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Western Airborne Electronic Warfare
From Vietnam to the Gulf War
A Revolution or Rediscovery of Fundamental
Principles and Practices?

A Thesis presented in fulfilment of the requirements for a degree of Master of
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This thesis is dedicated to my father, John Cresswell.

England Expects.

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Chapter 1.**Introduction**

The purpose of this thesis is to study electronic warfare to determine whether experiences and practices from the Vietnam War to the Gulf War represent a revolution in electronic warfare or a rediscovery of fundamental doctrine. This is a contemporary question because the idea of a revolution in military affairs and an associated information revolution is pervasive in contemporary military literature. Military revolutions 'are generally understood to be changes in military technology, concepts of operation, and military organisations which, over the course of perhaps two or three decades, transform the conduct of war and make possible order-of-magnitude gains in military effectiveness.'¹ Another definition is that a military revolution 'occurs when technological change ... combined with organisational and operational change, result in a transformation in the conduct of warfare.'² This thesis questions whether a revolution in military affairs extends to a revolution in electronic warfare (EW). Have new ideas and new technology been applied in the last 40 years to produce a new form of electronic warfare operations?

This thesis will study the development of airborne electronic warfare after the introduction and development of integrated air defence systems that include surface-to-air missiles (SAMs). It will ascertain and evaluate changes in officially sanctioned beliefs and the collective body of thought on the best way to employ airborne electronic warfare practices, equipment and theory. Practical experience will be considered to highlight a number of consistent themes that arise and indicate continuities. These include problems with doctrine, problems with planning, and a reluctance to fully utilize EW. Inconsistent application of EW practices and equipment, a consistent lack of electronic protection below 10,000 feet, incremental development of EW equipment and practices, and recurrent system failures also arise as themes. These themes do not represent quantum improvements or order of magnitude changes that would be consistent with an EW revolution.

¹ Keith Thomas, The Revolution in Military Affairs Warfare in the Information Age Canberra: Australian Defence Studies Center 1997,p.3.

² Thomas, p.28.

The problems with doctrine are important because the way that electronic warfare is utilised is dependant upon doctrine. EW doctrine represents the collective best thinking about EW based upon historical and contemporary experience. Doctrine, based upon the official USAF Doctrine Center definition, is defined as 'the compilation of officially sanctioned beliefs about warfighting principles. Doctrine is the collective body of thought on the best way to employ a given system or perform a given task. Doctrine is a guide to action.'³ This thesis will show there are recurrent themes of problems with EW doctrine and the application of EW doctrine. Examples from the Vietnam and Gulf Wars indicate electronic warfare is usually applied in an uncoordinated and disjointed manner despite the absolute necessity of control of the air as explicitly stated in USAF doctrine.⁴

Recurrent system failures are indicated by the failure of part or all of electronic surveillance systems, electronic countermeasures and electronic counter-countermeasures systems. For example, repeated electronic surveillance failures have often contributed to electronic countermeasures failures. The inconsistent application of EW is indicated by the irregular use of EW equipment and practices. An example cited in this thesis is the use electronic countermeasures equipment on B-52 bombers but not on other aircraft that were actually used to attack targets protected by the North Vietnamese integrated air defence systems. This example also indicates the reluctance to use EW equipment, with seven years passing before fighter/bomber aircraft were fitted with electronic countermeasures equipment such as automatic Chaff dispensers.

This thesis will examine the development and use of electronic surveillance measures (ESM), electronic countermeasures (ECM) and electronic counter countermeasures (ECCM) in response to the threat posed to aircraft by surface-to-air missiles and integrated air defence systems. The time frame studied is from 1960 to 1992 and includes significant military events such as the air war in North Vietnam from 1965-1972, the Arab/Israeli wars 1967-

³ [www.dctrine.af.mil/library/misc/50 questions](http://www.dctrine.af.mil/library/misc/50%20questions)

1982, and the Gulf War 1991-92. These wars were chosen because they were major conflicts that involved common equipment and reasonably similar protagonists within the time frame studied. The time frame involved is also substantial enough to enable a good sample of EW development to be assessed. The outcome of these conflicts was significantly influenced by the role of EW in an effort to overcome surface-to-air missile threats that were part of an integrated air defence system.

The focus on Western aerial EW was chosen because of the current military dominance of the U.S. and the dominance of Western literature. The large amount of secondary literature available provided a valuable source of information and assuaged the need to research large amounts of primary literature. This thesis utilizes the literature available in a new way to consider the question of whether there has been a revolution in electronic warfare. The aim, to adopt Clausewitz's formulation, is to examine 'the essential content of what has long existed, and to trace it back to its basic elements,'⁵ to ascertain if there is a revolutionary process in action or a rediscovery of fundamental doctrine.

The following chapter of this thesis will provide a working definition of electronic warfare practices and techniques with some selected practical examples. A brief introduction to World War II general EW practices will be provided to establish a basis for comparison. The third chapter will consider the experiences and developments resulting from the U.S. air war against North Vietnam between 1965 and 1972. The sequence of events will be described because of the incremental and sequential nature of electronic warfare development over a protracted timeframe. Comparisons will be drawn between Vietnam, World War II and later conflicts. The fourth chapter will study the wars in the Middle East, starting with the Six Day War in 1967 and culminating in the invasion of Lebanon by Israel, in 1982. The fifth chapter will consider the Gulf War. To conclude this thesis, the sixth chapter will highlight

⁴ John A. Warden, *The Air Campaign* San Jose: Excel 1998, p.7.

⁵ Michael I. Handel, *Masters of War Classical Strategic Thought* London: Frank Cass & Co. LTD. 1996, p.21.

the consistent themes that indicate a lack of profound change in EW and a rediscovery of fundamental principles and techniques.

A review of literature indicates that electronic warfare, as a subject, forms only a component part of other studies. Specific EW texts such as Streetly's '*Airborne Electronic Warfare: History, Techniques and Tactics*'⁶ only deal briefly with the air war in Vietnam and not at all with the Middle East Wars. There is no general or detailed study of the development of EW in the years following the introduction of SAMs in an integrated air defence system. There is also no study that deals specifically with the development of EW in a revolutionary context. Most works dealing with EW predate 1980. There are a few very detailed and comprehensive works on the World War II period such as Price's '*Instruments of Darkness The History of Electronic Warfare*.'⁷ As the post war years progress however, the detail falls away until the Gulf War. Texts dealing with the Gulf War EW campaign are comprehensive and offer a wealth of technical information. Detailed technical information is also available in a number of books published in the 1960s, such as Schlesinger's '*Principles of Electronic Warfare*.'⁸ On the whole however there are gaps in the coverage of EW. This thesis, whilst by no means claiming to be infallible, will attempt to provide new insights, particularly in regard to the context of revolutionary EW development.

The starting point of this thesis is the introduction of the surface-to-air missile into combat in Vietnam in 1965. This technology provided a test for contemporary electronic warfare practices and provides an opportunity to observe any changes. The degree of change can be measured against subsequent air campaigns to gauge if electronic warfare meets the criteria for revolutionary change established by Keaney and Cohen. These are a quantum change in the means of waging war, a quantum change in lethality and pace of military operations, an emergence of new warrior elites utilizing

⁶ Michael Streetly, *Airborne Electronic Warfare: History, Techniques and Tactics* London: Janes Publishing 1988

⁷ Alfred Price, *Instruments of Darkness The History of Electronic Warfare* London: Macdonald & Janes 1977

⁸ R.J. Schlesinger, *Principles of Electronic Warfare* New Jersey: Prentice-Hall Inc. 1961

new forms of organizations and new dominant weapons.⁹ In short, this involves a transformation of warfare operations, technology and organization in a quantum gain. Comparing the INSTANT THUNDER EW campaign of the Gulf War to the ROLLING THUNDER campaign in Vietnam would seemingly meet the criteria because of the change in terms of power, speed, and capabilities of technology. This thesis proposes however, that electronic warfare does not meet the criteria for revolution proposed by Keaney and Cohen.

⁹ Thomas A. Keaney & Eliot A. Cohen, Revolution in Warfare? Air Power in the Persian Gulf Annapolis, Maryland: Naval Institute Press 1995, p.200.

Chapter 2. Introducing Electronic Warfare

This thesis focuses on airborne electronic warfare after the introduction of SAMs because of the ensuing renewed interest in electronic countermeasures.¹ Aerial electronic warfare dominates electronic warfare in general as a result of the destructive application of missiles against aircraft.² Aerial EW accounts for the overwhelming majority of total electronic warfare operations. More generally the use of air power and the idea of air superiority occupy a pre-eminent place in Western military thinking. According to Cooling 'The contest for air superiority is the most important contest of all, for no other operations can be sustained if this battle is lost.'³

One of the reasons for the prominence of airpower is an increasing reliance upon technical solutions for military problems. Technical solutions embodied in aircraft and electronic warfare allows Western nations to maximize their technical superiority because as Gray writes 'war is waged in by societies in ways appropriate to them.'⁴ Also airpower is inherently attractive because of the possibility of quick, clean action with a low probability of friendly casualties and the high probability of significant destruction of enemy assets.

Contemporary USAF Doctrine considers control of the air through air superiority an absolute necessity.⁵ It states that 'Control of the electromagnetic spectrum is an essential and critical objective.'⁶ Air superiority means to control airspace and to operate air forces anywhere and at anytime without opposition. Obtaining air superiority means 'eliminating by one means or another enemy forces that can interfere with air operations.'⁷ EW provides one means for doing this. 'Unfettered access to selected portions of the

¹ Price, p.253.

