the simultaneous targeting of two assets.) Accordingly, where two assets are separated by a distance less than the length of the threat template, no third asset should be positioned between them, unless it is offset by more than the template width. Figure 10.4 clearly shows the linear model being applied in practice by sticks of bombs across the runways at Serbia's Sjenica Airbase during Operation *Allied Force.*

Figure 10.4 Linear Damage Model Demonstrated by Sticks of Bombs (NATO Photograph)

The Area Model. The area model is used to simulate area weapons such as cluster weapons, chemical weapons or fuel-air explosives. This template is characterised by a large area of moderate damage. The shape of the area model template may be circular or an irregular shape, depending upon the specific weapon design. Countering the area model is simply a case of separating critical facilities by a distance in excess of the applicable warhead template's longest dimension.

By deriving the expected types and sizes of warhead models applicable in each threat environment assets can then be positioned to ensure the minimum number will be exposed to each strike. Once these minimum separation criteria have been established other constraints such as the provision of engineering services then also should be considered. Another important factor is the appearance of the facilities from the air. Regular spacings and patterns will aid recognition of the targets from the air and should be avoided.

Facility Orientation

When planning facility dispersal it is also important to consider the orientation and arrangement of the assets. Many facilities will have specific features or visible characteristics that can be utilised as either aim or identification points or weak-points for attack. The doors on typical Hardened Aircraft Shelters (HAS) are a good example. When attacking a substantial HAS the attacker may choose to use the doors as the weapon aim point as they are the weakest part of the structure. They may also be the only part of the structure vulnerable to direct fired ground weapons, such as anti-armour rockets. They are also easy to distinguish and have a high contrast to the surrounding earth or concrete. Accordingly, weapons utilising electro-optical guidance (refer Chapter Three) may be aimed at the doors.

Therefore, when designing the layout for these facilities it is beneficial if the doors of neighbouring HASs are faced in different directions, making it difficult for a single attacking aircraft or direct fired weapon to engage more than one building in a single pass.

WHEN DISPERSING FACILITIES IT IS NOT ONLY IMPORTANT TO CONSIDER THEIR LOCATION, BUT ALSO THEIR ORIENTATION.

Mixed Force Dispersal

Mixed force dispersal has a slightly different thrust than the other forms and aims at preventing the destruction of any one form of asset rather than limiting the damage caused overall. Mixed force dispersal requires that the whole number of any one asset is not placed in the same place. To do this would require the placement of some fighter, some bombers, some AWACs etc at each base instead of all like aircraft at a single place. However, as in the case of horizontal dispersal this can also cause greatly increased logistic support costs.

SUMMARY

Dispersal is one of the most basic military principles and has been used for centuries to complicate the process of attacking more that a single target with any one weapon. In an age of increased weapon lethality and targeting accuracy this is now more important than ever. On a geographically fixed and strategically vital target such as an airbase it is essential. Dispersal provides a very effective method of protecting aircraft and their supporting assets. It simultaneously reduces the ability of the enemy to find targets and their ability to attack them with any economy of force. Small to medium sized air forces or small parties of Special Forces will find it very difficult to achieve significant results against an airbase that effectively employs these concepts.

Redundancy allows the airbase to continue to operate despite having suffered attrition. It is an effective defence mechanism against an enemy who will almost always seek out targets that are not only vulnerable, but also critical. The operational output of an airbase is the sum of the inputs provided by a large number of contributors. The removal of any of these contributing elements can jeopardise the whole. Redundancy provides the capability to replace damaged elements and thus maintain the output of the whole.

Redundancy, unlike most other forms of passive defence, can, when well designed and applied, actually improve the operating efficiency and effectiveness of an airbase. Multiple support systems and redundant facilities provide flexibility in operation. In addition to the defensive and operability benefits provided, this additional flexibility can be exploited as a force multiplier for peacetime capability maintenance and in support of offensive operations.

However, like all operability enhancements redundancy and dispersal carry a cost. Those imposed by redundancy are the initial and ongoing costs of the secondary systems and are fairly easy to determine. It is a popular misconception that dispersal can be achieved once the conflict is underway. Aircraft require extensive ground support, and cannot be dispersed into unprepared positions without appropriate ground support or they will be unable to complete their assigned missions. The dispersal points must be prepared and sufficient equipment and manpower available to support dispersed operations. RAF Fighter Command faced this problem when they were forced to disperse their operations during the Battle of Britain. It is also apparent in the history of attacks on airbases that surprise is a consistent factor, with many conflicts opening in this manner. Consequently, to disperse once conflict is joined may be too late.

CHAPTER 11

Recovery

From now on we expected the worst. We had to work well and work fast. IAF aircraft had to land, and the runway was a ruin. We had no damage-control unit, since it was made up of reservists who had not been called up.[1]

INTRODUCTION

To launch and recover aircraft capable of fulfilling their assigned tasks is normally the primary and most immediate mission of the airbase. If this ability is degraded by an attack or other threat, a repair capability will be required. Often the airbase's own aircraft will be its primary defence against air attack and the inability to launch them will make the base vulnerable to further attack. 'To have command of the air means to be in a position to prevent the enemy from flying while retaining the ability to fly oneself.'[2]

The visible ability to conduct these repairs can also serve as a deterrent to attacks, for it reduces the duration and severity of any disruption that can be expected from any given attack. An attack on the airbase will be then less attractive as the potential result will be less

Accordingly, each airbase should have a capability not only to defend itself from attack, but also to repair any damage that may occur. The damage could include such things as holes in the runway surfaces, damage to essential services, or chemical contamination of vital facilities. To conduct recovery operations effectively two essential components are required — suitable assets to conduct the recovery operation and an effective post-attack recovery plan. The aim of this chapter is to discuss both these elements.

AIRBASE RECOVERY ASSETS

All airbase personnel have an important role to play in the post-attack environment. However, there are six specific groups of people who, with their supporting

[1] Cohen, E., *Israel's Best Defence,* Airlife Publishing Ltd, Shrewsbury, 1994, p 329.
[2] Douhet, G., *Command of the Air,* Coward-McCann, New York, 1942, p 24.

equipment, have a highly specialised role and require more detailed mention. These are:

- a Post-Attack Recovery Command Cell (PARCC);
- Airfield Engineering (AE);
- Explosive Ordnance Disposal (EOD);
- Aircraft Battle Damage Repair (ABDR);
- ground defence and security, including a Nuclear, Biological and Chemical (NBC) decontamination capability; and
- emergency services.

Training for these personnel, as for all staff deployed to an operational airbase, is divided between individual and collective training. They must master their individual trade skills to a level that will allow them to operate in the demanding and unique post-attack environment. Once this is achieved they need to learn to work together and develop a thorough appreciation of each other's requirements. Time constraints during recovery operation will place a premium on concurrent activities forcing each element to work with each other. Any group with the attitude that their task is the most important, and that all else can wait until they have finished will compromise the ability of the airbase as a whole to regenerate. An example would be the personnel tasked with chemical decontamination expecting everyone else to remain in shelters until they have finished their survey or clearance operations. This is time consuming and it would be essential that other recovery personnel such as AE/EOD be capable of operating in the potentially contaminated environment so they can begin their tasks immediately.

As with all airbase contingency support assets, post-attack recovery personnel may need to be deployable to advanced airfields to prepare them for use as major airheads. This may require the ability to deploy with equipment by parachute to prepare damaged or retrograde airfields for follow-on insertions.

Post-Attack Recovery Command Cell

Post-Attack Recovery (PAR) operations are likely to be conducted with limited resources, under great stress, and with severe time constraints. Accordingly, these activities should be centrally controlled to ensure that resources are best used, and the priorities for repair are appropriately managed. To do this a PARCC should be established within the Base Command Centre (BCC). This will enable:

- Coordination with ground defence and airbase ground and flying operations.
- Immediate interaction with the base commander, ensuring that recovery priorities are decided at the appropriate level and are mandated by airpower requirements.

- Access to other C3I facilities and feeds.

Furthermore, the post-attack airfield environment is also a very hazardous one. Some of the threats that may be encountered include:

- Further air or ground attacks;
- Nuclear, chemical or biological contamination;
- Unexploded Explosive Ordnance (UXO), including those with long delay or anti-disturbance fusing;
- The risk of friendly fire or fratricide;
- Dangers posed by fires including burning fuel or ordnance, the collapse of damaged structures or exposed electrical services etc; and
- The normal hazards associated with operating airfields, particularly on one involved in actual combat sortie generation.

Centralised control of assets assigned to the task of post-attack recovery will help protect them from some of these dangers and maximise effective communication between the involved parties. A typical airbase post-attack recovery command centre structure is shown at Figure 11.1. This structure is not prescriptive, because there are many different ways of structuring or organising these assets. Figure 11.1 also does not include other typical occupants of an airbase command centre such as air liaison, airfield services, ground based air defence command/liaison, chaplaincy/welfare/discipline, legal and intelligence services. Accordingly, the structure shown is strictly conceptual rather than representing individual positions or command linkages. Given the variety of systems employed around the world, recommending specific structures is beyond the scope of this book.

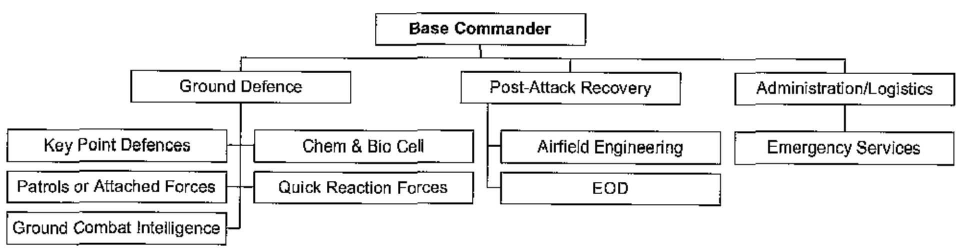

Figure 11.1 Conceptual Base Ground Command Centre Structure

Of importance is the placement of these services in a single location to allow maximum communication and information fusion between them. PAR must talk with ground defence who must talk with admin/log to ensure the recovery process is a single coordinated activity. Command of PAR and ground defence may be placed within a single cell, but this has the potential to dilute the ability of both areas to achieve their tasks due to the widely disparate skill sets being employed. Irrespective of how these relationships are managed each air force must develop clear doctrine on command and control of ground forces. Typically, these structures will need to be flexible and some specialist personnel such as AE tradesmen may be managed by a logistics cell during normal operations and then transferred to PARCC command if attack appears imminent.

The movement of PAR teams (AE/EOD) and emergency services on the airfield must be approved by the ground defence command cell to ensure they are not subject to enemy or friendly ground fire. Similarly, the movement of emergency services, patrols or reaction forces in the post-attack environment must be approved by the PARCC to ensure they are not exposed to dangers from UXO etc. This is an example of how much these groups must communicate with other.

Each Air Force will develop its own specific structure for control of PAR. It will depend upon a large number of factors, but will be mainly determined by the existing command and organisational structures of the functional areas responsible for PAR activities. The terminology used to describe the PARCC is equally diverse and can be referred to as the Airfield Damage Repair (ADR) cell, the Combat Operations Centre (COC), the War Operations Centre (WOC) or Damage Control Centre (DCC)

Communications and Information Systems

Communications between deployed airfield recovery assets and the PARCC is a key factor in the potential success of the operation. The requirements for airbase information systems presented in Chapter Seven should be applied rigorously to PAR information systems. The three most crucial requirements are security, survivability and priority.

Security. Information transferred between the deployed PAR assets and the PARCC can be highly sensitive, and secure means of communication should be available. The status reports passed from the deployed teams to the PARCC are of critical importance. This information can immediately reveal the residual capability of the airfield and the success or otherwise of the preceding attacks. Information passed from the PARCC to the deployed EOD teams may contain classified procedures for the render-safe[3] or disposal of unexploded ordnance. It may also include detailed references to airfield services and fittings that can provide important intelligence information to an adversary. This information must be denied to the enemy.

Survivability. The requirement for survivability in any information system serving the PAR effort should be self-evident. Damage from the initial attack may have disrupted power supplies and could have destroyed or isolated the primary Base Command Centre (BCC). Accordingly, radios and data systems used during PAR

[3] Render-safe is an EOD term referring to the manipulation of a piece of unexploded ordnance to prevent it from functioning as designed.

should be capable of operating in degraded environments without infrastructure support.

Priority. A vast amount of information will flow into and out of the BCC during the PAR. Much of this may be administrative or deal with the coordination and deployment of ground defence assets. Mixed in with this vast amount of data will be time-critical information such as the initial reports from the airfield surface reconnaissance teams. Systems and processes should be established to ensure that this time-critical data is not delayed or hidden by larger quantities of administrative communications traffic.

Airfield Engineering

AE personnel represent a broad range of disciplines centred on the civil engineering, construction and building trades. Typical skill sets present within an airbase AE organisation should include:

- **Professional Staff.** Civil engineers and personnel qualified and authorised to certify hasty repairs as safe for use.
- **Tradesmen.** Electricians, plumbers, carpenters and other tradesmen capable of undertaking the repair tasks and supervising unskilled labour where this is utilised.
- **Plant operators.** Personnel qualified to operate and trouble-shoot generating equipment, mobile plant and other mechanised or motorised equipment.