² Don Herskovitz, 'You Bet Your Life: Today's Missile Warning System' Journal Of Electronic Defence Vol. 23, No. 4 April 2000, p.51.

³ Benjamin F. Cooling, Case Studies in the Achievement of Air Superiority Washington: Center for Air Force History 1994, forward.

⁴ S. Gray, 'The Changing Nature of Warfare?' Naval War College Review Vol. 49 No. 2 (Spring) 1997, p.10.

⁵ John A. Warden, The Air Campaign San Jose: Excel 1998, p.7.

⁶ United States Air Force Doctrine Document 2-5.1 Electronic Warfare Washington D.C. HQ USAF 1999, p.5.

electro-magnetic spectrum is critical for weapon system effectiveness.⁸ Air superiority permits 'offensive air operations against an enemy target at a reasonable cost, and denies the same opportunity to the enemy.'⁹ Mason concludes that 'any nation intent on going to war ... must first secure the air above it.'¹⁰ But control of the air is possible without aircraft, as the Arab/Israeli War of Attrition will indicate, with surface to air missiles and an integrated air defence system challenging the dominance of aircraft.

Electronic warfare also saves lives by minimising losses of personal and equipment, and EW contributes to the military maxim that ideally wars 'should be won as quickly as possible at the lowest cost.'¹¹ Although the defender can rarely prevent penetration of its air space or inflict losses on every individual mission, 'even moderate losses can accumulate over time to make a protracted air campaign prohibitively expensive for the attacker.'¹² EW is one means to reduce these losses. Effective EW is also a force multiplier that saves military hardware from destruction. 'When EW actions are properly integrated with other military operations, a synergistic effect is achieved, losses minimized and effectiveness enhanced.'¹³

It is possible to quantify the effect of EW. The official USAF history of the Korean War, for example, stated that without electronic countermeasures, B-29 losses might have been three times greater than the 0.2 experienced.¹⁴ With the introduction of EW offensive and defensive operations loss rates dropped from one percent in World War Two to as low as 0.047 percent in the Gulf War.¹⁵ In the Vietnam War the application of ECM led to a decrease in air losses from 14 percent to 1.4 percent.¹⁶ This decrease occurred despite the

⁷ Warden, p.19.

⁸ United States Air Force Doctrine Document 2-5.1 Electronic Warfare, p.1.

⁹ Warden, p.21.

¹⁰ Anthony Mason, *Airpower A Centennial Appraisal* London: Brassey's 1994, p.278.

¹¹ Handel, p.xiv.

¹² R.A. Pape, *Bombing to Win Air Power and Coercion in War* Ithaca: Cornell University Press 1996, p.45.

¹³ United States Air Force Doctrine Document 2-5.1 Electronic Warfare, p.3.

¹⁴ Price, p.253.

¹⁵ Richard P. Hallion, *Storm over Iraq Air Power and the Gulf War* Washington: Smithsonian Institution Press 1992, p.196.

¹⁶ de Arcangelis, p.173.

increasing sophistication of SAMs and integrated air defence systems. Finally consistent loss rates of between 4-5% occur without EW protection, as examples in this study will indicate.

The decrease in aircraft loss rates reflects the changes and improvements in electronic warfare, which are part of an ongoing process of technological change and an evolution of doctrine and tactics. According to Knight a process of 'increasing sophistication in aids to navigation and target acquisition (radio, radar and infrared etc) has spawned a whole industry of countermeasures and counter-countermeasures.'¹⁷ The military historian Sir Michael Howard describes the technological processes associated with EW, as 'increasingly esoteric duels between technical experts.'¹⁸ One reason for developing this form of technology is that the most successful generals in the twentieth century 'tended to be those whose radio [and radar] interception services were able to bring them the promptest and most accurate information about the intentions of their opponents.'¹⁹ According to Howard, military success in the twentieth century 'ultimately goes to the side which is able to track the movements of its adversary, read his signals and electronic emissions while keeping its own secret.'²⁰ This is the essence of electronic warfare surveillance and countermeasures.

The essential elements of EW are the detection, denial, deception, disruption or destruction of electronic targets to protect friendly forces and degrade opposition forces. The Boer War provides an early example of detection and denial. At Cypherfontein in 1905 Boer guerrillas tapped into telegraph lines carrying British communications and used the information gathered to evade British forces.²¹ The Boers chose not to destroy or disrupt British communications because evasion in a guerrilla war is more important than the destruction of an enemy communication asset. Another example at the same time was the Russian navy's use of EW detection techniques to exploit

¹⁷ Michael Knight, Strategic Offensive Air Operations London: Brassey's (UK) Ltd. 1989, p.83.

¹⁸ Michael Howard, War in European History London: Oxford University Press 1976, p.134.

¹⁹ Howard, p.134.

²⁰ Howard, p.134.

²¹ J.P.R. Browne, & M.T. Thurbon, Electronic Warfare London: Brassey's (UK) Ltd. 1988, p.3.

Japanese navy wireless transmissions in the Russo-Japanese War (1904-05). Russian ships 'avoided trouble when they heard Japanese signals traffic before they were spotted.'²² The Russians also disrupted Japanese operations on several occasions by jamming the Japanese radio communications.

Operational success in any military operation depends upon a number of interdependent factors and electronic warfare is an increasingly important component of integrated military operations. EW does not win or lose battles in isolation, but 'can interfere with military operations just as effectively as lethal weapons, if one is proficient and the other is not.'²³ According to Schleher EW 'provides a method of neutralizing an enemy force (force divider effect) while simultaneously enhancing the power of friendly forces (force multiplier effect.)'²⁴ EW contributes to military operations 'by disrupting the enemy's command and communication, and by helping to reveal both his plans and his ability to carry them out.'²⁵ When combined with other intelligence sources, EW provides the tools to detect, deceive, disrupt or degrade an opponent's electronic systems by either destruction of enemy communications, command and control assets or deception and evasion methods.

At its most basic level EW is the 'use of electromagnetic energy to determine, exploit, reduce, or prevent hostile exploitation of the electromagnetic spectrum and concurrently retain friendly freedom of action in that medium.'²⁶ EW can be described as 'the interaction between two or more communications systems for the purpose of intentional interference,'²⁷ either for self-protection or the enemy's detriment. The first task associated with electronic warfare is the detection of targeted electronic emissions to obtain details of the enemy's position, and movements. EW exploits the enemy's electromagnetic

²² Browne & Thurbon, p.4.

²³ J.M. Collins, U.S.-Soviet Military Balance Concepts and Capabilities 1960-1980 Washington: McGraw-Hill Publications Co. 1980, p.233.

²⁴ D.C. Schleher, Introduction to Electronic Warfare Norwood, MA: Artech House Inc. 1986, p.1.

²⁵ Streetly, p.120.

²⁶ Collins, p.234.

²⁷ Schlesinger, p.1.

emissions 'in order to provide intelligence on the enemy's order of battle, intentions, and capabilities.'²⁸ The electronic order of battle details 'how many radars, radios and other emitters the enemy has, what their strengths and weaknesses are, where they are deployed, how they are organized or their readiness for war.'²⁹ Therefore determining this electronic order of battle is crucial for success.

Electronic warfare is usually separated into three subdivisions. The USAF Doctrine Document AFDD 2-5.1 *Electronic Warfare* identifies the current subdivisions of EW as electronic attack (EA), electronic protection (EP) and electronic warfare support (EWS).³⁰ In a slightly different and earlier interpretation, Gordon and Schleher identify three different major subdivisions within electronic warfare. They conclude that EW is organized into three major categories of Electronic Support Measures (ESM), Electronic Counter Measures (ECM) and Electronic Counter Counter-Measures (ECCM).³¹ For the purposes of this thesis the subdivisions, ESM, ECM and ECCM will be used.

Collins, Gordon and Schleher define Electronic Support Measures (ESM) as 'actions taken to search for, intercept, locate and immediately identify radiated electromagnetic energy for immediate threat recognition and the tactical employment of forces.'³² Electronic reconnaissance for ESM 'covers all active and passive techniques designed to detect transmissions and then derive information from them.'³³ ESM operates in the full range of environments and across the whole energy spectrum. ESM provides a source of information required for immediate decisions involving ECM, ECCM, avoidance, targeting and other tactical employment of forces. Consequently direction finding and classification of radio and radar emissions is an ESM technique.³⁴ The study

²⁸ Schleher, p.1.

²⁹ Neil Munro, *The Quick and the Dead* New York: St Martins Press 1991, p147

³⁰ United States Air Force Doctrine Document 2-5.1 *Electronic Warfare*, p.2.

³¹ Schleher, p.6.

³² D.E. Gordon, *Electronic Warfare: Element of Strategy and Multiplier of Combat Power* New York: Pergamon Press 1981, p.23.

³³ Streetly, p.120.

³⁴ Gordon, p.23.

of other countries' electronic countermeasures is also a part of ESM. These studies enable counter countermeasures to be developed and ensure that friendly electronic equipment can function as required without disruption by hostile ECMs and ECCMs.³⁵

Electronic Intelligence (ELINT) gathering is a key part of electronic surveillance and is important because 'The key to successful military operations is a thorough knowledge of enemy capabilities.'³⁶ ELINT is defined as the 'technical and intelligence information derived from foreign non-communications electromagnetic radiations.'³⁷ Concentrating on non-communications transmissions such as radar, 'ELINT embraces the whole field of electronic eavesdropping upon the electro-magnetic spectrum.'³⁸ Frequencies used by foreign radars and communications are identified by ELINT so countermeasures can be designed and developed. The various assets that gather ELINT include satellites, aircraft, ships and land based stations. One of the methods of gathering ELINT is provoking hostile radars into operation by entering contested airspace and recording the response with surveillance assets such as ships or aircraft.

Electronic countermeasures (ECM) are defined by Collins, Gordon and Schleher as 'action taken to prevent or reduce the enemy's effective use of the electromagnetic spectrum. ECM includes jamming and electronic deception.'³⁹ ECM targets communications networks, radar and missile guidance systems.⁴⁰ The primary requirements of effective ECM are the detection of active enemy radiation and establishing that it is desirable to engage the signal detected.⁴¹ The basic purpose of ECM is to degrade the performance of an enemy system.⁴² The tasks are to disrupt, deceive, or

³⁵ Peter Gudgin, *Military Intelligence A History* Surrey: Sutton Publishing Ltd. 1999, p.111.

³⁶ United States Air Force Doctrine Document 2-5.1 Electronic Warfare, p.20.

³⁷ Gudgin, p.111.

³⁸ Gudgin, p.111.

³⁹ Gordon, p.23.

⁴⁰ Gordon, p.155.

⁴¹ Schlesinger, p.2.

⁴² Schleher, p.109.

destroy opponents' sensors and systems and thus degrade the enemy's electronic systems effectiveness.

Electronic Countermeasures can be further refined into three sub-categories. These are Deception, Denial and Destruction. Deception is 'the deliberate radiation, reradiation, alteration, absorption, or reflection of electromagnetic energy in a manner intended to mislead a hostile force.'⁴³ Deception includes the use of transmissions to deceive or confuse an opponent. An example of deception from the Gulf War was the use of unmanned aerial vehicles (UAVs) to produce a radar signature of an attack aircraft. This drew fire from air defence assets and was used to activate air defence radars for identification and termination by anti-radiation missiles.⁴⁴

Deception includes the use of false returns through expendable electronic countermeasures such as flares or Chaff. Expendable ECMs are used only once and deployed from the platform that they are designed to protect. To deploy these countermeasures aircraft use ECM pods that are usually carried externally. Chaff and flares are generally used because they are the most inexpensive and effective of these expendable ECM.⁴⁵ Flares are designed to lure infrared seeking missiles away from the targets heat source. Chaff is designed to produce spurious radar returns. Chaff usually consists of a large number of radar reflecting metallic strips similar to tinfoil. They are dispensed into the atmosphere and resonate at the frequency of the radars they are attempting to confuse.⁴⁶ Chaff use can be very effective. In 1945 for example, both the massive use of Chaff and electronic jamming by Allied aircraft effectively 'swamped every counter-countermeasure fitted to the Wuerzburg and Mannheim fire-control radars,'⁴⁷ of the German air defence system.

Denial includes jamming opponent's radar and communications across the whole electronic spectrum. This includes support jamming by specialist aircraft. An early example of denial was the jamming of German

⁴³ Schleher, p.10.

⁴⁴ Keaney & Cohen, p.285.

⁴⁵ Schleher, p.178.

⁴⁶ Alfred Price, The History Of US Electronic Warfare Massachusetts: Lew A. Cummings Printing Co 1984, p.178.

communications by the French during World War I. During the Battle of Marne in 1914 the French employed a transmitter mounted on top of the Eiffel Tower and 'successfully jammed German wireless communications.'⁴⁸ The reason for jamming an opponent's communications or radar is to isolate that unit or component. The rationale for this is the disruption of command and control, which is the 'sine qua non of military operations. Without command, a military organization is nothing but a rabble.'⁴⁹

Electronic destruction includes attacking and destroying target radar, communications antenna, power sources and equipment with explosive devices. Described as hard-kill techniques, these originated during World War II when the Luftwaffe dive-bombers attacked the British Chain Home radars in 1940. This was the first example of what are now termed defence suppression "hard-kill" countermeasures.⁵⁰ Current destruction methods use High-speed Anti-radiation Missiles (HARM) to destroy radar systems. Once the radar is neutralised a conventional attack to destroy ancillary equipment and the missile launcher is undertaken, usually with cluster bombs.

Electronic Counter Countermeasures (ECCM) are defined by Collins, Schleher and Gordon as 'actions taken to ensure friendly use of the electromagnetic spectrum against EW.'⁵¹ This is a form of electronic protection that involves actions taken to protect personnel, facilities and equipment from any effects of friendly or enemy employment of EW. ECCM seeks to reduce degradation that neutralizes or destroys friendly combat capability. An example of current counter countermeasures is the use of multi frequency radar and communications equipment that utilise a number of pre-selected frequencies in an algorithmically generated order. Using multiple frequencies reduces the time spent transmitting on any one frequency and reduces the possibility of jamming, interception or interference, whether intentional or accidental.

⁴⁷ Price, p.187.

⁴⁸ Van Creveld, p.271.

⁴⁹ Warden, p.44.

⁵⁰ Price, p.11.

⁵¹ Gordon, p.23.

This thesis will cite specific equipment and operations from World War II as a point of comparison for the development of EW. Operations such as the bombing campaign against Germany and operation OVERLORD in particular, reflected the best practices derived from years of experience and testing under both laboratory and combat conditions. According to Glister OVERLORD was 'the classic large-scale joint force operation.'⁵² World War II was a period of intense and profound progress for electronic warfare. EW development in World War II was a systematic, comprehensive and concerted effort to overcome ground and air-to-air threats that were part of an integrated air defence network. The problems dealt with in World War II would recur in the suppression of air defences in the period studied in this thesis. World War II therefore provides a useful benchmark against which subsequent developments could be measured.

The OVERLORD electronic warfare plan of 1944 encapsulated the best practices and theory, derived from experiences during the war. OVERLORD plans sought to use overwhelming force in a rapid operation to dominate the electronic spectrum.⁵³ The priorities were to destroy as many German radar stations as possible and to prevent the enemy obtaining early warning of, and accurate plots on, approaching forces. Another objective was to reduce and confuse the enemy's early warning system, thus delaying the arrival of fighters. Further objectives included interfering with enemy fighter radio control voice communications, thus affecting both the movement of fighters into the area of operations and the directing of intercepting fighters. The final objective was to produce diversionary threats, and thereby divide the enemy's available fighter effort.⁵⁴

OVERLORD electronic warfare operations were designed to be comprehensive and systematic. The 92 radars in the German West Wall were targeted with destruction or deception. The entire radar network was isolated

⁵² Herman L. Glister, *The Air War In Southeast Asia Case Studies of Selected Campaigns* Alabama: Air University Press 1993, p.24.

⁵³ Price, p.116.

using ESM and a detailed electronic order of battle was established, refined and maintained⁵⁵. The majority of radars were destroyed by a systematic campaign of high and low level attacks by fighters and heavy bomber aircraft. 2,000 sorties by Typhoons and Spitfires of the 2nd Tactical Air Force destroyed all but 16 German radars.⁵⁶ Those radars not destroyed were jammed. Feint attacks were used to draw enemy fire and interceptor aircraft. Feint attacks also provided a level of confusion and a complex air defence problem for defenders. A complete invasion fleet with associated bombing aircraft was replicated using bombers dispensing Chaff and 'Moonshine' equipment that re-radiated radar signals to give false returns.⁵⁷ In operations TAXABLE and GLIMMER all air to ground communications were jammed.

Some specific operations from World War II have a direct relevance with the period studied in this thesis. These include the breaching of linear air defences and operating airborne early warning systems. For example, after the loss of France as a result of the D-Day operations, the opportunity existed to exploit a gap in the German air defence early warning system. From September 1944 all RAF bombers attacking strategic targets in Germany were routed through the radar corridor.⁵⁸ Also Mosquito fighter aircraft equipped with fuel drop tanks were able to escort bombing aircraft, thus providing fighter protection and seriously degrading the German air defence system. Organic aerial early warning devices were fitted to Mosquito aircraft to enhance the ability to detect and attack German interceptor aircraft. As well as providing fighter escorts, 100 Group provided escort-jamming aircraft and carried out fake attacks to draw air defence fighters away from the bombing groups. These tactics also exhausted German air defences.⁵⁹ Attacks were also undertaken at high and low altitudes in day and night operations that used varied routes and exploited known defence radar blind spots.

⁵⁴ Price, p.116.

⁵⁵ Alfred Price, Instruments of Darkness The History of Electronic Warfare London: Macdonald & Janes 1977, p.200.

⁵⁶ Price, p.201.

⁵⁷ C. Latham, & A. Stobbs, Pioneers of Radar Gloucestershire: Sutton Publishing 1999, p.191.

⁵⁸ Price, p.219.

⁵⁹ Streetly, p.12.