To conduct PAR tasks effectively these personnel should be provided with specialist equipment. Such assets could include:

- Tracked or wheeled excavators for removing debris from craters and lifting sections of broken pavement.
- Front-end loaders, capable of moving large quantities of fill and placing it into deep wide craters.
- Graders.
- Dump trucks.
- Concrete cutting equipment to remove sections of damaged pavement.
- Runway sweepers.
- Wheeled hydraulic compacters for tamping filled craters. Vibratory rollers can be difficult to manoeuvre into a crater and hand-held compacters may not provide sufficient compaction.
- Grout mixing and pumping vehicles.

- Vehicles to load and transport bomb damage repair mats.
- Portable lighting or marking systems to indicate cleared taxi-ways, pathways and safe routes.

Given the risk that anti-personnel or area denial bomblets or mines may be located in the debris, the damage repair task can be quite dangerous. Where possible, equipment should be capable of remote operation or be armoured to provide the operator with a degree of physical protection. The US Air Force Engineering and Services Centre (AFESC) have developed a multi-purpose remotely controlled excavator, based on a John Deere JD690, that can undertake many crater repair tasks whilst the operator remains in a safe location.[4]

Other specialised plant is available to dispose of large quantities of UXO from the Aircraft Operating Surfaces (AOS). This is designed to remove the UXO either by detonating it, or pushing it from the AOS, whilst providing physical protection for the driver and to its own critical components. One such product is the Ahlmann Baumaschinen AS200, a modified swing shovel loader claimed to be able to clear an area of 15,000 m^2 in one hour. The crew of two are protected by an armoured cockpit which is claimed to be proof against 5.56 and 7.62 millimetre armour-piercing ammunition as well as anti-personnel mines of up to two kilogram TNT equivalent explosive weight.[5] As with any form of mechanised bulk UXO clearance equipment it may still be vulnerable to large UXO or from attack by ground forces, such as a Special Forces team equipped with an anti-materiel or light anti-armour weapon.

In addition to this plant a large quantity of material needs to be available to conduct repairs and fill craters. As an example of the scale of this requirement, a single 750 pound bomb crater displaces approximately 400 cubic yards of debris. Even when this debris is back filled into the crater, nearly 150 cubic yards of additional fill is required to repair it completely.[6] This occurs because of the degree to which earth is scattered beyond recovery during the explosion.

Such a large amount of debris scatter will also cause a large amount of foreign material, referred to as Foreign Object Damage (FOD), to litter the AOS. This material, a combination of dirt, debris and fragments of ordnance, can be ingested by jet engines and cause severe damage. The requirement to clean this material from the AOS in use before being trafficked by jet aircraft will require motorised sweeping equipment. This equipment should be capable of operation at night under black-out conditions. The requirement for AOS sweepers to operate in a very predictable, exposed and isolated manner can make them easy targets for hit and run ground attacks.

---

[4] Alexander, E.F., 'Advancing Towards RRR Robotics', *The Military Engineer,* August, 1990, pp 48-50.
[5] Industrial Focus, *Military Technology,* December, 1999, p 53.
[6] Groat, G.L., Gilette, J.E., and Barber, V.C., 'Airfield Damage Repair', *Engineer,* Summer, 1986, p 27.

In addition to repairing damage to pavement surfaces, AE personnel will be required to undertake a wide range of temporary and permanent repairs to other airfield structures and services. These may include electricity supplies, data and communications cabling, water and waste services and lighting systems. Consequently, flexibility is the key to providing an AE capability that can perform this very broad range of PAR functions at an affordable cost. Highly trained engineers, tradesmen and operators who can undertake these tasks in a stressful and unusual environment are essential.

Explosive Ordnance Disposal

Effect of UXO on Air Operations

UXO can be extremely effective in disrupting air operations. UXO that has been caused by fusing malfunction can be highly sensitive and may detonate at the slightest disturbance. Areas contaminated with UXO must be cordoned off and entry by personnel, aircraft or machinery prohibited. However, the most disruptive UXO are those fused deliberately to remain unexploded after deployment. These weapons, referred to as area denial weapons, may combine random delay and sensitive anti-disturbance/influence fusing to hinder removal attempts and prevent movement near the ordnance or within its danger template.

Removal of the UXO threat is a function of Explosive Ordnance Disposal (EOD) personnel. EOD is defined as the detection, identification, field evaluation, rendering safe, recovery and final disposal of Explosive Ordnance (EO) when the disposal of such EO is beyond the capabilities of personnel normally assigned the responsibility for routine disposal.[7]

Why Airbases Are a Unique Environment for EOD

Airbases represent a unique environment for the conduct of EOD operations. EOD assets deployed to protect airbases from interdiction by UXO will face unique challenges not experienced outside that environment. The reasons for this include:

High Value Target. A modern airbase represents a strategically significant target, which if negated provides a substantial advantage to the attacker. For this reason airbases may be targeted more heavily than other facilities, and with the best weapons available to the opposing force. This likely to increase the quantity and quality of UXO encountered in what is a relatively small area.

Airbases are a Large Geographically Fixed Target. The airbase, and many of its vital component parts, are large immovable targets. This makes them easy to target from a variety of platforms, including direct attack munitions, stand-off munitions, unguided rockets, infantry weapons and Special Forces. This will increase both the concentration and variety of UXO likely to remain after an attack.

---

[7] Department of Defence, *Australian Defence Force Publication 56 Explosive Ordnance Disposal*, 1996.

Air Operations are Time Critical. Any delay in generating air missions is unacceptable in that it results in a significant reduction in the military capability. Modern combat air operations occur with a high tempo during both day and night, and in inclement weather. When an airfield is contaminated by UXO the first priority is to restore operational capability. EOD assets must be available to the airbase immediately an attack has ceased. Additionally, the primary defence of an airbase is often its own air power. Interdiction of air operations by UXO reduces the self-defence capability of the base, making it more susceptible to further attack.

Airbases are a Crowded and Busy Environment. During operations modern airbases are teeming with movement 24 hours a day. EOD operations conducted in this environment present a serious risk to personnel and equipment in the vicinity of the UXO. Additionally, many of the airbase activities are potentially hazardous to those around them, for example jet aircraft taxiing. EOD personnel must be trained in these hazards and be familiar with the nature of airbase operations to minimise the risk to themselves and others.

The Vulnerability of Airbase Operations to Interdiction by UXO. Although a high degree of redundancy normally exists in aircraft pavements, the soft nature of many of the airbase components make them ideal targets for area denial weapons such as cluster munitions and persistent chemical agents. These weapons are difficult to render safe and present a higher than normal level of risk to EOD personnel and can effectively prevent movement and operations in a large area. Many of the targets within airbases, such as fuel and ordnance storage, can be intrinsically hazardous themselves, further complicating the EOD mission. For these reasons, casualties amongst airfield EOD personnel can be expected to be higher than typical amongst other ground personnel.

Airbase Design Features. Airbases that lack effective passive defensive measures increase the likelihood that UXO will be located within areas of critical importance. UXO in these locations can usually not be detonated in situ, but must be made safe using a variety of controlled techniques. This can be time consuming and potentially dangerous.

Aircraft Battle Damage Repair (ABDR) EOD. The types of ordnance likely to be fired at aircraft are typically difficult to render safe and require specialist EOD resources to be available.

EOD Equipment Requirements

Forces allocated to post-attack airfield EOD must be capable of undertaking this task quickly in all weather and lighting conditions. In order to undertake this mission the assigned assets should be provided with specialist equipment as follows:

- **Helicopter support.** Airfield reconnaissance is most effectively undertaken initially by helicopter. This acts as a force multiplier for small numbers of EOD personnel and will identify the bases residual capability in the shortest possible time frame. The use of helicopter to conduct PAR can also reduce the vulnerability of personnel to UXO on the airfield surface.

- **Remote Fuse Removal and Render-safe Equipment.** A variety of equipment designed to render safe ordnance. This includes personal body armour, NBC protective ensemble and a variety of specialist tools.

- **Stand-off Munition Disruption (SMUD) Equipment.** During high intensity, high category, the traditional EOD operations that allocate one bomb to an individual who renders it safe using manual techniques may be too slow to meet clearance time constraints.[8] Additionally, the EOD personnel are directly exposed to the UXO whilst conducting the hands-on procedures. SMUD refers to the use of large calibre small arm gunfire to destroy, initiate or deflagrate UXO from a safe distance. This technique is particularly useful when sub-munitions or area denial munitions have been used to make large areas dangerous to enter. SMUD can allow the rapid disposal or immunisation of multiple UXO items with minimal exposure of the EOD personnel.

Figure 11.2 EOD Operator Wearing Bomb Disposal Suit (Photograph courtesy RAAF EOD Flight)

[8] US Navy EODB 60A-2-1-39 Rapid Clearance of UXO from Airbases, 15 June 1987.

- **Armoured Vehicles.** Armoured vehicles are used to conduct reconnaissance and allow EOD teams to approach UXO with a degree of physical protection. Airfields provide almost no physical protection to exposed personnel making operating inside the danger template of UXO particularly hazardous. Armoured vehicles equipped with scraper blades can be a time effective method of clearing some sub-munitions, although some sub-munitions are specifically designed to defeat this approach.

- **Technical data.** Technical data on threat weapon systems must be available. This needs to be sourced by defence intelligence agencies prior to the conflict. This data must be promptly available to the EOD teams at all times in deployed locations.

- **Night Vision Equipment.** To support constant operations the EOD forces must be capable of operating at night under total or partial blackout conditions. To achieve this they must be supplied with, and adequately trained on, night vision equipment.

Ground Defence and Security

The principal tasks of ground defence and security personnel during the post-attack recovery operation can include:

- Conducting clearance operations to locate and remove enemy forces that may have infiltrated into the airbase Airfield Approach Zone (AAZ).

- Supervising and assisting in searches for UXO, fires and damage within their assigned areas of responsibilities.

- Preparing for and conducting on-going airbase ground defence operations.

- Assisting in emergency service functions, including the provision of support to fire fighting, medical, rescue and facility repair personnel.

- Conducting Nuclear, Biological or Chemical (NBC) survey, assessment and decontamination. This will include items such as:

    - Equipment to detect and identify chemical or biological contaminants.

    - Bulk quantities of decontaminating agents such as DS2 or Super Tropical Bleach.

    - Bulk quantities of absorbent material (activated charcoal etc) and packaging equipment.

    - Equipment to dispense decontaminating agent suitable for use on personnel, equipment, facilities and aircraft.

- Providing close protection for specialist personnel, VIPs or other high value groups.

Aircraft Battle Damage Repair

Aircraft returning from combat operations may have been damaged and require repair. This function will normally be provided by personnel from the aircraft's unit and is beyond the scope of this study. The EOD aspects of ABDR have been covered in the EOD section of this chapter.

Emergency Services

Airbase emergency services encompass a broad range of personnel with responsibilities during the normal operation of the airbase as well as during the post-attack recovery process. Airbase emergency services can include the following:

- Fire fighting and rescue;
- Medical services; and
- Environmental health services.

Specific skills required of these assets in the post-attack environment include:

- Capability to clean up toxic spills.
- Aircraft crash/accident recovery and rescue.
- Fighting fires in facilities and buildings, including hardened or buried facilities.
- Fighting fires in hazardous materials such as explosive ordnance, exotic aircraft metals or composites, or fuel.
- The ability to provide specialist advice during repairs to water and sewerage systems, and the provision of safe drinking water if the primary supply is severed.
- Assisting in the analysis and decontamination of biological and chemical weapons.

Fire fighting, rescue and medical services may be required to operate in a non-benign ground environment. This is particularly the case where friendly aircraft may crash or crash-land near, but not on, the airfield. This is verging on a combat search-and-rescue capability. Although Law of Armed Conflict (LOAC) considerations give some degree of protection to emergency services personnel, careful planning must be given to the deployment of these services outside the defended area. Firstly, not all potential adversaries respect the same LOAC considerations and secondly, even if they do, accidents still occur which could result in the rescue party being engaged by the enemy.

Figure 11.3 A Fully Encapsulated Suit for Use during Toxic Chemical Clean-up Operations (RAAF Photograph)

AIRBASE RECOVERY OPERATIONS

Introduction

Actions on an airbase following an enemy attack will need to be undertaken with the utmost urgency. The speed at which modern air operations are conducted will dictate that any damage to the airbase is assessed, and if necessary, repaired in the minimum amount of time feasible. *Ad hoc* recovery plans and the attitude that 'we will cross that bridge when we come to it' will ensure that any recovery operation is sufficiently slow to hinder air operations seriously in that theatre.

> The importance of recovery efforts to operation of an airbase and the base's continued use by a flying force was soon emphasised. After devastating raids during the Battle of Britain, the RAF restored several of its bases to operation only through the most exemplary efforts of leadership and diligence. Fighters could operate largely because of the repeated efforts of military and civilian crews who repaired bomb damage. Elsewhere, American and Japanese

commanders in the Solomon Islands went to great lengths to repair bomb damage and keep airfields serviceable. The Americans succeeded at Guadalcanal; the Japanese lost at Munda and had to abandon their important airfield there.[9]

The Post-Attack Recovery Sequence

When developing a post-attack recovery sequence different sources emphasise those activities they believe to be more urgent than all others. At any airbase that has been attacked there will be uncounted numbers of tasks which will all be crucially important and urgent.

The following list is one possible order in which activities should be undertaken.