Another specific operation from World War II that has a direct relevance with the period studied in this thesis was operation GAMORAH. This was the air battle for Hamburg that started on July 24th 1943.⁶⁰ GAMORAH was the first operational deployment of Chaff in an operation that was planned to produce a radar free air corridor through which bombers could enter and exit the target zone.⁶¹ Before this tactic was employed, Bomber Command lost 6% or fifty of its attacking aircraft against Hamburg. With the use of a radar free air corridor and Chaff, the loss rate was 12 aircraft or 1.5%.⁶²

The World War II benchmark, for comparison of electronic warfare practice and principles, consisted of the full range of electronic surveillance, electronic countermeasures and electronic counter-counter measures. The idea that control of the electro-magnetic spectrum was vital was recognised from Prime Minister Churchill down.⁶³ The full range of targets including electronic navigation systems,⁶⁴ fighter control communications⁶⁵, missile guidance and unmanned aerial vehicles guidance systems⁶⁶ were systematically and successfully electronically attacked. EW operations were practiced with the full range of tactics, techniques and equipment that including jamming, Chaff and destruction of electronic targets. An example was the co-ordinated effort prior to D Day, where Bomber Command dealt with electronic targets that were outside the range of fighter/bombers. At the end of World War II

⁶⁰ Allan Michie, 'The Radar Screens that told lies' Secrets and Stories of the War London: Readers Digest 1963, p.563

⁶¹ Latham & Stobbs, p.197.

⁶² Price, p.158.

⁶³ Price, p.19.

⁶⁴ Latham & Stobbs, p.190.

⁶⁵ Streetly, p.27.

⁶⁶ <http://www.accessweb.com/users/mconstab/v1.htm>

however, Western electronic countermeasures 'fell into disuse.'⁶⁷ Electronic warfare 'was allowed to atrophy rapidly'⁶⁸ because there was no threat until the Korean War. During the Korean War, World War II equipment was taken out of storage and applied against the limited North Korean air defences. Following the Korean War the electronic warfare hiatus continued until the events of the Vietnam War forced changes.

⁶⁷ Price, p.251.

⁶⁸ Streetly, p.33.

Chapter 3 Electronic Warfare Operations in Vietnam 1964-1972

On August 4th 1964 aircraft of the Seventh Fleet carriers *Constellation* and *Ticonderoga* retaliated against perceived North Vietnamese aggression by attacking motor torpedo boats in the Gulf of Tonkin. Four harbours and oil storage depots were also attacked.¹ This was the start of an air war against North Vietnam that had three primary political objectives. These were to provide a morale boost for Saigon, to force Hanoi into ceasing its support for insurgency and to gain a bargaining position from which the U.S. could help keep a non-communist government in power in the South.² To achieve these objectives, air power was used to bring to bear 'America's outstanding military strength--the massive firepower made available through advanced technology and material wealth.'³ It is ironic in the context of this electronic warfare thesis that the perceived threat to U.S. ships may have come from spurious electronic signals.⁴

This chapter will examine the contribution of the air war in North Vietnam to the development of electronic warfare. It will consider the application of electronic warfare doctrine, strategy and the use of new technology. It will ascertain if electronic warfare in the Vietnam War meets the conditions of revolutionary application of new ideas and technology. This chapter will also consider new capabilities and limitations to establish if there is continuity with later conflicts and where departures and discontinuities exist. This chapter will examine themes that emerge from Vietnam. These themes include problems with doctrine and problems with planning. An initial reluctance to use electronic warfare was followed by an incremental adoption of EW equipment and tactics. A process of relearning lessons was coupled with recurrent systems failures and the lack of EW protection at low altitudes.

¹ M.J. Armitage & R.A. Mason, Air Power In The Nuclear Age, 1945-82 Theory and Practice London: Macmillan Press Ltd. 1983, p.84.

² R. Littauer & N. Uphoff, (eds) The Air War in Indochina Boston: Beacon Press 1972, p.34.

³ Littauer & Uphoff, p.1.

⁴ John Prados, The Hidden History of the Vietnam War Chicago: Ivan R. Dee Inc. 1995, p.53.

In accordance with U.S. doctrine, the U.S. Joint Chiefs of Staff (JCS) advocated a rapid and overwhelming strategic air campaign against North Vietnam in JCSM-955-64 dated 14 November 1964.⁵ USAF bombing doctrine was 'geared to a fast paced conventional war, and the conviction that such a doctrine is appropriate for any kind of war [permeated] the service.'⁶ The Joint Chiefs proposed air combat operations that used a systematic application of force on a selected series of vital targets. The objective was the 'progressive destruction of the enemy's war-making capacity.'⁷ Against the advice of the Joint Chiefs, the White House chose a policy of a limited strategic air campaign against North Vietnam.⁸ This policy totally contradicted contemporary military doctrine and strategy, and the adopted strategies were flawed.⁹ The subsequent gradual escalation wasted the U.S. military advantage.¹⁰

To prosecute the air war against North Vietnam the U.S. conducted a series of major bombing campaigns. These were ROLLING THUNDER from March 1st 1965 to October 31st 1968, FREEDOM TRAIN in April 1972, LINEBACKER I from May 10th to October 23rd 1972 and LINEBACKER II from December 18th to 29th 1972. In accordance with policy, ROLLING THUNDER was conducted 'to send signals of strength and resolve to the North Vietnamese.'¹¹ ROLLING THUNDER was a limited and measured air campaign undertaken primarily by fighter/bombers rather than heavy bombers such as the B-52 that carried ECM equipment. The political and diplomatic conditions that 'applied during 1965-1968 made a 1972-style air campaign impossible.'¹² Instead of ROLLING THUNDER dissuading Hanoi from further aggression, the air campaign prompted the installation of a comprehensive and efficient air defence system.

⁵ Neil Sheehan, Hedrick Smith, E.W. Kenworthy, & Fox Butterfield, The Pentagon Papers New York: Bantam Books 1971, p.533.

⁶ R. Mason, p.65

⁷ Richard Nixon, No More Vietnams New York: Arbor House 1985, p.148.

⁸ Sheehan, p.210.

⁹ Harry G. Summers, On Strategy II A Critical Analysis of the Gulf War New York: Dell Publishing 1992. p.46.

¹⁰ Nixon, p.87.

¹¹ Phillip S. Meilinger, Ed. The Paths of Heaven The Evolution of Airpower Theory Maxwell AFB, Alabama: Air University Press 1997, p.334.

Targets of ROLLING THUNDER included radar sites, airfields and ammunition storage areas.¹³ However, contrary to a doctrine of rapid and overwhelming force, in 1965 no attacks were permitted within a 30 nautical-mile radius of Hanoi or within a 10 nautical-mile radius of Haiphong and in a buffer zone along the Chinese border.¹⁴ The strict rules of engagement that governed what ground targets could be attacked and when air targets could be engaged, provided the North Vietnamese sanctuaries from air attack. The exclusion zones around Hanoi allowed the North Vietnamese to station aircraft close to Hanoi and build an extensive radar and SAM network centred on the city. The early warning radars that were part of the system enabled air defence assets to be active and ready for U.S. aircraft. Without the ability to destroy the early warning radars in particular, existing organic electronic countermeasures were fatally disadvantaged. No subsequent EW strategy or equipment could reasonably cope with limitations imposed by policy imperatives.

An indication of planning problems in ROLLING THUNDER was the division of North Vietnam into a series of "Route Packages." Initiated in November 1965, Route Packages divided North Vietnam into six designated areas that were assigned to specific services. Whilst easier to administer, the subsequent repetitive operations weakened U.S. electronic deception and denial countermeasures. Repetition enabled the North Vietnamese air defence forces to predict the type of aircraft, probable location and times of U.S. air attacks 'sometimes even down to the hour.'¹⁵ When used in conjunction with early warning radars, the entire Northern air defence system 'was alerted, and usually their fighters were airborne minutes before our forces started their penetration.'¹⁶ This eliminated any chance of surprise or effective application of denial countermeasures. Clear communications further

¹² Prados, p.185.

¹³ David Middleton, Air War Vietnam London: Arms and Armour Press 1978, p.227.

¹⁴ Nixon, p.87.

¹⁵ Cooling, p.515.

¹⁶ William W. Momyer, Airpower in Three Wars (WWII, Korea, Vietnam) Washington: U.S. Government Printing Office 1978, p.23.

degraded electronic denial with the North Vietnamese knowing 'everything there was to know'¹⁷ about U.S. attacks.

Inconsistent use of electronic destruction resulted from the restrictive rules of engagement. Restrictions on interdiction in designated zones enabled North Vietnam to develop an integrated air defence system. SAMs, radar controlled anti-aircraft artillery (AAA) and new interceptor aircraft were introduced with Chinese and Soviet assistance. The air defence system evolved from 'a fairly primitive capability in 1965 to the most concentrated and deadly air defence in history by 1972.'¹⁸ In 1965 the North Vietnamese air defences were 'in an embryonic state and could have been destroyed with no significant losses.'¹⁹ However, President Johnson prohibited attacks on missile sites to avoid the possibility of killing any Soviet personnel.²⁰ The destruction and elimination of the limited North Vietnamese air defences would have precluded the need for subsequent SAM countermeasures and seriously degraded AAA capabilities. In 1965 the intact North Vietnamese air defences were able to launch 180 SAMs and destroy 11 US aircraft.²¹

Improvements in North Vietnamese early warning and height finding radar capabilities resulted in U.S. jamming systems failure. In 1965 early warning radars increased from 20 to 31 and were controlled by the three major ground controlled intercept (GCI) radar sites at Bac Mai, Phuc Yen and Kep.²² It was impossible to jam all of these radar because they operated on different frequencies and directional jamming assets were limited. Jamming was restricted to specific GCI radar but radar included so many redundancies that it was almost always sufficient to provide good GCI control.²³ Also the SA-2 radar incorporated an early operational bi-static system. This separated the transmitting antenna from the receiving antenna and provided the ability to

¹⁷ W. Scott Thompson, & Donaldson D. Frizzell, The Lessons of Vietnam New York: Crane, Russak & Company, Inc. 1977, p.143.

¹⁸ Middleton, p.24.

¹⁹ Momyer, p.118.

²⁰ Nixon, p.88.

²¹ Armitage & Mason, p.107.

²² Momyer, p.118.

²³ Momyer, p.119.

utilise other radars emissions for target acquisition.²⁴ The North GCI radar capability and coverage extended to all of North Vietnam and much of the Gulf of Tonkin.²⁵ There was thus 'little opportunity to surprise or deceive the North Vietnamese about strike force targets or times.'²⁶

Technical difficulties were compounded by incremental development with both sides initially being guilty of 'fighting at jet age speeds with horse and buggy tactics.'²⁷ Sight was the principal method of target acquisition and verification for engagements by the U.S. until the introduction of significant numbers of B-52s in the LINEBACKER II campaign. Rules of engagement limited the destruction of North Vietnamese aircraft unless visual contact was achieved. Optical verification limited targets and 'affected the tactics.'²⁸ The expansion of North Vietnam's anti-aircraft capability was the principal tactical factor that induced change. The U.S. had to relearn the basics and paid a terrible price, in terms of aircraft losses and casualties, in doing so.²⁹ The expansion of North Vietnam's anti-aircraft capability and the introduction of SAMs influenced strategy and doctrine and resulted in new procedures and tactics being adopted by both sides in Vietnam.

The primary threat to US aircraft in North Vietnam in 1964 came from radar controlled anti-aircraft artillery (AAA). US aircraft practiced simple electronic denial, avoiding radar guided AAA by simply flying above its effective range. Although the early warning/fire control radar could track the aircraft, the AAA shells could not reach them. Flying outside the effective range of AAA denied the North Vietnamese the ability to engage but the U.S. lost total control of the air as radar controlled AAA dictated operational altitudes in certain areas. This unwillingness to engage early warning/fire control AAA radar indicated a reluctance to use EW and inconsistent application by electronically attacking only the missile threat. This has not changed and remains a feature of EW

²⁴ de Arcangelis, p.171.

²⁵ Middleton, p.26.

²⁶ Momyer, p.231.

²⁷ Middleton, p.210.

²⁸ Middleton, p.212.

²⁹ Summer, p.106.

operations. The North's defences were relatively 'sparse to nonexistent'³⁰ in 1964, with no SAM systems, only about 700 AA guns, 20 early warning radars, and four fire control radars with very little definitive tracking capability. The AAA coverage in North Vietnam was limited to key population areas and restricted to altitudes below 20,000 feet.³¹ With subsequent improvements, in the period 1965-66 approximately 500 U.S. aircraft were lost to North Vietnamese air defences.³²

The Vietnam War was 'the first occasion when modern combat aircraft were faced by electronically guided missiles,'³³ in combat and the U.S. was unprepared. Before the SA-2 Guideline missile was used operationally for the first time by North Vietnam, U.S. aircraft avoided radar controlled enemy ground fire by simply flying above it. Countermeasures other than denial through avoiding low altitudes or exploiting gaps in radar coverage were unnecessary because there was no threat. However, aircraft were forced to lower altitudes by the introduction of the SA-2. There, without countermeasures, aircraft became vulnerable to AAA and automatic weapons. Restricted zones enabled SA-2s to be positioned in areas safe from U.S. attack but could still give protective coverage. With a 17-mile effective firing range and a safety zone of up to ten miles around Hanoi, SA-2s could effectively engage targets up to 27 miles from Hanoi. Also, despite intense reconnaissance 'it was practically impossible to determine precisely where the SAMs would be in advance of any given mission,'³⁴ thus simple avoidance was extremely difficult. In terms of human lives, one pilot was being lost for every forty sorties³⁵ because of the missiles.

The USAF was unprepared for an electronic warfare campaign or for missile related combat. The 1964 exercise "DESERT STRIKE", conducted in the Californian desert, indicated that U.S. aircraft could not operate in a SAM

³⁰ Middleton, p.50.

³¹ Middleton, p.215.

³² Meilinger, p.351.

³³ Martin Van Creveld, The Sword and the Olive: A Critical History of the Israeli Defence Force New York: Public Affairs Perseus Books Group 1998, p214

³⁴ Momyer, p.123.

³⁵ Sheehan, p.580

protected environment. DESERT STRIKE and the subsequent experiences of the Vietnam War demonstrated 'the need for special equipment and tactics to counter SAMs.'³⁶ Despite DESERT STRIKE and Francis Gary Powers U-2 being shot down by an SA-2 in 1960, the U.S. did not anticipate the threat posed by SAMs. When American strike aircraft began operating on the North, they lacked even rudimentary ESM radar receivers and SAM warning receivers. Experience in Korea indicated that in a limited war such as Vietnam, tactical electronic warfare would count heavily. However, the emphasis on long-range nuclear strike by heavy bombers meant that tactical EW was neglected and it took the losses in the air war over North Vietnam to prompt changes.³⁷

The primary missile threat to U.S. aircraft in North Vietnam was the Soviet SA-2 radar guided missile. SA-2s had an operational ceiling of 20,000 feet and used a proximity-fused fragmentation warhead. This meant that the missile did not have to hit the target aircraft, but only get close enough for the blast fragments to inflict enough damage to cause the aircraft to crash. The efficacy of possible countermeasures was reduced because the missile only needed an approximate location and altitude, which could be supplied by accessible collocated radar. SA-2s were initially deployed in a 30-40 mile circle centred on Hanoi with 20-30 active SAM battalions. Each had four to six launchers, and about 100 ready-to-use missiles-on-launchers were deployed at a time.³⁸ SA-2s were operated with the assistance of Soviet technical advisers and the North Vietnamese made their first kill of the war on July 23, 1965.³⁹

The initial U.S. response was limited because EW equipment for the fighter/bombers was inadequate. ECM equipment for individual fighter/bombers was not available and the U.S. doctrine 'preferred to trade performance for ECM equipment.'⁴⁰ There was continued resistance when

³⁶ Momyer, p.136.

³⁷ Streetly, p.35.

³⁸ Momyer, p.125.

³⁹ Streetly, p.81.

⁴⁰ Momyer, p.126.

ECM pods were introduced because they initially 'worked so intermittently that operational commanders had little confidence in them.'⁴¹ External ECM pods also increased the weight of the aircraft and decreased the bomb payload that could be carried whilst increasing fuel consumption. The lack of ECM equipment for fighters was also based upon the precedent of ECM equipment being used predominantly by bombers during the Korean War and World War II. One reason for this was the perceived lack of threat to fighters and another was the size of existing equipment that was generally too large and complex for fighter aircraft. The task of developing appropriate systems was 'assigned to leading U.S. companies'⁴² in 1966, only after losses increased.

In reaction to the new and serious threat posed by missiles, top-level meetings to study the problem were held in 1965⁴³ and induced the U.S. to develop specialised EW aircraft and tactics.⁴⁴ Military leaders 'unanimously acknowledged that the only way of dealing with the new threat was to develop airborne electronic warfare systems.'⁴⁵ A re examination of AA suppression tactics was undertaken and resulted in an increased reliance on electronic protection and suppression, coupled with antiradar missiles to destroy missile launch sites.⁴⁶ In an incremental process, key aircraft systems deployed included standoff jamming aircraft and airborne early warning aircraft. Organic EW equipment and anti-radiation missiles coupled with electronic combat aircraft such as the F-105G Wild Weasel flying "IRON HAND" missions⁴⁷ were introduced. F-105 IRON HAND flights were employed to attack SAM sites before the bulk of the attacking planes entered the target zone.

On November 23rd 1965 an F-105 IRON HAND mission successfully flew using terrain masking in order to reach the target undetected and destroyed two missile sites.⁴⁸ This was one of the significant EW developments of the

⁴¹ Momyer, p.126.

⁴² de Arcangelis, p.160.

⁴³ de Arcangelis, p.160.

⁴⁴ Cooling, p.511.

⁴⁵ de Arcangelis, p.160.

⁴⁶ Hallion, p.20.

⁴⁷ Hallion, p.57.

⁴⁸ Middleton, p.235.

war and provided an example that would be exploited using specialist aircraft such as the F-111 and cruise missiles in the future. Flying low and fast reduced the time and opportunity for early warning, GCI and fire control radar to target an aircraft. Aircraft could effectively fly below the radar horizon and hide in the ground clutter of radar reflections from landforms. The time over target was also reduced, with radars only having seconds to acquire targets, instead of minutes. Problems arose because Shrike anti-radiation missiles needed active radars to home on. Penetration had to be at high altitude to activate the air defence system and expose the missile radar systems. The equipment and co-ordination necessary to independently activate the radar system and then accurately task the radar killers did not exist.