- Clearance to move.
  - Verification that hostile forces have been cleared from the airfield.
  - Verification of airfield ground defence and NBC status.
- Post-Attack Reconnaissance.
  - Determination of safety of unit command centres.
  - Further (more thorough) determination of airfield NBC status.
  - Determination of residual airfield capability.
  - Determination of nature and type of ordnance used, UXO or chemical weapons.
  - Determination of casualties and fires.
- Restoration of Aircraft Operating Surfaces.
  - Evaluation of AOS damage.
  - Determination, surface clearance and relocation and promulgation of new MOS, if one immediately available.
  - Render safe of immediate UXO threats on or near MOS.
  - Determination, relocation and promulgation of new MAOS, if one immediately available.
  - Render safe of immediate UXO threats on or near MAOS.
- Protection or relocation of unit command centres.
- Restoration of essential airfield facilities and services (RESF).
  - Collection and analysis of sector or flight reporting.

[9] Kreis, J., *Air Warfare and Airbase Defence,* Office of Air Force History, Washington D.C., 1988, p 347.

    - ♦ Prioritisation of UXO and facility damage reports.
    - ♦ Decontamination of chemical or biological contamination.
- Post-attack operational intelligence collection, analysis and dissemination.
- Restoration of non-essential services.
    - ♦ Prioritisation of UXO and facility damage reports.
    - ♦ Environmental remediation.

Clearance to Move

Before the initial reconnaissance can start it must be determined if it is safe to move in the open on the airbase. Three principal threat groups exist:

- Airborne threats. Information on the possibility of air attacks (or further air attacks) will be provided by the organisation assigned local responsibility for this task. This may be the local air component command, air defence command or air traffic control etc.
- Ground force threats. Information on these threats should be available from the ground defence command cell. This information will be based on reports from fixed defensive positions, patrol reports, contact reports, ground combat intelligence assessments and the status of friendly defensive positions. When deploying personnel or vehicles around the airbase in the post-attack environment there is always a heightened risk of friendly fire incidents. This risk is particularly high at night or in the vicinity of non-professional ground combat staff who may not have well developed fire discipline. The ground force threat will also include the chemical and biological threat status of the airfield where known.
- The threat posed by unexploded ordnance, fires and damaged buildings and services.

Normally the airfield threat and combat status will be displayed on situation boards in the airbase command centre. In this manner the information is available immediately to everyone in the centre and for dissemination where required.

The Post-Attack Reconnaissance

The aim of the initial post-attack reconnaissance is to determine the effects of the enemy attack upon the airbase and allow planning for the recovery process to be undertaken on the basis of valid information. To make effective use of base recovery assets the PARCC requires full knowledge of post-attack conditions. Ideally, the initial reconnaissance and appreciation will be fully complete before active recovery operations are begun. However, this will rarely be possible due to time and resource constraints.

Following an attack there may be damage to the AOS or critical facilities, which may impact upon the ability of the airbase to fulfil its mission. Accordingly, the first aim of the reconnaissance is to determine the residual level of capability remaining at the unit, ie how capable the base is of continuing to generate, support and control air missions. This information must be relayed immediately via the BCC to the appropriate higher authority.

The aim of the post-attack reconnaissance is to determine the:

- level of residual capability at the airbase;
- location and nature of UXO;
- location of casualties and fires;
- location and nature of any chemical or biological contamination;
- location, severity and consequences of damage, and
- location and status of crashed or damaged aircraft.

Modern air operations can be conducted twenty-four hours a day and in bad weather. Accordingly, the airbase should have the capability to conduct PAR, and particularly the initial reconnaissance, during darkness and inclement weather. This would be despite military threats such as hostile NBC, electronic warfare or ground combat conditions.

Post-Attack Reconnaissance on the Aircraft Operating Surfaces

The initial reconnaissance should be undertaken on the AOS by dedicated multi-disciplinary AE/EOD teams, preferably in an armoured vehicle. This should be a rehearsed operation with the appointed team/s on stand-by in hardened, concealed or dispersed facilities before and during the attack. The status of the AOS is critical to determining the level of residual capability of the base and is to be relayed immediately to the BCC.

The first requirement of the AOS reconnaissance team is to determine the existence (or otherwise) and location of a piece of pavement suitable for immediate aircraft operation. The two principal pavement requirements are the Minimum Operating Strip (MOS) and a supporting Minimum Aircraft Operating Surface (MAOS). The MOS is the smallest area of runway required to launch and recover the types of aircraft stationed at the airbase. The MOAS consists of the MOS plus the additional pavements required to support immediate flying operations. This would include a small amount of additional taxiway to allow aircraft to enter and exit the MOS and park safely. The dimensions of the MOS and MAOS will be dependent upon the aircraft type, configuration, mission requirements and the local environmental conditions. Generally, an area 1,500 metres in length by 15 metres in width would be the minimum size useable as a MOS.

If aircraft from that airbase were airborne during the attack, and have no viable diversion airfield, the speedy determination of a MOS will prevent those aircraft from potentially being lost.

The task of identifying a useable MOS will be hastened and made safer if armoured vehicles, or ideally, a helicopter are available to the reconnaissance teams. Short delay fused weapons are likely to be functioning during the reconnaissance and little if any cover from fragmentation or blast is available on the AOS.

The dedicated AOS reconnaissance team should be able to determine accurately the nature of any UXO hazard present on the AOS. They should be capable of conducting some initial render safe or disposal action, particularly on simple sub-munitions. This may be necessary to enable the teams to reach safely parts of the airfield contaminated with these weapons. The establishment of a MOS and then MAOS is the highest priority of the recovery teams and until one is established, there will be great pressure on EOD/AE resources to clear one. Operating under time-critical conditions such as this places the PAR resources at great risk and may result in high casualties.

Off the AOS the initial reconnaissance is undertaken by personnel from the local work area under the control of the local sector commanders. Reports on the airbase condition are then forwarded through the local commanders to the BCC. These reports may be quite vague as the personnel conducting these reconnaissances will have highly limited training in UXO recognition and should be taught to be extremely circumspect when approaching or observing UXO. The reports should also include information on damage to facilities or engineering services. Again, due to lack of training these reports may be quite vague.

The use of non-EOD trained personnel to search for and to assess UXO is dangerous and should be avoided. Modern munitions may be area denial fused and may be activated by a variety of stimuli. Simply not touching or physically disturbing a piece of UXO is no longer guarantee that it will not be activated. Accordingly, all personnel should be taught to recognise basic classes of UXO and a simple set of worst-case safety precautions. Once UXO is spotted it should not be further investigated or disturbed except by fully trained EOD staff tasked by the post-attack recovery commander.

The use on non-EOD qualified personnel to search for Improvised Explosive Devices (IEDs) poses similar hazards. However, in the main, the fusing systems of IEDs are generally not as complex as those encountered in conventional military ordnance. Accordingly, some personnel with background skills in ordnance (such as ground combatants or security) may receive training in the search for IEDs. Provided these personnel fully accept the limitations of their training and are aware of the variety of dangers posed by IEDs they can be effectively employed in this role.

Aerial Post-Attack Reconnaissance

Conduct of the initial reconnaissance will be quicker and safer if a helicopter or Uninhabited Aerial Vehicle (UAV) is available to assist. Where there is a high probability of air attack upon an airbase a helicopter should be dedicated to this purpose and placed away from the base with EOD and AE qualified observers on-board. This resource should be capable of operation in darkness and during inclement weather.

Immediately following an attack upon the airbase, the helicopter can be tasked to conduct an aerial reconnaissance to identify areas of UXO and attack damage. Details of any items noted should then be delivered directly to the BCC and the helicopter returned to its ground location to await further tasking. The use of this airborne reconnaissance capability will make the deployment of ground based reconnaissance teams safer and more efficient.

When using a helicopter to assist with the reconnaissance the following considerations should be noted.

- The local air space control authority, all armed personnel and air defence assets must be briefed on the helicopter's presence and operations to prevent it from being fired upon.

- The helicopter must be flown in such a way that its rotor downwash does not buffet sub-munitions or other UXO fitted with area denial or anti-disturbance fusing. This will require the helicopter crew or UAV controller to have an understanding of the hazards posed by UXO and ideally they should be well practiced in this operation.

Plotting and Recording

Within the PARCC it is essential that systems are in place to record and manage post-attack recovery operations. A separate map and recording system should be available to enable PAR data to be recorded quickly and clearly without interfering with ground defence operations. However, both maps should be co-located and use the same grid system and symbology. This will allow close coordination of AE, EOD, fire, medical and ground defence assets.

The PAR map is used to mark damage, unexploded ordnance and unconventional weapon contamination. It should cover the entire airfield and be of a scale sufficiently small to permit plotting to within 10 metres. The following items should be marked on this map:

- Location and nature of damage.

- Location and nature of UXO.

- Location and status of post-attack recovery resources.

- Hazard templates of UXO or EOD operations being conducted.

- Location and nature of chemical contamination, including the prevailing wind direction.

- Current MOS and MAOS being used.

Prior to combat each facility on the airbase should be assessed as to its importance. Traditionally, a four level system is employed with the most critical facilities allocated an A category, the least, a D category. The pre-allocated category for each facility should then be marked on the PARCC airfield map to permit faster determination of recovery priorities. For example, AE assets would be tasked to restore electrical power to an A class facility before a B class. Pre-allocation of categories reduces the amount of time taken following the attack to generate these prioritised taskings. Obviously, these categorisations also need to be flexible and may be dependent upon changing circumstances. Using the same example, a maintenance facility for aircraft radars may be a low priority if that form of maintenance is currently not required, but may immediately become far more important if that situation changes.

EOD Operations

The primary aim of EOD personnel in the post-attack environment is not to destroy or demolish UXO, but to prevent it from detonating, a process known as rendering it safe. Once ordnance has been rendered-safe it may no longer pose a hazard to airfield operations and can often be left in-situ to be dealt with later.

The EOD task becomes one primarily of access and identification — obtaining access to buried or concealed UXO and quickly identifying it and the hazards it poses. Simply approaching some area denial UXO may cause it to detonate, so identification, and wherever possible, render-safe action, should be undertaken from a safe distance. Once identified, the appropriate render-safe action can be undertaken.

During the 1991 Gulf War attacks against the aircraft operating surfaces proved relatively unsuccessful. The use of the British JP233 system proved particularly ineffective in closing airfield surfaces for extended periods of time. The SG357 runway cratering sub-munition made holes which were cleaner than expected, and these proved easy to repair using fast setting concrete. In many cases the HB876 area denial bomblets were hosed away from critical areas with fire hoses.[10] Thus the use of a single weapon strategy for airfield attacks could have proved troublesome for the coalition and assisted the Iraqis charged with PAR tasks. In future airbase attacks where a broader range of area denial munitions were used, expedient methods such as fire hoses may not be suitable. The presence of large unitary bombs fitted with anti-disturbance or influence fusing may prevent the use of these methods.

Scope of the Post-Attack EOD Task

The generic types of ordnance that could be encountered in post-attack situations include:

Unintentional UXO. The most common form of UXO is from ordnance that, although designed to function immediately, has malfunctioned or otherwise failed to

[10] Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia,* Air Power Studies Centre, Canberra, 1992, p 154.

explode. Modern general purpose bombs have UXO rates between 1 and 10 per cent, sub-munitions between 5–30 per cent. These figures depend on the weapon design, target nature, release parameters, skill of the operator (both air and ground crews) and the age and condition of the weapons. Therefore, any conventional attack, particularly with sub-munitions, can be expected to leave UXO.

Area Denial Munitions. These weapons are designed to deny the use of a target area to the enemy for a period of time after an attack. Area denial weapons generally are GP bombs or sub-munitions with long delay and/or anti-disturbance fusing which fused to detonate at random times after deployment or when disturbed. Methods of triggering include magnetic influence, seismic, acoustic, trip wires or movement. Persistent toxic chemical agents can also be considered as area denial weapons.

Improvised Explosive Devices (IEDs). IEDs are explosive devices fabricated with a combination of commercial, homemade or military components and are commonly identified with the terrorist. During, and in the transition to conflict it can be expected that IEDs may be directed against targets of importance by domestic sympathisers or irregular forces. Airbases are high profile targets, which unless rigorously secured are vulnerable to IED attack. IEDs may be pre-positioned at the bare base before occupation, delivered by mail or cargo delivery, or emplaced by irregular or Special Forces (SF).

Special Forces Sabotage and Booby-Trap Devices. Airbases can expect to be targeted by enemy SF due to their high strategic value. These forces can place a range of conventional and improvised explosive devices in either carefully planned locations or targets of opportunity within the airbase. These devices will normally be booby-trapped and incorporate features to make their removal or render safe hazardous. The hybrid nature of these weapons makes them a difficult EOD task. SF can also employ direct and indirect fire weapons to attack airfield facilities, personnel and aircraft, which may result in a wide variety of UXO.

Ordnance Accidents. Explosive Ordnance (EO) can be easily damaged during storage, handling, preparation or loading. The accelerated pace of combat operations, relaxed safety margins and fatigue make such accidents more likely during conflict. When they occur the ordnance may be left in an indeterminate state of fusing and highly dangerous. Again EOD resources must be on hand to ensure the incident is safely and quickly resolved.

Dummy Fused Ordnance. A technique to increase the potential for area denial is the use of weapons with dummy or unarmed fusing. This increases the amount of UXO present after an attack requiring greater EOD effort to restore operations. This is particularly effective when used with unitary general-purpose bombs, which normally bury themselves and require excavation to be investigated and declared safe.

Nuclear, Chemical or Biological Weapons. Airfields are particularly attractive targets for NBC weapons as they are effective over large areas and usually have a residual area denial effect. EOD on NBC weapons is a highly specialist skill and requires proper equipment, training and exercises.