IRON HAND aircraft were the first into target areas usually entering five minutes before the main force and were the last out.⁴⁹ When radar activity was located, F-105s would attack it using Shrikes. The missile attack was followed immediately with an attack by F-4s or F-105s loaded with conventional weapons.⁵⁰ In early 1966 the Wild Weasel aircraft armed with Shrikes, 2.75-inch rockets and 20mm cannon 'offered the best solution at the time against SAMs.'⁵¹ To further counter AAA and SAM radars, new cluster bomb units (CBU) flak suppression weapons were introduced. These proved to be 'highly successful,'⁵² because cluster bombs destroyed the whole SAM site. The continued use of air defence suppression tactics such as IRON HAND missions 'drastically reduced SAM effectiveness.'⁵³

The use of Wild Weasel aircraft armed with Shrike missiles prompted a progressive process of countermeasure and counter countermeasure. The North Vietnamese responded to the Shrike with the use of co-ordinated SAM radars with long-range EW/GCI radars, thus eliminating the tracking phase needed to acquire the aircraft. SAM radars could be left in standby "dummy load" and activated at the last moment to guide the missiles. The U.S.

⁴⁹ Mike Gilroy 'First In ... Wrong Way Out A Wild Weasel Saga' Journal of Electronic Defence Vol. 22, No. 10. October 1999, p.35.

⁵⁰ Momyer, p.131.

⁵¹ Middleton, p.239.

⁵² Middleton, p.52.

response to dummy load operations was the use of ECM pods. These pods could theoretically totally jam the enemy missile guidance radar, so that no ranging and bearing information could be determined. The pods improved bombing accuracy and reduced aircraft loss rates. ECM pods allowed aircraft to 'roll in on targets from medium altitudes 12,000 to 15,000 feet-giving more positive target identification and improved weapons delivery accuracy.'⁵⁴ If flights maintained proper distances and altitudes, ECM pod coverage forced in North Vietnamese to use inaccurate barrage firing with SAMs and AAA.

In conjunction with missile air defences, North Vietnamese MIG aircraft developed as another significant threat to U.S. aircraft. The MIG threat also provoked an incremental process of measure and countermeasure. The key to dealing with the MIG threat was the development of the EC-121 COLLEGE EYE air early warning (AEW) aircraft in conjunction with the F-4. AEW aircraft gave the U.S. improved electronic detection capabilities to augment fighters onboard systems. The principles and practices of AEW were first used with 'Monica,' a fighter early warning radar system deployed by the British in 1943.⁵⁵ AEW aircraft provided airborne control and intercept capabilities far superior to individual fighter capabilities and ground-based control. AEW aircraft could warn F-4s of MIG activity and direct combat air patrols into favourable engagement positions. The EC-121M Rivet Top aircraft, which was deployed in late 1967, could detect MIG on take-off and report their position to USAF aircraft in the area. This allowed U.S aircraft to avoid or engage MIGs as required. Rivet Top's ability to detect MIGs as they took off, 'proved to be decisive,'⁵⁶ when used in combination of F-4Cs armed with Sidewinder air-to-air missiles.

Another innovation in the incremental process of measure and countermeasure was the use of EB-66 Destroyer as a specialised airborne electronic jamming aircraft to support strike packages. The use of airborne jamming using a converted bomber had precedent in World War II and the

⁵³ Cooling, p.533.

⁵⁴ Middleton, p.240.

⁵⁵ Price, p.139.

EB-66 reintroduced this idea. The difference was the World War II bombers fitted with jammers, such as 'Mandrel,' flew with the attacking squadrons, thus providing jamming coverage over the target areas.⁵⁷ The EB-66Cs were also used to locate North Vietnamese radar sites, determine their function, and identify their frequency to determine the enemy electronic order of battle. An EB-66 was the first to intercept radar signals used to guide SAMs on July 10th 1965, confirming the operational status of North Vietnamese SAM sites. The EB-66 was too slow and lightly armed to be risked being flown with strike packages and there were also too few of these specialised EW aircraft available to be risked. Limits imposed by lack of specialised EW aircraft were an impediment that persisted through to the Gulf War.

The deployment of fourteen EB-66s was important because they reduced the effectiveness of the North Vietnamese GCI and fire control radars.⁵⁸ However, there were problems. The EB-66s were positioned on the outer limit of the 30-mile restricted area to cover the approach and withdrawal routes to targets. Two aircraft flew elliptical orbits so they could jam SAM acquisition, early warning, and GCI radars. The EB-66 provided effective coverage into and out of Hanoi by flying in the northwest and southwest quadrants.⁵⁹ From late 1966 to mid 1967 it was possible to position EB-66s at 25,000 feet, if protected from MIGs with F-4 fighter cover.⁶⁰ A problem of distance from the target of jamming arose for the EB-66 because they were prone to attack from MIGs and SAMs. As the SAM and MIG threat increased, the EB-66s elliptical orbits had to be moved further into Laos and out over the Gulf of Tonkin, away from the threat zone. 'As a consequence, the effectiveness of the EB-66 declined.'⁶¹ The problem of standoff jamming would not be resolved until jamming aircraft could accompany attacking aircraft.

The limitations of the EB-66s were overcome with the development and acquisition organic jamming capabilities. In October 1966 the F-105s received

⁵⁶ Cooling, p.528.

⁵⁷ Price, p.112.

⁵⁸ <http://194.205.16.17/ency/B/B-66.asp>

⁵⁹ Momyer, p.220.

⁶⁰ Momyer, p.222.

external barrage jamming pods. The effect of the introduction of jamming pods 'combined with the proper formation of F-105s, was cumulative; when coupled with the spot jamming done by the EB-66s, the impact on North Vietnamese radars was dramatic.'⁶² The ECM pod introduction was 'soon recognised as the most important new development,'⁶³ in Vietnam. The penetration altitude for all aircraft could be increased to 15,000 feet. Higher altitudes provided better target acquisition, made the control of formations easier and avoided most of the AA artillery fire.⁶⁴ Although losses to AAA 'dropped considerably,'⁶⁵ AAA activity still dictated operational altitudes and the North Vietnamese controlled the airspace below 15,000 feet. The problem of height restrictions would remain unresolved for the rest of the century.

Another incremental improvement was the development and introduction of ESM equipment for F-4Cs. ESM equipment included a cockpit radar-warning device that indicated SAM radar was active and gave an approximate direction and range to target.⁶⁶ Radar-warning devices reintroduced radar detection capabilities of World War II equipment such as 'Boozer,' a passive radar-warning receiver.⁶⁷ The Radar Homing and Warning (RHAW) sets 'had a profound effect on both the counter air and the interdiction missions.'⁶⁸ Radar warnings were provided by a series of lights that indicated a missile was in preparation for launch and indicated when it had been launched.⁶⁹ Once detected, the standard practice to avoid the SA-2 was to dive toward it because the missile could not manoeuvre as well as the aircraft. Although the RHAW was effective, it could be overwhelmed by multiple missile activations over heavily defended areas such as Hanoi.

The North Vietnamese responded to improvements in U.S. EW equipment and methods by more aggressive use of their fighters during August. To

⁶¹ Momyer, p.222.

⁶² Cooling, p.356.

⁶³ Momyer, p.127.

⁶⁴ Armitage & Mason, p.107.

⁶⁵ Momyer, p.223.

⁶⁶ Armitage & Mason, p.108.

⁶⁷ Price, p.139.

⁶⁸ Momyer, p.127.

⁶⁹ Momyer, p.128.

counter the rising threat from the F-105s, the NVAF also introduced the MIG 21 into service. The MIGs flew from protected areas such as bases at Hoa Lac, Kep, and Kien Am.⁷⁰ The North Vietnamese used their MIGs 17s, 19s and 21s, 200 SAM sites and 7,500 AAA in coordinated packages. The MIGs covered the approach and departure routes of USAF strikes whilst the SAMs and AAA covered the area adjacent to the targets. MIGs were always under control of ground control intercept (GCI) radar. The radar systems high degree of redundancy meant that the US was unable to deceive or surprise it.⁷¹ If a radar site was jammed or attacked, another could provide warning and targeting information to other elements of the system. GCI radars were thus able to direct MIGs towards incoming F-105s, forcing the F-105s to drop their bomb loads prematurely.

The solution adopted was to attack and destroy the MIG threat. On January 2nd 1967 the USAF undertook Operation BOLO to lure the MIGs out their sanctuaries and into a position to be destroyed by F-4Cs. Using EW deception, F-4Cs were equipped with ECM jamming pods to mimic the F-105s and flew in formations to appear on enemy radar as a normal F-105 attack flight. Deception was enhanced using aircraft call signs and all other indicators that gave 'the impression that the penetrating force was just another daily strike force.'⁷² Three flights of F-4Cs from 8th Tactical Fighter Wing then engaged and shot down seven MIG 21s. On January 6th two more MIG 21s were shot down. On April 24th F-105s and F-4Cs carrying jamming pods and guns pods destroyed nine MIGs on the ground at Kep, thirty miles northeast of Hanoi. Operation BOLO 'showed that MIG-21s could be defeated by F-4Cs,'⁷³ but MIGs and particularly the MIG-21 continued to be a significant threat. Restrictions against attacking North Vietnam's airfields were subsequently lifted briefly in 1967.⁷⁴ The result was the destruction of 26 MIGs on the ground and a reduction of the MIG threat. Coupled with AEW this

⁷⁰ Cooling, p.533.

⁷¹ Momyer, p.141.

⁷² Momyer, p.145.

⁷³ Cooling, p.536.

⁷⁴ Middleton, p.247.

provided an indicator for successful future interceptor aircraft threat suppression.

Despite the development of U.S. electronic countermeasures, ROLLING THUNDER operations ended with 'a distinct possibility that the enemy had regained the upper hand in the use of SAMs.'⁷⁵ This was the result of an increase in SAM battery numbers, the change in engagement tactics and despite the electronic countermeasures used by the United States. Most SAMs were also regularly moved so as to avoid pre-planned air attack.⁷⁶ This provided a complex electronic detection problem that made it difficult to ascertain the electronic order of battle of the North Vietnamese. The problems associated with mobile targets would prove to be a significant ESM/ECM difficulty that was not resolved in the period studies

In July 1966 the North Vietnamese changed missile firing tactics, launching two missiles at once and fusing them for different altitudes. The missiles were also fired with their radars on standby until the missile entered its final phase, then the guidance radar was activated. Another North Vietnamese tactic was the engagement with missiles fired in series. One SAM site engaged an aircraft with a volley of SAMs and while the aircraft was trying to avoid these SAMs, another SAM site would engage from a different direction. Varied missile firing techniques also included the use of a single missile launch to induce a flight into an area where three or four SAMs could be launched in rapid succession.⁷⁷ ECM could not protect the aircraft from multiple threats from multiple directions. Multiple engagements overwhelmed U.S. aircraft countermeasures and greatly increased the probability of a missile being successful. Although the number of missiles expended had more than doubled, their employment was still more cost effective than the use of aircraft. Parity in costs would never be reached because the U.S. could not afford the loss aircrews. The solution for the U.S. was an improved and effective electronic warfare campaign.

⁷⁵ Middleton, p.247.

⁷⁶ Armitage & Mason, p.108.

⁷⁷ Momyer, p.132.

President Johnson terminated ROLLING THUNDER on November 1st 1968.⁷⁸ Strategic air operations over North Vietnam ceased until FREEDOM TRAIN and LINEBACKER operations were initiated in 1972. During the hiatus between ROLLING THUNDER and LINEBACKER campaigns, the North Vietnamese 'rebuilt their air defences while the US applied technology and perfected tactics.'⁷⁹ By May of 1972 the North Vietnamese had acquired 250 MIGs, 300 strategically placed imbedded SAMs and over 1,500 AAA weapons deployed.⁸⁰ The U.S. also improved air attack capabilities in 1970, constructing its own secure ground-control-intercept and early warning systems over enemy territory. This was achieved by combining aerial early warning aircraft, secure communications, and data display and analysis assets.⁸¹ Control and warning capabilities were 'advanced by integrating an airborne radar aircraft and the USN radar ship.'⁸² The improved radar picket ship USS *Pelee*, codenamed RED CROWN, operated in the Gulf of Tonkin. RED CROWN gave the US fighters effective GCI coverage over Hanoi and the advantage of detection and early warning of enemy aircraft activity.

LINEBACKER I

On March 30 1972 the North Vietnamese carried out a general military offensive against South Vietnam. In response to intelligence warnings of a military build up by the North, a series of BULLET SHOT operations were undertaken in February 1972. BULLET SHOT saw a total of slightly less than 200 B-52s committed to operations in South East Asia. BULLET SHOT operations were the first to use significant numbers of B-52s over North Vietnam. Paradoxically B-52s had been used for close air support in the South,⁸³ and LINEBACKER II was 'the first use of B-52 bombers against northern cities.'⁸⁴ BULLET SHOT represented a major build-up in U.S. air

⁷⁸ Glister, p.2.

⁷⁹ Middleton, p.253.

⁸⁰ Middleton, p.258.

⁸¹ Cooling, p.543.

⁸² Middleton, p.259.

⁸³ Summers, p.106.

⁸⁴ Archer Jones, Elements of Military Strategy An Historical Approach Westport CT: Praeger Publishers 1996, p193.

power and also indicated a change in U.S. strategy.⁸⁵ The change in strategy was accompanied by important changes in operational management and rules of engagement.⁸⁶

In contrast to the gradual escalation under President Johnson, President Nixon was determined to mount a vigorous counter response and would 'go for broke.'⁸⁷ The U.S. would 'stop at nothing to bring the enemy to his knees.'⁸⁸ In a return to traditional U.S. doctrine, the response to the invasion was a large-scale air interdiction campaign with over 17,000 air strikes in April alone.⁸⁹ The successful change in strategy and subsequent EW effectiveness highlighted the doctrine problems that existed during ROLLING THUNDER. An essential political difference between FREEDOM TRAIN/LINEBACKER campaigns and ROLLING THUNDER was the decision to isolate the North from external re-supply.⁹⁰ Mining Haiphong harbour reduced the re-supply of missiles. Limited re-supply meant that expended SAMs could not be replaced, thus degrading the North's air defence capability. Exhausting the missile supply would develop as an important objective in future air wars.

LINEBACKER operations commenced with FREEDOM TRAIN strategic air operations carried out by the US 7th Air Force, Commander Task Force-77 (CTF-77) and B-52s from Strategic Airlift Command. The carriers *Constellation*, *Midway*, *Kittyhawk* and *Oriskany* joined the USN CTF-77 carriers *Hancock* and *Coral Sea*. In a departure from previous strategy, the objective of FREEDOM TRAIN was to achieve maximum damage to the North's SAM sites, GCI radar sites and AAA.⁹¹ Thus the strategy and doctrine of overwhelming force coalesced. The destruction of the integrated air defence system as a primary objective was a significant step forward in the development of EW in Vietnam. Destruction not only eliminated the threat to aircraft but also increased the effectiveness of existing EW equipment and

⁸⁵ Thompson, & Frizzell, p.167

⁸⁶ Thompson & Frizzell, p.165.

⁸⁷ Nixon, p.148.

⁸⁸ Mark, p.374

⁸⁹ Hallion, p.57.

⁹⁰ Middleton, p.251.

⁹¹ Mark, p.376.

assets as the EW threat decreased. Despite improvements, during the months of April, May and June 1972 52 aircraft were lost over North Vietnam. 17 were lost to SAMS, 11 to AAA, 3 to small arms and 14 to MIGs. The North fired 777 SAMs in April, 429 in May and 366 in June.⁹²

Despite electronic denial and deception improvements during ROLLING THUNDER and the hiatus, losses were incurred due to new SA-2 missile firing tactics being encountered. These included use of optical guidance, a brief use of guidance radars and ripple firings of missiles. Ripple firing resulted in two missiles being fired in series. The first fired high to force the aircraft to take evasive action and second fired low at the aircraft. Losses were held to an acceptable level with the extensive use of countermeasures and the introduction of new tactics and countermeasures. These included Chaff being dropped from dispensers fitted to F-4s and Chaff being used by all B-52s over North Vietnam. Some B-52s were also fitted with equipment to jam radars and none of these were lost to enemy action. EB-66s were not often used over North Vietnam because they were slow and vulnerable to MIGs.⁹³

LINEBACKER I operations saw the first major use of Chaff in the Vietnam War. Although Chaff played a major role in the 1972 offensive, it was not used often in earlier operations because the US forces lacked a suitable dispenser for fighter aircraft. Also, prior to Vietnam there was an expectation that no fighters would be engaged over heavily defended areas because this was traditionally a mission for long-range strategic bombers such as the B-52. Chaff bundles were released in large amounts from large bombing aircraft, which were grouped together for protection. In 1944, for example, 8th Air Force lead bombers crews had dispensed large quantities of the metal foil to seed the path of the main bombing force.⁹⁴ This tactic was replicated during LINEBACKER operations, using specially fitted F-4 Phantoms. Chaff dispensing aircraft were equipped with ECM pods and accompanied by

⁹² Mark, p.378.

⁹³ Mark, p.378.

⁹⁴ Alfred Price, The History Of US Electronic Warfare p.168.

MIGCAP aircraft because they needed 30-50 miles of uninterrupted airspace to provide Chaff corridors. Individual aircraft also started to carry Chaff bundles in the speed brake compartment. When a SAM was fired at an aircraft, 'a pilot would open his speed brakes and deploy his chaff bundles into the slip stream, causing the missile to guide on the chaff rather than on the missile-dodging aircraft.'⁹⁵ Chaff cartridges were also ejected from the RF-4 in the LINEBACKER I campaign.

In a process of incremental development, a number of different methods were tried before the most effective method for dispensing Chaff was found.⁹⁶ Replicating the practice used in operation GAMORAH on July 24th 1943⁹⁷, Chaff corridors were initially used. However, they had disadvantage of dispersing rapidly and leaving aircraft exposed to enemy radar. The effective coverage times of fifteen minutes were not long enough to protect aircraft. Chaff clouds replaced the corridor method over the target area during LINEBACKER II. Chaff clouds were dispensed between 25,000-35,000 feet 'to protect laser strike forces and the B-52s.'⁹⁸ Timing was important, so that target coverage was maximised for when the attacking aircraft arrived over the target. Wind was an ongoing problem and neither Chaff corridors nor clouds were perfect. The Chaff cloud was preferred during LINEBACKER II because 'it provided the best protection for a striking aircraft in the final seconds of weapons delivery.'⁹⁹ A single cloud rather than Chaff corridors were found to be particularly successful against acquisition and tracking radars.¹⁰⁰

Another significant improvement of the LINEBACKER campaign was the significant use of the B-52 over North Vietnam. With a payload of up to 84,000lb of bombs, the B-52s saturated a target box roughly one kilometre wide and three kilometres long. Three B-52s inflicted the same amount of

⁹⁵ Middleton, p.259.