UXO Encountered During Aircraft Battle Damage Repair. Aircraft returning from combat missions may be damaged by enemy or friendly fire. Furthermore, it is also possible that aircraft may return from operations with UXO lodged within their airframes. This poses a great hazard to ABDR crews and unless safely dealt with may prevent the repair and continued operation of that aircraft. Dealing with ordnance encountered during ABDR within aircraft is a specialist EOD task and teams skilled in ABDR EOD must be available if ABDR is to be continued on aircraft with UXO on board. These skills may also need to be applied to friendly ordnance that has been damaged during a mission and could not be jettisoned.

EOD Options

Once UXO has been mapped, prioritised and identified something must finally be done about it. It is important to remember that any EOD situation can be broken into two distinct parts — removal of the hazard and disposal of the ordnance itself.

The rendering safe of EO may be defined as the breaking of the explosive train, preventing the normal functioning of the weapon. EOD has the following options and must consider the advantages and disadvantages of each before deciding on a solution. Some of these methods dispose only of the incident, others dispose of the incident (or hazard) and the ordnance simultaneously. The options are:

- **Blow in Situ.** By using an explosive charge the weapon can be detonated where it is found. This option is most often used when the item is highly movement-sensitive and is in a location that can withstand a detonation. This technique is commonly used on area-denial bomblets or smaller land-service ordnance such as grenades etc.

- **Leave.** This option is most commonly used on buried GP bombs where there is little likelihood of delay fusing.

- **Tow or carry away.** This is for ordnance where the fusing is not movement susceptible. The initial movement may be done remotely to verify that the ordnance is in fact safe to move.

- **Leave and Protect.** Ordnance with a low priority for disposal, which is located near a vulnerable or vital facility, may be left in place with some form of protective works built around it. This technique can be used on ordnance with variable delay and anti disturbance fusing where there is no time (or option) to perform a render-safe procedure.

- **Defuse or Render Safe.** This method requires the actual defusing or immunisation of the weapons fusing system. A variety of methods can be employed, each specifically tailored for a particular piece of ordnance. Sometimes this method can require delicate manipulation of the ordnance and accordingly may be a high-risk option. This method will normally be chosen when the ordnance must be removed from its location but cannot be done so with the fusing present.

- **Remove or destroy the main fill.** This is an old technique whereby the explosive fill of the weapon is either burnt or steamed away before the fuse can detonate it. Again this is a high risk operation that can be very time consuming. It is particularly used when an anti-removal fuse has been fitted. A modern development of this technique is SMUD, where precise gunfire is used to set the explosive fill burning.

Aircraft Operating Surface Repair/Reinstatement Options

It is likely that a serious attempt to attack the runways and taxiways will result in some pavement damage. This may render the normally used MOS (the normal centre line strip beginning at the threshold) unusable. The priority for pavement repair will depend upon the operational circumstances at the time. The principal determining factors will include:

- The requirement to recover aircraft already airborne.
- The requirement to launch aircraft to defend the airbase against further attack.
- The requirement to launch or stage aircraft for other operational requirements.
- The availability of airfields nearby capable of fulfilling these requirements until airbase recovery can be completed.

There are two main options available to continue aircraft operations if critical pavement areas have been damaged:

- Relocate aircraft movements to pavement areas which are undamaged, or
- Repair a sufficient amount of the damage to allow a MOS to be created.

Temporary Relocation of the Minimum Operating Strip

Where runway surfaces have been damaged it is often possible to relocate the MOS used. This will certainly be quicker than attempting repairs on the pavement surfaces to recover the original strip. Most airbases will have several useable runways as well as taxiways which can be used as runways, providing a large amount of redundant pavement to prevent the complete denial of a MOS or MAOS. If an airbase is designed in this manner it is very difficult to deprive aircraft of a MOS at least somewhere on one of the strips.

Ideally, the MOS relocation will have been pre-planned, and furthermore, its use will have been rehearsed. The MOS can be physically relocated in a number of ways. Some typical methods include:

- Normal (or fast drying) pavement paint can be used to paint a new runway outline on the old surface.

- The use of pyrotechnic flares or burning lanterns or drums to mark the new surface.

- Portable airfield lighting systems can be used to delineate the new MOS. These systems provide not only the capability to light the runway if the primary lighting system is damaged, they can also be moved to delineate a relocated MOS. Portable airfield lighting systems, although vulnerable to damage during attack, are usually quite easy to repair. Buried lighting systems, integral to the normal surface, are usually quite resilient to attack, but once damaged can be difficult to access and repair.

- Where possible, transportable aircraft arrester systems and barriers can be emplaced to provide short MOS for aircraft recovery. These systems may be transportable but require foundation blocks or hardstands to be built in appropriate locations.

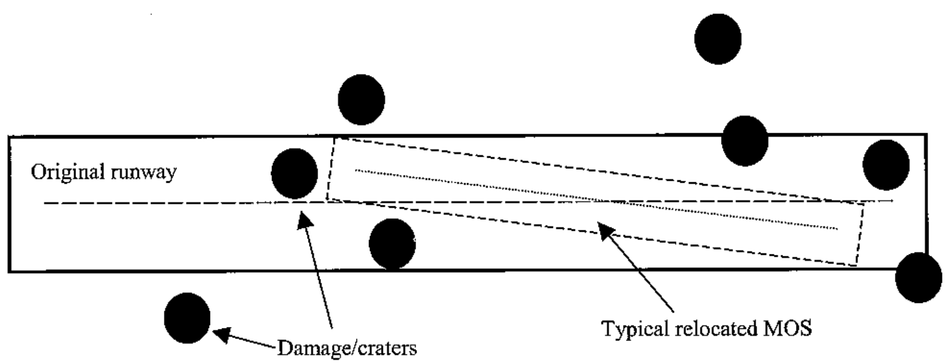

Figure 11.4 Typical MOS Relocation

Relocating the MOS, and operating from it, can cause considerable difficulties to aircraft operations. The difficulties that may be encountered include:

- Most pavement surfaces have a camber; that is, they gently rise to a high point at the centre-line to promote water run off. A MOS placed transversely across a pavement may force aircraft to ride over this camber, which can be potentially hazardous.

- Offsetting a MOS can cause problems when attempting Instrument Landing System (ILS) approaches during poor visibility. The degree to which ILS landings will still be feasible will depend upon the severity of the MOS relocation and the degree of remaining visibility. Where visibility is extremely poor and very high levels of ILS support are required, the relocation of the MOS can cause serious problems.

- In selecting a MOS, supporting pavements such as taxiways and access routes should also be available. Normally, supporting pavements at an airbase will be designed to provide maximum efficiency to the normally used main runway. Operation off this runway may be far less efficient and unlikely to be capable of sustaining normal aircraft movement rates.

- Urban development or tall trees surrounding the airbase may limit the ability to utilise offset approach paths. Even if they do not prevent the use of the new MOS, they could make operations more dangerous by removing the cleared approach lanes that provide safer places to ditch in emergencies.
- The size of the MOS will be determined by the aircraft characteristics, atmospheric conditions and the loading of the aircraft. Accordingly, other factors being equal, the more lightly loaded the aircraft, the shorter its MOS will normally be. When a retrograde MOS has been established, this will allow for a specified aircraft loading. A requirement to operate different aircraft, or aircraft with heavier loads, may render this MOS no longer satisfactory. Therefore, the use of retrograde MOS may reduce the flexibility of the employment of the airbase.
- Access to a full length runway allows aircraft to abort take-offs safely a substantial way into them. Similarly, when landing the full length of runway can allow successful recovery despite damaged brakes etc.

Repair of Pavement Surfaces

Another option to restore operations is the repair of selected damaged sections of AOS. This can be a time consuming task unless crews are equipped with specialist equipment and training. In the most general terms the ability of an airbase recovery crew to perform rapid runway repair is governed by:[11]

- The extent and severity of the damage.
- The expertise and training levels of the repair teams.
- The construction methods of the AOS itself.
- The use or potential use of chemical weapons being employed.
- Personnel levels available to the recovery crews, whether sufficient to allow multiple shifts to be run.
- The availability, suitability and survivability of heavy equipment.
- The presence of and ability to render safe UXO.
- The availability and quality of repair materials.
- The possibility of attack during the repair operation. This includes the potential for sniper fire and harassment of repair crews by enemy ground forces. It must be noted how vulnerable runway repair crews will be to follow-on attacks, whether they be air or ground launched.
- The type of aircraft using the airfield and their specific pavement requirements.
- The weather conditions and the time of day during which the repairs will be undertaken.

[11] Bahm, P.C. and Polasek, K.W., 'Tactical Aircraft and Airfield Recovery', *Airpower Journal*, Summer, 1991, p 47.

Figure 3.5 in Chapter Three describes the different forms of craters that can be caused in concrete surfaced runways. Table 11.1 details the repair methodology that may be applied to each crater and the relative length of time to conduct the repair. Craters on surfaces used for high speed or high impact operations (ie take-off and landing) will need to be finished to a higher standard than those on surfaces used for low speed operations. Similarly, taxiways used for aircraft parking or where sharp turns are made will need higher strength finishes.

Heavy Equipment Required	Crater Type	Probable Repair Technique	Relative Repair Time
No	Spall crater	Clean out by hand, fill with cement, resin, asphalt or select material with mat cover	Short
No	Blow-out crater	Clean out by hand or machine, fill with select material, compact manually or by machine, top with asphalt, cement or mat	Moderate
Yes	Standard crater	Clean out crater and damaged pavement or push into crater void, complete fill with select material, compact by machine, top with asphalt, cement or mat	Long
Yes	Heave crater	Clean out crater and damaged pavement or push into crater void, complete fill with select material, compact by machine, top with asphalt, cement or mat	Very Long
No	Camouflet with spall crater	Clean out by hand, fill camouflet with sand or select material, compact manually, top with asphalt or cement	Short
Yes	Camouflet with heave crater	Clean out damaged pavement by machine, fill with select material, compact manually or by machine, top with asphalt, cement or mat	Very Long
No	Camouflet	Fill void with wet cement or sand to bottom of pavement, vibrate cement or ram-pack sand by hand or machine, top out with cement	Very Short

Table 11.1 Repair Requirements for Various Crater Types in Concrete Runways[12]

A principal determinant of the effectiveness of any AOS repair technique is surface smoothness. Modern combat aircraft have little tolerance for surface irregularities, particularly during high-speed ground movement such as take-off and landing. Excessive surface roughness can cause structural damage to the aircraft, loss of

[12] Adapted from US FM 101-50-19 p 5-14.

external stores or loss of pilot control.[13] Determining the roughness allowable for any given aircraft operation is important as the rougher the allowable surface, the less time required for repair.

Some of the factors that contribute to surface roughness in a repaired pavement include:[14]

- The presence of large areas of upheaved pavement, beyond the area that can be economically excavated.
- The thickness and length of the mat or capping material.
- Subsidence due to imperfect compaction of the crater fill.
- Resonance developed when an aircraft traverses multiple repairs at speed.

Capping of Crater Repairs

Following the removal of any damaged pavement the crater can be filled with a combination of debris and select fill and then compacted. Using the original debris to fill the crater can be quicker but it may be difficult to obtain sufficient compaction. There are four main methods of capping a repaired AOS. These are:

- Flush capping with pre-cast concrete slabs.
- The use of bomb damage repair mats.
- Flush capping with pourable substances such as asphalt, cement, resin or modified grouts.
- Crushed stone repair.

Each of these methods has its own comparable advantages and disadvantages. Some are quicker than others, whilst some provide a better quality final product. Accordingly, the ideal situation is to have a range of solutions available that can be selected, depending upon the specific requirements at that time. Appropriately trained and equipped AE staff are required to utilise any of these methods properly in a post-attack environment.

Flush capping with pre-cast concrete slabs. This method involves the use of pre-cast concrete slabs to replace sections of the pavement surface. Once the underlayment has been refilled and compacted a section of pavement larger than the original damage radius is cut out square and removed. Into this prepared hole a pre-cast concrete slab is

[13] Van Orman, J.R., and Knox, K.J., 'Developments in Rapid Runway Repair, *The Military Engineer*, No 464, November-December, 1979, p 401.
[14] Van Orman, and Knox, 'Developments in Rapid Runway Repair', p 401.

placed. This method can be very time consuming and requires accurate and detailed preparatory work to be done. This method is more suited to slower follow-on repairs of a semi-permanent nature.

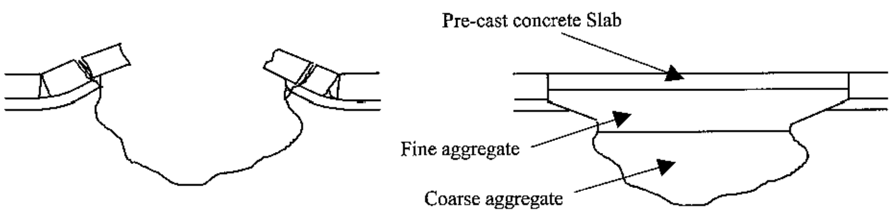

Figure 11.5 Repair of Standard Heave Crater with Pre-cast Concrete Slab

Aluminium Bomb Damage Repair Mats. These mats can be stored at the airbase rolled in various sizes. Preparatory works consists of removing or tamping any heave effects and filling and compacting the crater void. This fill should be finished flush with the original pavement surface. The mat is laid over this and bolted to pavement surface around the crater. In some configurations the lying of the mat proud of the existing surface can create roughness problems. The mat should cover the entire width of the MOS and be square to the direction of aircraft movement.[15] However, these mats can provide the quickest and simplest method for repairing AOS.

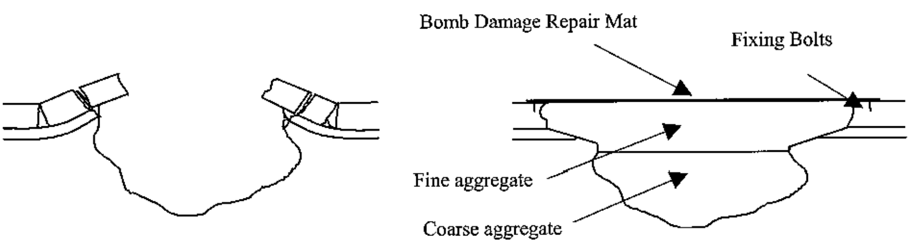

Figure 11.6 Repair of Standard Heave Crater with Bomb Damage Repair Mats

[15] Cowan, H.A., 'Airfield Damage Repair', *Sapper*, Vol 2, No 9, 1982, p 29.

The advantages of this form of repair include:

- Simple, reliable and requires less skilled engineering staff to lay, although can require a large amount of unskilled labour to deploy.
- Useable in all climatic conditions and the mats are not sensitive to storage conditions.
- The mats have a long life, are fully reusable and may be redeployed giving enhanced flexibility.
- Once laid, the mats may be trafficked immediately.
- The mats do not perform well when traversed by large cargo aircraft and can interfere with tail-hook barrier engagements by fighter aircraft.[16]

Flush Capping with Poured Materials. This technique utilises materials that can be poured into a partially filled crater to provide a flush finished and hardened surface. Preparation includes removal of heave damaged pavement, partial filling of the crater and light compaction of this material. The flush capping material is then poured into the remaining void and smoothed level with the surrounding pavement surface. The advantages and disadvantages of this form of repair include:

- Most of these materials require time to cure or harden, limiting their use in priority MOS repairs.
- Some of these fill materials, particularly epoxies or resins, have finite storage lives and require controlled environment storage conditions.
- Some of the fill materials require specialist equipment to mix, lay or cure.
- Once poured and cured the repair surface cannot be lifted to recompact the sub-course if required.
- This method can provide a smooth semi-permanent repair where surface roughness is critical.

[16] Pierre, D.J., 'Rapid Runway Repair: Seeking Advanced Materials', *The Military Engineer,* No 496, October, 1984, p 447.

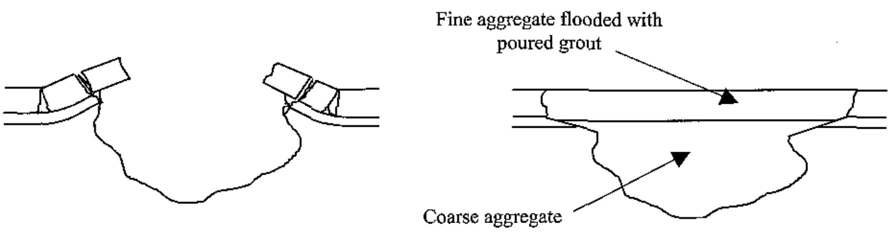

Figure 11.7 Repair of Standard Heave Crater with Poured Flood Grout

Crushed Stone Repair. The crushed stone repair requires the excavated crater to be filled with crushed stone that is then heavily compacted. A thin membrane of polyurethane impregnated fibreglass is then placed over this to prevent foreign object damage to aircraft from the stones. This technique has been validated with actual aircraft traffic and is recommended as an interim repair method for all craters. It has the advantages of the bomb damage repair mat, but provides a smoother surface.[17]

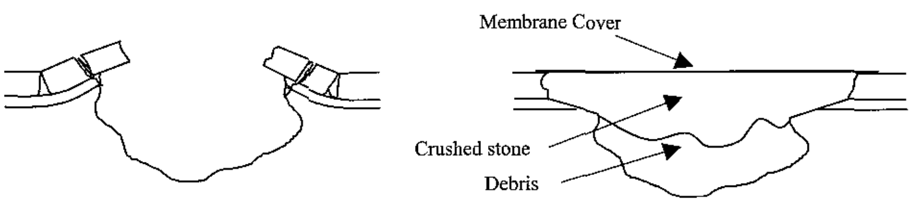

Figure 11.8 Repair of Standard Heave Crater with a Crushed Stone Repair

The Use of Metal Matting as a Temporary Aircraft Operating Surface

In addition to repairs to existing hard surfaced runways, metal matting can be used to create AOSs over lightly prepared or unprepared ground. The use of temporary metal matting as an AOS was pioneered by Allied forces in the Pacific theatre of WWII. The demands of heavier and higher performance aircraft and the need to rapidly establish airfields during island hopping campaigns led to the development of airfield construction techniques. 'By 1943, Allied forces were able to lay out a flying field, grade the surface, and cover it with perforated steel planks (PSP), crushed rock, or coral in a matter of days.'[18] However, PSP had significant drawbacks. It was susceptible to sinking into the mud during tropical storms and allowed the mud to seep through its holes, which was highly slippery and could damage the aircraft. It is also susceptible to lifting, particularly by rotor downwash, as was experienced during the 1982 Falklands War.

[17] Pierre, 'Rapid Runway Repair: Seeking Advanced Materials', p 447.
[18] Kreis, *Air Warfare and Airbase Defence*, p 348.

Perhaps the largest disadvantage of PSP was the manner in which it damaged the tyres of aircraft. Used at Milne Bay in 1942, 'the metal mesh [tore] pieces out of [the tyres]'.[19] During the Falklands War metal matting was used at the San Carlos forward base for Harrier aircraft landings. Here again this problem was evident as many Harriers departed with severely damaged tyres.[20]

Restoration of Essential Airfield Services

Once the initial reconnaissance has been completed and a satisfactory MAOS has been identified or cleared, attention can be turned to the restoration of essential airfield services. These services are those critical to the maintenance of air operations from that airbase. The exact nature of these facilities will therefore differ depending upon the requirements of each unique location and situation. However, the following services can generally be considered likely candidates for priority repair: (This list is not presented in a recommended priority order)

- Air defence warning and weapon systems.
- Aircraft refuelling facilities.
- Ordnance storage and handling facilities.
- Aircraft operational level maintenance services.
- Command, control and communications systems.
- Medical and other emergency services.
- Air traffic control and instrument landing systems.

The priority order in which these services should be restored will vary greatly depending upon circumstances. However, the BCC should have a clearly predetermined plan for that airbase which details this requirement.

When conducting repairs on airfield services five levels of repair can be undertaken. Each of these will provide a different level of service and each requires a commensurately larger investment of time, resources and expertise. The level chosen for a particular service will depend upon the time and resources available to conduct the repairs and the degree to which a lower level of repair will meet the immediate requirements. In some cases temporary repairs can actually make the follow-on permanent repairs more difficult or costly due to improvised changes made to the system or through causing further damage.

---

[19] Wilson, D., *The Decisive Factor*, Banner Books, Melbourne, 1991, p 108.

[20] Burden, R.A., Draper, M.I., Rough, D.A., Smith, C.R. and Wilton, D.L., *Falklands The Air War*, Arms and Armour Press, London, 1986, p 221.

Level of Repair	Nature of Repair
Operational Assessment	This level does not physically repair the service, it merely assesses the damage which has been sustained and provides and estimate of the degree to which repairs will be required. One major aim of the assessment is to determine if the service/facility is a hazard to personnel or other equipment, for example exposed live high voltage wires.
Safety Repair	At this level, the service is not actually restored; it is merely prevented from being a hazard to those around it and from causing further damage to itself. Examples could include the isolation of exposed electrical wiring, shutting off a broken gas pipe or the fencing or marking of a dangerous deep hole.
Bypass Repair	This level of repair bypasses the service, allowing operations to continue around it, or to prevent it from sustaining further self-inflicted damage. An example could include bypassing a broken light fitting to allow electricity to be supplied to other undamaged lights. However, the service provided by the actual broken light was not replaced.
Temporary Repair	Temporary repairs reinstate the damaged service, however, not at a level that meets the initial full standard of service. An example could be the use of bomb damage repair matting to cover a crater in a runway surface. In this case, the repair has enabled the runway to be used, but more permanent repairs (to the normally accepted standards) will be required when time and resources permit. Temporary repairs will normally have a limited life span, have reduced operational capabilities or run less efficiently than the original full service.
Permanent Repair	Permanent repairs reinstate the damaged service fully and meet all the standards expected during normal operation.

Table 11.2 Different Post-Attack Repair Options

Chemical and Biological Decontamination

Once the airfield has been contaminated by Chemical or Biological (CB) weapons decontamination operations will need to be conducted before full operations can be recommenced. Although, most airfield operations can be conducted in a contaminated environment the protective equipment required will greatly reduce the speed and endurance of the personnel conducting them. Similarly, aircraft and vehicles cannot be allowed to leave a contaminated airfield towards clean areas unless they are decontaminated first.

One of the initial tasks during the post-attack reconnaissance is to determine the presence and nature of CB contamination. This will alert staff as quickly as possible of the requirement to wear protective ensemble and prevent immediate casualties. This survey will also allow the requirement for decontamination to be determined.

CB decontamination can be divided into several basic tasks:

- Decontamination, packaging and/or disposal of gross liquid contamination, including the render-safe of CB UXO.
- Decontamination of personnel and the exchange of the personnel protective ensemble, once used.
- Decontamination of specialist equipment and specific areas such as hangers etc, in accordance with priority directives.
- Decontamination of aircraft and vehicles leaving the contaminated zone.
- Broad area decontamination. This may often be left for considerable periods of time, due to the resources required. Environmental factors will degrade most CB agents over time.

Decontamination is a very slow and resource intensive procedure. The chemicals used are also often corrosive or dangerous and may damage some materials such as rubber or paint. Where personnel are well trained and equipped, weathering should be relied upon to provide most broad area decontamination.

SUMMARY

An effective PAR capability can be a valuable deterrent against attacking an airbase. An adversary who is aware that they cannot disrupt operations from the airbase for a significant length of time may be unlikely to risk the losses that the attack on the airbase may cause.

However, if an attack is undertaken, the highest priority of the airbase will normally be to resume air operations in short order. This will require a rapid, rehearsed and efficient PAR operation involving the close coordination of many different airbase services. The rapid pace and 24 hour a day nature of modern air operations will put a pressure on recovery crews to restore operations as soon as possible. Delays due to inadequate resources and preparation will directly jeopardise the quick resumption of operations and the ability of the base to recover its aircraft and to defend itself from further attack.

It is not possible to effectively recover an airbase following any serious attack unless these resources are provided and the task is thoroughly rehearsed. These are generally not expensive capabilities, and usually need not be provided in excessive quantities. The likely scale of airbase damage following an attack by a small to medium sized power allow this. However, they must be fielded and be equipped and trained appropriately for this extraordinarily difficult task.

Central command of this operation is crucial to minimise time wastage and ensure the safe and appropriate allocation of scarce recovery resources. Human resources should be specialists in the airbase recovery process and should be appropriately trained and equipped and exercised before they are required for operations.

CHAPTER 12

Conclusions

The survival of American air power on Guadalcanal, in the final analysis, depended upon the survival of the airfield. The base could not survive without a flow of supplies, especially gasoline, and the Japanese Navy made every effort to cut these essentials off. Obviously the field could not operate if it was overrun by Japanese infantry, and this too the Japanese attempted with all their might. The field could not be used if it was kept out of operation by bombs from Japanese aircraft; this too the enemy attempted.[1]

INTRODUCTION

This book has attempted to detail a wide variety of the threats faced by a modern airbase and the measures that can be used to defeat them. Given the reliance of fixed-wing air operations on these few bases their survival is essential to the effective employment of air power. The ability of air power to influence the battle space makes Airbase Operability (ABO) not just an air power problem but a joint problem, of critical relevance to all stakeholders in the theatre.

CONSISTENT THEMES

Layered Defences

All airbase defences and operability features should be layered; ie, they must possess depth and be multi-faceted. This applies to both active and passive defence. Airbases are by their nature 'shallow' targets, in that they possess little inherent depth themselves. They are geographically small, immobile targets composed of a variety of components each individually vital to the success of the airbase mission. Significant damage to any of these components may be sufficient to stop air operations from that facility.

Accordingly, the airbase defences themselves must provide depth to the airbase. Ground defence forces must dominate the ground around the airfield to deny the enemy infiltration routes, observation points and firing positions for indirect fire weapons. Air defences must seek to deter or destroy attacking aircraft at a distance

[1] Cooling, B.F., *Case Studies in the Achievement of Air Superiority,* Center for Air Force History, Washington DC, 1994, pp 334-335.

where they cannot effectively acquire their (well camouflaged) targets and deploy their weapons of choice. Hardened facilities can provide depth, by limiting the choice of methods available to the enemy to destroy key targets, possibly removing some of the initiative from their hands and perhaps making them more vulnerable to active defences.

In many ways, it is unfortunate that in the last 20 to 30 years the vast majority of air attacks on airbases have been undertaken by air super-powers against much weaker foes, for this has provided a skewed view of the ineffectiveness of airbase operability measures.

Mobility and Dispersal are the First Choices to Protect Assets

Given the lethality of modern weapon systems the most desirable method of avoiding destruction is for the enemy to be unable to find their targets. This principle has been borne out by history, and advances in weapon and sensor technology make it even more important in today's battle space. During Korea, Vietnam and the 1991 Gulf War it was the assets which were constantly mobile and that could be easily hidden that survived the longest in wars dominated by Western air power. As pervasive sensor systems such as commercial reconnaissance satellites become more capable and their product more widely available it will become progressively more difficult for any nation to hide fixed installations. Accordingly, mobility is critical to the successful concealment of important assets. Multi-spectral camouflage and concealment systems can reduce the chances of the adversary locating the asset in the first place, and constant mobility will ensure that any information obtained is highly perishable.

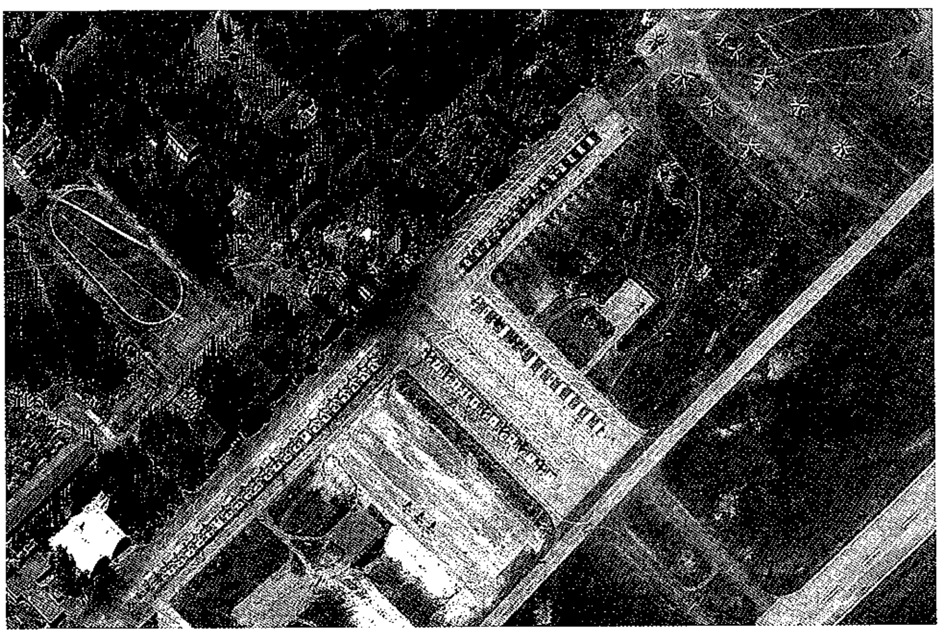

Figure 12.1 Serbia's Podgorica Airbase — A Picture of a Modern Military Airfield (NATO Photograph)

Mobility and dispersal should be applied as widely as possible. The use of self-propelled (and perhaps armoured) vehicles as air-defence systems, command centres, maintenance shops and for ground defence will make them very difficult targets to find and attack, if appropriately hidden.

Camouflage, Concealment and Deception is Essential

Mobility alone will not provide protection if the targets can be easily detected and attacked using modern precision strike systems. Also, some targets are not amenable to mobility and their fixed locations make them seemingly easy targets for guided or unguided weapons.

Concealment and deception operations must observe two fundamental principles — they must be planned to provide a complete deception image and they must be tailored to the surveillance, reconnaissance and target acquisition systems employed by the adversary. These may be air or space borne and they may seek to acquire targets by using many different parts of the electromagnetic spectrum. Accordingly, camouflage, concealment and deception must be three dimensional and multi-spectral. The improvised use of hasty and simplistic camouflage is unlikely to be very successful in a world of advanced multi-spectral sensors and integrated information processing systems.

Fortunately, concealment and deception systems are being developed to counter such high technology target acquisition systems. Multi-spectral camouflage netting, obscurant smokes and surface panelling can provide the means to defeat these threats. However, as with all operability measures they must be employed as part of a well-planned and layered system of mutually supporting methods. This system should start with a comprehensive vegetation plan in which to hide these fixed and mobile assets. Despite the development of foliage penetrating target acquisition systems the use of advanced multi-spectral (including radar) camouflage systems should provide high levels of protection.

Harden Fixed and Mobile Targets

The employment of mobility and camouflage can provide airbase assets with protection from attack, particularly from the air. However, if sighted by the adversary these assets may then be attacked with a wide variety of weapons, the attackers choosing the specific weapon providing them with the greatest chance of achieving the desired level of damage whilst surviving themselves. Hardening targets limits this choice of attack methods and returns some of the initiative to the defence. Forcing the enemy to employ weapons capable of defeating armour or hardened facilities may make then more vulnerable to active defences or limit the results that can be expected per sortie. Hardening complements other survivability measures by converting the airbase from a single soft target, into a collection of smaller harder ones. A significantly more difficult objective to destroy. A moderate degree of hardening provides a disproportionate increase in weaponeering effort that must be expended to destroy the target. This is particularly so if there are a large number of potential targets that must be destroyed with limited resources.

Hardening can also provide comprehensive protection from less advanced weapons and ensures that no single weapon can destroy multiple targets. It is virtually impossible to destroy a hardened facility with anything approaching a reasonable number of unguided or area weapons. It also greatly complicates the task of the attacking ground forces as these shelters are virtually impervious to ground weapons.

Active Surface-to-Air Defences are Necessary

Fixed ground based ABO measures will not protect airbase assets alone, they simply make them harder to destroy. Active defences (layered appropriately) make airbase attacks not only more difficult, but more costly. If ground ABO measures can make the task of closing airbase operations long and difficult, and active defences can make it an expensive one, the enemy may be less likely to undertake the task.

Active defences must also seek to do more than destroy attacking enemy aircraft, they must also be capable of destroying incoming missiles and bombs. Naval forces rely on a range of active measures to defeat anti-ship missiles and that technology is rapidly being transferred to land based units. To achieve this requires integrated, mobile, and dispersed gun and missile systems with effective command and control. The ability to shoot down bombs, cruise missiles, and tactical ballistic missiles or automatically deploy a range of camouflage and obscuration screens will make fixed hard targets more difficult to destroy.

Ground Defences must be Professional and Aggressive

It has been shown that effective and determined airfield defences can defeat the majority of penetrating ground attacks before they inflic t severe damage. Attack by stand-off weapons is now clearly the method of choice and has been aided by the development of technologies such as GPS and automously guided small calibre mortar bombs. These attacks can be launched in forward and urban locations and by both uniformed military forces and irregulars or terrorists.

Accordingly, airbase ground defences must control and deny the territory from which these attacks can be orchestrated or launched. This requires thorough training, good equipment and the assistance of force multipliers such as uninhabited aerial vehicles.

The Total is Greater Than the Sum of the Parts

Individual ABO features may often seem to be trivial or to be so easily countered as to be ineffective. However, it is almost always true that these measures will depend upon each other for their effectiveness. Take for example the defence of a critical facility such as a base electrical power generation station from air attack. The hardening of the facility will force the attacker to use precision guided weapons to obtain a reasonable certainty of being able to destroy the facility. The placement of mobile point defence weapons around the airfield can force the attacker to use stand-off techniques. The placement of surface-to-air weapons at unpredictable locations away from the airfield at distances where the attacker is likely to be attempting to pop up, to bomb toss or to designate with a laser can be highly effective. Similarly, automated obscurants and jammers can be employed to make target designation more difficult. Finally, modern gun/missile point defence systems can be used to shoot down both direct attack munitions and stand-off weapons.

Accordingly, relying upon a single operability characteristic is unsatisfactory. A good example is the reliance on hardening alone to protect a critical facility, such as by the placement of a single earth-covered facility on an airbase to house the base command centre. Imagery intelligence will have identified the precise location of this facility during its construction and if it is the sole hardened facility on the unit, its intended use can be guessed with some confidence. Accordingly, resources can be devoted to its destruction with a high probability of destroying the airbase command function.

From the above it can be seen that active defences are an extremely important complement to passive defences. Where active defences do not exist or have been destroyed or suppressed by the attacker passive defences can be overcome by utilising weapons and systems purpose designed for that task. For example, a buried fuel storage facility can be destroyed by the use of a precision guided penetrating weapon. However, these weapons (with some accepted exceptions) require the attacker to expose themselves to the airbase active defences to some extent. An integrated air defence system composed of fighter aircraft, missiles and guns can make the employment of these weapons difficult.

Combining all the above into a typical airbase would see the development of a sizeable airfield with a large number of well-dispersed multi-purpose roofed revetments. Built into the natural vegetation these revetments could have concrete and earth covers and would be linked by taxi-ways to large areas of redundant pavement. Each revetment could be used to house aircraft, fuel bladders, personnel, command and control or remain empty. They would be difficult to see, difficult to attack and if many were built would form a complex targeting problem. Each would be supplied from underground services and would be resistant to ground fired weapons, near misses from bombs and missiles, or area weapons. The employment of active point defences and automatically activated obscurant systems would further protect them from attack.

Information Operations are Critical

The vast number of electronic information systems employed at a typical modern airbase make them extremely vulnerable to enemy offensive information operations. These systems may be targeted as part of a combined attack, as a prelude to a conventional attack or as a self-contained asymmetric strategy. Information operations are often more politically acceptable than convetional military attacks, provide superior deniability and offer a less escalatory prelude to other operations.

Airbase information systems face two primary classes of threat — internal and external. During peacetime the internal threat is perhaps the greatest of these two as personnel fail to appreciate the impact that their actions or inaction can have upon the ability of the airbase to continue to operate.

Surprise

Surprise has been a consistent feature of attacks on airbases. In nearly all conflicts since World War I where air power played a major part, attacks on airbases were part of the opening day's operations. This is response to three factors:

- Air power could be so crucial to a campaign that efforts to negate it must be made at the outset of a conflict.
- Airbases can be defended quite effectively if appropriately prepared, making surprise essential to reduce the attacker's attrition.
- It has consistently proven easier to destroy aircraft on the ground than in the air. Surprise is required to achieve this before the enemy can disperse or scramble.

The requirement for the airbase, above all other military assets, to remain vigilant against surprise has been borne out by history and there is little evidence to suggest that surprise will cease as a vital enabling factor in airbase attacks. Therefore, the airbase commander must be constantly vigilant against surprise in all its forms, tactical & strategic, doctrinal and technical. The two best ways of achieving this practically are preparedness and constant awareness.

However, this is a very difficult task, for just as long as surprise has been utilised in war, naive military and political bureaucrats have been poisoning preparedness with meaningless and contemptibly ignorant assertions that war could not possibly be imminent. This is despite the obvious fact that no enemy is likely to broadcast their intention to open a conflict with a series of airbase attacks, as this would rob them of the advantages described above. It is also a blatant failure to accept the inherent instability of many nation's political systems and is usually solely designed to reduce costs. As stated in a paper on Imperial Defence in 1926: 'The size of the forces of the Crown maintained by Great Britain is governed by various conditions peculiar to each service, and is not arrived at by any calculation of the requirements of foreign policy, nor is it possible that they should ever be so calculated.'[2]

It is therefore up to the service men and women who live, work and unfortunately have died in unnecessarily large numbers on airbases to accept preparedness and awareness as their most important mantra. When this mindset is fully inculcated into

[2] Dixon, N.F., *On the Psychology of Military Incompetence,* Pimlico, London, 1994, p 111.

every staff member operability will seem an obvious and necessary part of every airbase activity.

Operability Measures Can Have a Significant Deterrent Effect

It has been shown that the application of suitably high force levels can subdue the strongest of airbases. This was demonstrated during the 1991 Gulf War and again during Operation *Allied Force* in 1999. However, caution must be exercised when drawing lessons from a conflict where the attacker had almost limitless military resources.

Where the potential attacker has forces more typical of a regional conflict the ability to strike decisively and economically at an airbase will be a major determining factor in deciding whether to attack that target. In many cases, an a well defended target is unlikely to be attacked by a rational force if the results are uncertain or likely to be indecisive. Accordingly, the implementation of a broad operability plan at an airbase is likely to have a significant deterrent effect against an adversary planning to attack there.

Airbase Rear Linkages are Vulnerable

Airbases do not exist in isolation, they require extensive support from rear areas for consumable resources, personnel, deeper maintenance and C^3 functions. Accordingly, the ability of the airbase to access these services as required is a major determinant of its ability to sustain ongoing operations.

The rear linkages can be broken by either enemy action or natural circumstances. An adversary can interdict these supply lines by mining, the use of Special Forces or through conventional attack. Natural forces such as flooding or other destructive weather can interrupt them as well. In some cases the simple scale of the resources required by an operating airbase can stretch logistic support services to breaking point, even in ideal conditions. Accordingly, it is important to ensure that logistic requirements are well understood and can be met, even in non-ideal circumstances. The reliance upon a single supply route, such a lone roadway, must be avoided at all costs as it introduces extraordinary vulnerabilities and its severance can render the airbase inoperable very quickly.

There is No Such Thing as a 'Bad' Operability Plan

There are 'better' operability plans and there are 'not quite so good' operability plans, but there are no truly 'bad' plans. This may seem a bold statement, however, the completion of the planning process described in Chapter Six will produce an operability plan that is better than what preceded it. Even if the operability measures identified are not implemented the process will serve to educate base personnel on the threats and vulnerabilities they face. This may have the beneficial effect of dispelling any misconceptions the airbase staff may have. As long as whatever operability measures are employed are done so in accordance with a rational plan they will contribute to the survivability of that facility.

A Post-Attack Recovery Capability is Essential

A post-attack recovery capability greatly increases the damage an adversary must achieve before the airbase becomes inoperable for a useful period. Just as other passive defences reduce the effects a given attack can be expected to produce, a recovery capability reduces the length and severity of any disruption to operations. By employing an effective explosive ordnance disposal, airfield engineering and biological and chemical decontamination force the adversary will be required to inflict far higher levels of damage to achieve their mission aim. This commensurately increases their risk and reduces the attractiveness of attacking that airbase. Weapons such as chemical or biological agents have limited utility if the enemy is thoroughly prepared for their employment; however, they have enormous tactical effect if the victim is unprepared.

Given the dangerous nature of the modern post-attack environment and the severe time constraints imposed by air operations, post-attack recovery must be undertaken by highly trained and well-equipped professionals. To utilise *ad hoc* groups of personnel with limited specific training and experience will result in high casualties and severely delay the recovery of the airfield.

SUMMARY

This book has not sought to describe how an airbase should be protected. There are far too many different techniques available for each to be described in any detail. Similarly, there are so many different circumstances in which airbases exist that any prescriptive ABO formula would be applicable to very few. Instead, it has attempted to explain the concepts and rationale behind the employment of operability measures. Once the importance, value and concepts behind ABO measures are understood it is then up to the experts employed by all air forces to apply these to their own unique circumstances.

A common method of measuring the cost of operability enhancements at an airbase is to compare this cost against the monetary value of the aircraft based there. Normally the enhancements will appear relatively inexpensive in comparison. In a combat environment, or where the airbase contributes to a deterrent against war, this is a fundamentally flawed approach. The cost of airbase operability enhancements should be measured not against the monetary value of the airbase but against the cost of that airbase being unable to function as designed during a conflict. Where this inability to employ air power results in the loss of a campaign or conflict this is a very high price indeed. The complete destruction of the Egyptian Air Force in 1967 was surely a major contributing factor to their loss of that war. Operability enhancements by comparison now seem downright cheap.

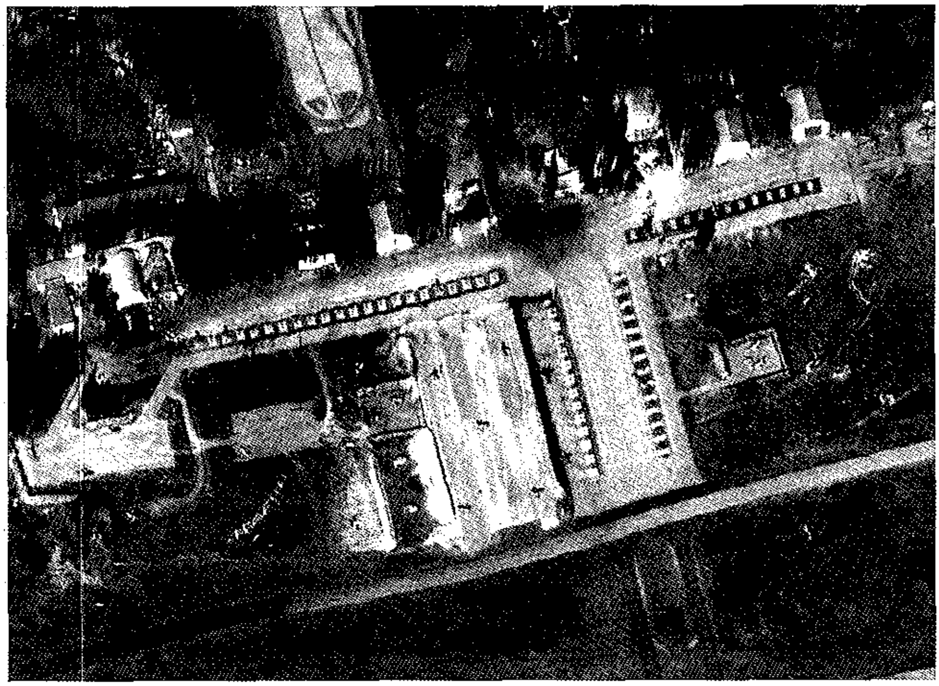

Figure 12.2 Serbia's Podgorica Airbase Post-Strike. Note missing buildings, destroyed aircraft and ad hoc dispersal. (NATO Photograph)

In conclusion, the lessons presented in this study are not new. They have been learnt and relearnt every time air forces have been required to base themselves on fixed pieces of dirt and generate the air power that is a crucial component of modern war fighting. It is unfortunate that they must be forgotten at the conclusion of each conflict and then relearnt at great cost.

CHAPTER 13

Airbase Operability Checklist

The plane is a strange creature. In the air, refuelled, armed and piloted by a good flyer, it represents an incarnation of power and fighting ability that strikes fear into tanks and ships at sea... But the plane, so powerful in the air, is a despicable object on the ground. Not only is it harmless, it lacks the most minimal defensive capacity. It squats on the runway, clumsy and prostrate, at the mercy of any enemy. Not only is it vulnerable to air attack (which makes air-bases attractive targets in war), but even some humble mortar, correctly deployed, can tear it to pieces. It costs a fortune, it can decide the fate of a war, and yet, it's as helpless as a baby.[1]

Ezer Weizmann
Chief of Staff, Israeli Air Force
1967 Arab–Israeli War

AIRBASE DESIGN AND CONSTRUCTION

General

- Has the design of the airbase included an initial master operability plan?
- Are controls in place to limit and monitor the distribution of airbase planning materials and information?
- Has a coordinated operational airbase illumination plan been developed?
- Has the airbase plan considered environmental factors unique to that location such as weather, flooding, sensitive areas and flora and fauna?
- Is the airbase design conducive to recovery operations through the employment of dispersal, hardening and redundancy? Are facilities to support recovery operations built into the initial plan?

---

[1] Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987, p 10.

Construction Layout

- Are all vulnerable areas, including aircraft parking and taxi-ways, protected from observation and direct fire weapons by revetments, screens or other obstructions.
- Have foundation blocks for transportable aircraft arrester systems and crash barriers been built at multiple locations to maximise the number of minimum operating strips that can be used?
- Have facilities been designed and placed where they can be defended by reasonable numbers of troops?
- Does an airbase wide camouflage and deception plan maximise the use of existing natural vegetation and topography?
- Are vital facilities dispersed to a sufficient extent to prevent the simultaneous attack by single weapons or sorties?
- Have law of armed conflict requirements been considered during facility placement?
- Are all critical facilities and services duplicated and redundant?
- Are satellite dispersal airfields available?

Logistics Planning

- Has a sustainability plan been developed for the air base?
- To what extent will critical consumables be stockpiled on the airbase? Are these stockpiles survivable?
- What is the capacity and survivability of planned and back-up supply routes?
- How will consumable item resupply (particularly POL, water, fuel, ammunition and rations) be supplied to the airbase? How easily can these resupply routes be interdicted?
- Have facilities to allow recreation, or physical fitness or martial skills training been built to support medium to long-term personnel deployments?

Construction Hardening

- Are facilities hardened to an extent appropriate to the given threat?
- Are facilities designed to survive any destructive weather in that area?

- Have immobile and important (although not necessarily critical) facilities been provided with hardening to protect them from incidental or collateral damage during attack?

Ground Defence and Security Planning

- Have appropriate areas been cleared to provide visibility and clear lanes of fire?
- Have appropriate open areas been obstructed to deny their use to the enemy, block visibility and prevent long-range fire?
- Have all applicable terrorist and non-traditional (including non-violent) ground threats been considered during the planning process?
- Have land-line communications links been emplaced for voice, data and sensor systems?

AIRBASE ACTIVATION AND OPERATION

Redundancy and Dispersal

- Have the critical consumable (eg POL, water, fuel, ammunition and rations) flows within the airbase been mapped, checked for vulnerabilities and counter-measures employed?
- Are vital services such as electricity, information systems, water supplies and roadways suitably redundant? Have single point vulnerabilities been identified?
- Have all vulnerable assets been camouflaged, duplicated, hardened and/or dispersed?
- Are mobile assets being moved at regular intervals in unpredictable patterns?
- Are vital personnel protected appropriately and separated in case of casualties?

Camouflage and Deception

- Are the enemy's reconnaissance and surveillance capabilities known?
- Is the enemy using third party or proxy reconnaissance, such as commercial satellites or local people?
- Has an airbase wide camouflage and deception plan been established? Has this plan been implemented and its effectiveness validated?
- If desired, can the airbase adopt a zero radiated emission posture on command?
- Is natural regrowth meeting the requirements of the base vegetation plan?
- Are airbase activities protected the maximum extent feasible from observation by space, air or ground based observation?

- Have street signs and identifying signage on important facilities been removed to prevent enemy ground forces using them for assistance?

- *Are all CCD measures effective in three dimensions and across the electromagnetic* spectrum?

Ground Defence and Physical Security

- Have likely drop-off points, drop-zones, infiltration routes, form-up points, observation hides and stand-off weapon firing positions been identified and denied to the enemy?

- *Has a plan to detect and defeat enemy ground forces in the area surrounding the airbase* been developed, resourced and implemented?

- Does the airbase have a capability to defeat a stand-off weapons attack? Have acoustic or radar-based counter-battery and location finding systems been deployed?

- Have a prisoner-of-war processing and holding facilities been established and prisoner-of-war and enemy casualty processing procedures been established and briefed?

- Is there a plan to rescue/recover a crashed aircraft near the airbase?

- Are emergency service and post-attack recovery personnel briefed on the ground defence plan?

- To what extent can isolated and critical assets such as runway sweepers be protected from ground or air attack?

- Are attack and stand-to drills prepared and well rehearsed?

- Are all personnel well briefed in law of armed conflict and rules of engagement requirements?

Ground Combat Intelligence

- Have intelligence linkages been established with neighbouring military units and local *organisations*?

- Is the intelligence collection process structured (such as at Figure 7.2) to ensure that knowledge is presented rather than data.

- To what extent are the culture, loyalties and characteristics of the populations surrounding the airbase known?

- Have civil affairs operations been established to foster local support?

Air Defence

- Has an air threat intelligence capability been established, both theatre wide and locally?
- Do air defences exist against all applicable air threats — cruise weapons (high and low speed), manned bombers, ballistic missiles, airborne operations?
- To what extent are these air defence systems diverse, survivable and sustainable?
- Are both active and passive means available to locate approaching aircraft?
- Are the air defences sufficiently mobile to
- Is it possible to employ active counter-measures systems to protect critical facilities?

Information Operations

- Do all airbase Information Systems (IS) meet the requirements for survivability?
- Are airbase information systems and distribution networks as survivable as the capabilities they are designed to support?
- Are control systems in place to prevent malicious or inadvertent damage to airbase IS by staff, including a COMMSEC plan?
- Has an active counter-intelligence capability been established?
- Who is responsible for planning and supervising the use of security counter-measures on the airbase?
- Has a baseline OPSEC plan been developed, briefed and implemented?
- Has the airbase OPSEC plan been revised or audited to ensure it is current and active?
- How robust are the air base command, control and communications systems? Will these survive degradation or attempts at decapitation?
- Do all IS meet the requirement for fault tolerance, a robust and adaptive response, distribution and variability, and recovery and restoration?
- Does the airbase have access to a tactical SIGINT capability to support defence operations?

Post-Attack Recovery

- Have all airbase facilities been pre-allocated a recovery priority?
- Are assets such as helicopters or armoured vehicles available for post-attack reconnaissance work?

- Have appropriate MOS and MOAS requirements been determined for the aircraft operated from the airfield?
- Has a post-attack recovery command cell been established within the base command centre?
- Do all personnel have prepared and allocated bunkers or pits for use during air or indirect fire attack?
- Are all personnel, including aircrew familiar in operations from retrograde facilities such as shortened pavements?
- Are airbase recovery assets prepared and in protected or dispersed locations ready for action?
- Are medical and casualty handling services adequate and survivable?

Explosive Ordnance Disposal

- Have all base personnel been briefed on the hazards of unexploded or improvised explosive ordnance?
- Is an Explosive Ordnance Disposal (EOD) or post-attack recovery command cell established within the base command centre?
- Are sufficient EOD forces deployed to conduct operations?
- Has a safe disposal or storage area for ordnance been established?

Chemical and Biological Defence

- Have all personnel been inoculated against likely biological agents and endemic local diseases?
- What capability does the unit have to detect the use and presence of Chemical and Biological (CB) agents and provide dissemination and warning?
- Has an appropriate level of individual and collective CB protection been deployed?
- Does the air base have a decontamination capability and appropriate stockpiles of necessary materiel?

Airfield Damage Repair

- Is appropriate equipment and plant available to remove heave-damaged pavement and conduct pavement repairs?
- Is appropriate fill material available to fill crater voids?

- Are appropriate materials and equipment available to cap crater repairs?
- Are appropriate materials and equipment available to conduct hasty and longer-term facility repairs?
- Is appropriate technical data available? Are engineering drawings for important facilities and plant held, can the manufacturers be contacted in an emergency for expert advice?

Environmental Operations

- Are waste disposal and recycling operations sufficient to meet the airbase needs?
- How resilient are these services to sabotage or incidental damage?
- Have disease, pest and vector control programs been undertaken as required?

Rear Echelon Support

- Have family liaison activities been undertaken in support of dependants of deployed personnel?
- How are dependants, family and friends being notified of activities on the airbase, particularly to counter typically unprincipled and inaccurate media reporting?
- Are contractor support facilities available in the rear-echelon to provide support to forward deployed equipment?

CONCLUSION — THE 10 RULES OF AIRBASE OPERABILITY

1. Operability measures must be thoroughly planned, complementary and in place in sufficient time to be effective.

2. Know your enemy — culture, aims, intentions and capabilities.

3. Develop and protect rear linkages, they are vital and vulnerable.

4. Ground defence must be undertaken by professional ground soldiery and must be well resourced and aggressive.

5. Hide important assets and make them mobile. Make the enemy work for their intelligence and make it perishable.

6. Harden critical assets that cannot be mobile to limit the means by which they can be destroyed. But never forget they can still be destroyed.

7. Never have only one. All critical people and systems must be redundant and dispersed.

8. Information systems and knowledge are a critical strength and vulnerable weakness.

9. Employ strong active defences and counter-measures to prevent the enemy from undoing your operability measures in detail.

10. A dedicated recovery capability is an effective deterrent and is an essential complement to other active and passive defences

Bibliography

Adkin, M., *Urgent Fury: The Battle for Grenada*, Lexington Books, Lexington, 1989.
Armitage, M.J., Mason, R.A., *Air Power in the Nuclear Age*, Macmillan Press, London, 1985.
Ball, D., (Ed), *Air Power: Global Developments and Australian Perspectives*, Pergamon Press, Sydney, 1988.
Barker, A.J. *Suez: The Seven Day War*, Faber and Faber, London, 1964.
Bateson, C., *The War with Japan - A Concise History*, Ure Smith, Sydney, 1968.
Bergquist, R.E., *The Role of Airpower in the Iran-Iraq War*, Air University Press, Maxwell AFB, 1988.
Betts, Richard K., *Surprise Attack*, The Brookings Institution, Washington DC, 1982.
Burden R.A., Draper M.I., Rough D.A., Smith C.R. and Wilton D.L., *Falklands The Air War*, Arms and Armour Press, London, 1986.
Campbell, C., *Air War Pacific*, Hamlyn, London, 1991.
Carus, W.S., *Cruise Missile Proliferation in the 1990s*, Praeger Publishers, Westport, 1992.
Chow, B.G., Jones, G.S., Lachow, I., Stillion, J., Wilkening, D. and Yee, H., *Air Force Operations in a Chemical and Biological Environment*, RAND Corporation, Santa Monica, 1998.
Cohen, E., *Israel's Best Defence*, Airlife Publishing Ltd, Shrewsbury, 1994.
Cooling, B.F., *Case Studies in the Achievement of Air Superiority*, Centre for Air Force History, Washington DC, 1994.
Conley, H.P., *A History of Camouflage: Concealment and Deception*, Air University, Maxwell AFB, Alabama, 1988
Cordesman, A.H. and Wagner, A.R., *The Lessons of Modern War Volume 1: The Arab-Israeli Conflicts, 1973-1989*, Westview Press, London, 1990.
Coulthard-Clark, C.D., *The RAAF in Vietnam*, Allen & Unwin, St Leonards, 1995.
Coyne, J.P., *Airpower in the Gulf*, Aerospace Education Foundation, Arlington, 1992.
Crabtree, J.D., *On Air Defence*, Praeger, Westport, 1994.
Craven, W.F. and Cate, J.L., (Eds), *The Army Air Forces in World War II – Vol V*, Office of Air Force History, Washington DC, 1953.
Cull, B., *Wings Over Suez*, Grub Street, London, 1996.
Cutlack, F.M., *The Australian Flying Corps in the Western and Eastern Theatres of War 1914-1918*, 10th Edition, Angus and Robertson, Sydney, 1940.
Darman, P, *Surprise Attack*, Brown Books, London, 1993.
Dixon, N.F., *On the Psychology of Military Incompetence*, Pimlico, London, 1994.
Douhet, G., *Command of the Air*, Coward-McCann, New York, 1942.
Eddy, P., Linklater, M. and Gillman, P., *The Falklands War*, Andre Deutsch, 1982.
Elsam, M.B., *Air Defence*, Brasseys, London, 1989.
Ethell, J. and Price, A., *Air War South Atlantic*, Sidgwick and Jackson, London, 1983.
Forestier, A.M., *Into the Fourth Dimension: An ADF Guide to Space*, Air Power Studies Centre, Canberra, 1992.
Fricker, J., *Battle for Pakistan: The Air War of 1965*, Ian Allen Ltd, London, 1979.
Friedman, N., *Desert Victory: The War for Kuwait*, Naval Institute Press, Annapolis, 1991.
Futrell, Robert F., *The United States Air Force in Korea*, Duell, Sloan and Pearce, New York, 1961.

Gailey, H.A., *The War in the Pacific: From Pearl Harbor to Tokyo Bay,* Presidio Press, Novato, 1995.

Galeotti, M., *Afghanistan, The Soviet Union's Last War,* Frank Cass, London, 1995.

Gillison, D., *Royal Australian Air Force 1939-1945,* Australian War Memorial, Canberra, 1962.

Gunston, B., *Illustrated Encyclopedia of the Worlds Rockets and Missiles,* Salamander, London, 1979.

Haas Michael E., *Apollo's Warriors – US Air Force Special Operations during the Cold War,* Air University Press, Alabama, 1997.

Hajjar, S.G., *Security Implications of the Proliferation of Weapons of Mass Destruction in the Middle East,* US Strategic Studies Institute, Carlisle, 1998.

Halliday, J.M., *Tactical Dispersal of Fighter Aircraft: Risk, Uncertainty, and Policy Recommendations,* Rand Corporation, Santa Monica, 1987.

Hallion, R.P., *Precision Guided Munitions and the New Era of Warfare,* Air Power Studies Centre, Canberra, 1997.

Hallion, R.P., *Storm over Iraq Air Power and the Gulf War,* Smithsonian Institute Press, Washington, 1992.

Hamlin, J.F., *Military Aviation in Malta G.C. 1915-1993,* GMS Enterprises, Peterborough, 1994.

Handel, M.I., *War, Strategy and Intelligence,* Frank Cass, London, 1989.

Hartcup, G., *Camouflage: A History of concealment and Deception in War,* David &Charles, North Pomfret, 1979.

Hastings, M., *The Korean War,* Michael Joseph Ltd, London, 1987.

Hastings, M. and Jenkins S., *The Battle for the Falklands,* Michael Joseph Ltd, London, 1983.

Hogben, A., *Designed to Kill,* Patrick Stephens Ltd, Wellingborough, 1987.

Holcomb, D.H., *Aircraft Battle Damage Repair for the 90s and Beyond,* Air University Press, Maxwell AFB, 1994.

Hough, R. and Richards, D., *The Battle of Britain,* Norton & Company, New York, 1989.

Jones, C., *A Security Police Strategic Vision for Operational Considerations into the Next Century: New Criminal Threats and the Australian Defence Force,* Air Power Studies Centre, Canberra, 1998.

Karnow, S., *Vietnam A History,* Century, London, 1983.

Keegan, J. and Holmes, R., *Soldiers: A History of Men in Battle,* Guild Publishing, London, 1985.

Kelly, O., *Brave Men Dark Waters: The Untold Story of the Navy SEALs,* Pocket Books, New York, 1993.

Kennett, L., *The First Air War 1914-1918,* The Free Press, New York, 1991.

Kreis, J., *Air Warfare and Air Base Defence 1914-1973,* Office of Air Force History, Washington D.C., 1988.

Lambert, A. and Williamson, A.C., (Eds), *The Dynamics of Air Power,* Joint Services Command and Staff College, Bracknell, 1996.

Macbean, J.A. and Hogben, A.S., *Bombs Gone: The Development and Use of British Air-Dropped Weapons from 1912 to the Present Day,* Patrick Stephens Ltd, Wellingborough, 1990.

Mahan, A.T., *Naval Strategy: Compared and Contrasted with the Principles and Practice of Military Operations on Land,* Greenwood Press, Westport, 1911.

Marolda, E.J., *By Sea, Air and Land An Illustrated History of the US Navy and the War in South East Asia,* Naval Historical Centre, Washington, 1994.

Marolda, E.J. and Schneller, R.J., *Shield and Sword,* Naval Historical Centre, Washington, 1998.

Middlebrook, M., *The Fight for the 'Malvinas',* Viking, London, 1989.

Molander, R.C., Riddile, A.S., Wilson, P.A., *Strategic Information Warfare: A New Face of War,* RAND Corporation, Santa Monica, 1996.

Murray, W., *Air War in the Persian Gulf,* Nautical and Aviation Publishing, Baltimore, 1996.

Murray, W., *Luftwaffe,* George Allen and Unwin, London, 1985.

Odgers, G., (Ed), *The Defence Force in the Relief of Darwin after Cyclone Tracy,* Australian Government Publishing Service, Canberra, 1980.

O'Neill, R., (Ed), *An Illustrated Guide to the Modern US Army,* Salamander Books, London, 1984.

Pile, F., *Ack-Ack: Britain's Defence Against Air Attack During the Second World War,* George Harrap & Co., London, 1949.

Royal Australian Air Force, AAP 1000, *The Air Power Manual, 3rd Edn,* Air Power Studies Centre, Canberra, 1998.

Royal Australian Air Force, AAP 1002, *The Operational Air Doctrine Manual,* Headquarters Air Command, Glenbrook, 1999.

Schneider, B.R. and Grinter L.E., (Eds), *Battlefield of the Future,* Air University Press, Maxwell AFB, 1998.

Schwartau, W., *Information Warfare: Chaos on the Electronic Superhighway,* Thunder's Mouth Press, New York, 1994.

Shlapak, D.A. and Vick, A., *Check Six Begins on the Ground',* RAND Corporation, Santa Monica, 1995.

Simpkin, R.E., *Race to the Swift: Thoughts on Twenty-First Century Warfare,* Brassey's Defence, London, 1985.

Shores, C. and Cull, B., *Bloody Shambles,* Grub Street, London, 1992.

Shultz, R.H. and Pfaltzgraff, R.L., *The Future of Air Power in the Aftermath of the Gulf War,* Air University Press, Maxwell AFB, 1992.

Stephens, A., *Defending the Air Sea Gap,* Australian Defence Studies Centre, Canberra, 1992.

Stephens, A., *High Noon of Air Power,* Air Power Studies Centre, Canberra, 1999.

Stephens, A., (Ed), *New Era Security,* Air Power Studies Centre, Canberra, 1996.

Stephens, A., (Ed), *The RAAF in the Southwest Pacific Area 1942-1945,* Air Power Studies Centre, Canberra, 1993.

Stephens, A., (Ed), *The War in the Air 1914-1994,* Air Power Studies Centre, Canberra, 1994.

Stewart, J.T., (Ed), *Airpower: The Decisive Force in Korea,* D. Van Nostrand, Princeton, 1957.

Stillion, J. and Orletsky, D., *Airbase Vulnerability to Conventional Cruise Missile and Ballistic Missile Attacks,* RAND Corporation, Santa Monica, 1999.

Story, W.C., *Third World Traps and Pitfalls – Ballistic Missiles, Cruise Missiles, and Land Based Airpower,* Air University Press, Maxwell AFB, 1995.

Sun Tzu, translated by Griffin, S.B., *The Art of War,* Oxford University Press, London, 1963.

Sutherland, B.E., *Evaluating Air Base Operability: An Australian Perspective,* Air Power Studies Centre, Canberra, 1997.

United States Air Force, *Air War Vietnam,* Arms and Armour Press, London, 1978.

United States Army War College, *Case Study – Operation Just Cause Panama 1989,* US Army War College, Carlisle Barracks, 1993.

Vick, A., *Snakes in the Eagle's Nest,* RAND Corporation, Santa Monica, 1995.

Walker, J.R., *Air-to-Ground Operations,* Brassey's Defence Publishers, London, 1987.

7Waltz, E., *Information Warfare: Principles and Operations,* Artech House, London, 1998.

Warden, J.A., *The Air Campaign,* Pergamon-Brasseys, Washington DC, 1989.

Waters, G., *Gulf Lesson One – The Value of Air Power: Doctrinal Lessons for Australia,* Air Power Studies Centre, Canberra, 1992.

Waters, G. and Casagrande, R., (Eds), *Operational Support Workshop,* Air Power Studies Centre, Canberra, 1995.

Waters, G. (Ed), *Line Honours – Logistics Lessons of the Gulf War,* Air Power Studies Centre, Canberra, 1992.

Westwood, C.J., *The Future is not what it used to be,* Air Power Studies Centre, Canberra, 1997.

Weizman E., *On Eagles Wings: The Personal Stories of the Leading Commander of the Israeli Air Force*, McMillan, 1976.

Williams, G., *The Power of Many: The Human Factor and Air Power,* Air Power Studies Centre, Canberra, 1996.

Wilson, D., *The Decisive Factor,* Banner Books, Melbourne, 1991.

INDEX

E

F

G

H

I

J

K

L

AIRBASE OPERABILITY

Since World War One air power has evolved into a potent weapon. It has been supported by constant technological improvement that has increased the range, precision and mass effect of air-delivered weapons. Consequently, air power is now a vital element of any campaign and this means that aircraft and their supporting infrastructure have become a centre of gravity.

One of the fundamental weaknesses of air power is its reliance on fixed airbases. These have been a target since World War One because it became readily apparent to early practitioners that it was easier to destroy the enemy's air force on the ground than in the air.

This book considers the history of attacks on airbases, the modern threats, and offers a broad range of options for increasing the survivability of air power's most vulnerable element.

AEROSPACE CENTRE

DPS JUN005/01