⁹⁶ Momyer, p.129.

⁹⁷ Price, p.152.

⁹⁸ Momyer, p.130.

⁹⁹ Momyer, p.130.

¹⁰⁰ Armitage & Mason, p.108.

damage as 60 fighter-bombers.¹⁰¹ This was significant because it reduced aircraft exposure to the air defence system and reduced losses whilst maintaining bomb payload delivery. The area of damage is also significant, given the relatively the small target zones and the ability of the B-52s to eliminate all air defence assets within the target area. The saturation attacks, made possible using B-52s, reduced the need for IRON HAND and standoff jamming because electronic threat was removed with the destruction B-52s produced. B-52s flew at 30,000 feet, which meant they could neither be seen or heard and therefore could not be optically targeted by SAM batteries or AAA. Flying in groups of 3-4 aircraft, B-52s could effectively jam SA-2 Fan Song radars and provide each other with ECM support.

Part of LINEBACKERS success was due to the development of standoff weapons such as laser-guided bombs (LGBs). LGBs were a significant new electronic denial weapon. The introduction of these precision-guided weapons resulted in an 80 percent strike rate or 17,000 direct hits from the 21,000 laser guided bombs used.¹⁰² Laser-guided bombs allowed strikes on previously restricted targets because of their increased accuracy. Standoff weapons such as the Mk-84 general-purpose 2,000lb bomb were guided to their targets, providing simple but effective electronic denial because missile/AAA radar could track but not reach delivery aircraft. The accuracy of LGBs also reduced the number of aircraft and time over targets. For example, 16 F-4s with 15 LGBs destroyed a bridge target in one mission that would have taken 2,400 unguided bombs to destroy in multiple missions.¹⁰³ This meant less acquisition time and targets for air defence assets and a consequential increase in ECM effectiveness.

Another significant incremental development of the Vietnam War was the use of Ryan147 remotely piloted vehicle (RPV) drones. RPVs were used as early as 1963, for low-level reconnaissance over North Vietnam.¹⁰⁴ 3,000 missions were flown during the Vietnam War with an attrition rate of only four percent,

¹⁰¹ Middleton, p.201.

¹⁰² Hallion, p.20.

¹⁰³ Mark, p.387.

despite having no electronic countermeasures protection.¹⁰⁵ LINEBACKER operations saw a comparatively extensive use of RPVs. RPVs undertook various missions and some were equipped with chaff dispensers to provide countermeasures for attacking aircraft. RPVs use was limited because of the lack of C-130 mother ships that provided a launch and control platform.¹⁰⁶ The RPV was a copy of the Henshel HS 293 guided glider that was launched from Heinkel HE III aircraft.¹⁰⁷ Although the RPV was not a major contributor to the air war in North Vietnam, its use would provide operational experience and the basis for further development that would culminate in the Gulf War.

LINEBACKER II

On October 23rd 1972 bombing in North Vietnam was halted but the lack of North Vietnamese co-operation in peace negotiations resulted in an all-out offensive against the North.¹⁰⁸ From December 18th to 29th the U.S. launched LINEBACKER II, an all weather, day/night continuous bombing operation.¹⁰⁹ LINEBACKER II 'called for swift, massive application of airpower at the heart of NVN.'¹¹⁰ LINEBACKER II lasted eleven days and ended when the North asked for a ceasefire. Political restrictions that had been applied to ROLLING THUNDER operations were removed and targets such as airfields that had been off limits, were added to the target lists. The subsequent neutralizing and destroying early warning radar, AAA, SAM and MIG threat, kept the aircraft loss rates at an acceptable level.

LINEBACKER II 'shattered North Vietnams air defence network'¹¹¹ with comprehensive air attack packages that included F-111s being used for the first time. The F-111 was significant because it strengthened electronic denial with an all weather day/night low-level high-speed attack capability. The F-

¹⁰⁴ Paul Dickson, *The Electronic Battlefield* Bloomington: Indiana University Press 1976, p.187.

¹⁰⁵ Dickson, p.189.

¹⁰⁶ Dickson, p.189.

¹⁰⁷ <http://home.inreach.com/rickylaw/wonder/missile/fritz/fritz.html>

¹⁰⁸ Armitage & Mason, p.88.

¹⁰⁹ Thompson & Frizzell, p.168.

¹¹⁰ Middleton, p.277.

¹¹¹ Hallion, p.21.

F-111's low-level bombing capability of flying below 200 feet if needed 'was a revolutionary breakthrough in an all-weather delivery system.'¹¹² The F-111 ability to fly fast at low altitude enabled them to enter Northern airspace undetected and strike targets at night and in bad weather. The employment of low level F-111s, B-52s flying at 30,000 feet and nighttime strikes were a significant development in LINEBACKER II operations.¹¹³ This reintroduced fighter/heavy bomber co-operation to attack air defences. Before LINEBACKER II B-52s were not used against North Vietnam.¹¹⁴ Using F-111s and B-52s enemy targets could be hit at any time and from any altitude. For the first time in the Vietnam War the U.S. had control of the air and ability to dictate terms. The strategy of using a comprehensive approach against all air defence assets to remove threats would provide a template for future successful mission planning.

Despite the B-52's electronic countermeasures equipment, planners had been concerned about the heavy concentration of SAMs the B-52s would face. 'Experts estimated the US would lose three percent of the total force of fighters and bombers in the 12 day effort.'¹¹⁵ Part of the problem facing the older B-52G series was that their ECM equipment was outdated, as were the initial tactics.¹¹⁶ It was planned to conduct operations using level runs at high altitude 'in the face of a missile designed specifically to confront the B-52.'¹¹⁷ The EB-66 was employed to compliment the ECM systems carried by the B-52s. Forces of specialized aircraft were grouped for mutual protection and 'stood a much better chance of both mission accomplishment and survival.'¹¹⁸ On 22 December countermeasures adopted by the U.S. included varying operational altitudes, varying routes into and out of target areas, bombing runs and post-target turns. Bombing runs were compressed to reduce the time over target from 30 to 15 minutes and more ECM equipment was

¹¹² Momyer, p.181.

¹¹³ Middleton, p.279.

¹¹⁴ Nixon, p.87.

¹¹⁵ Middleton, p.278.

¹¹⁶ Andy Vittoria 'First Person Singular' *Journal of Electronic Defence* July 1999, p.74.

¹¹⁷ Hallion, p.65.

¹¹⁸ Middleton, p.278.

added.¹¹⁹ Although the Christmas Day halt to operations allowed the North to re-supply SAM sites, missile firings became sporadic and ineffective as a result of the of U.S. countermeasure improvements.

LINEBACKER II indicated the efficacy of rapid, high intensity operations to overwhelm SAM positions and integrated air defences. LINEBACKER II also indicated the necessity of up to date ECM equipment for all aircraft. Over 900 SA-2s were fired against B-52s during LINEBACKER II and only 15 B-52s bombers were lost,¹²⁰ or 2.1 percent of B-52s were lost in 724 sorties.¹²¹ The majority of lost aircraft were the B-52Gs that did not have the updated ECM equipment. LINEBACKER operations showed that tactical aircraft could operate within SAM envelopes and in the face of heavy AAA fire, if properly supported by electronic warfare assets. The effects of the destruction, missile exhaustion and countermeasures were cumulative. Degrading air defence assets and disrupting interception aircraft reduced the threat to U.S aircraft. The experience of LINEBACKER II would provide a guide for future planners.

Vietnam Air War Conclusions

The war in Vietnam from 1964 to 1972 embodied a series of important events in the development of Western airborne electronic warfare. The Vietnam War was significant because it provides a unique opportunity to evaluate and compare the development of electronic in response to new technological threat, in a combat environment. The Vietnam War also provides a useful baseline to measure developments both in terms of new technology and in a combat environment. Vietnam provided the conditions and impetus necessary to develop appropriate practices that would provide the precedent for operations in future conflicts studied in this thesis. The conflict in Vietnam and each subsequent war resulted in the use of more sophisticated equipment but

¹¹⁹ Vittoria, p.36.

¹²⁰ Cooling, p.552.

¹²¹ Armitage & Mason, p.110.

none of these conflicts 'seems to have brought to light any revolutionary principles in electronic warfare.'¹²²

The general lessons that were learned from the conflict in Vietnam included the idea that the development of an air strategy between World War II and Vietnam was a repetitious process.¹²³ There was a lack of basic EW equipment and an incremental implementation of aggressive EW tactics. This contributed to North Vietnam's air defence effectiveness. There was a lack of surprise or deception used in operations as a result of the Route Package system and clear communications. The North Vietnamese defenders had known when, where, and in what strength U.S. air attacks would take place. ECM improvements, encryption of communications and variations of flight paths and attack altitude denied the North this advantage. 'Where the North Vietnamese lacked intelligence and warning, U.S. aircraft losses were small.'¹²⁴

Both mobile SAMs and mobile radar-directed AAA 'hindered the operation of strike aircraft'¹²⁵ and imposed restrictions on operational altitudes and areas of activity. One result was an increase in the requirement for electronic support aircraft. An effect of this was pressure on the already undersupplied specialist EW aircraft, principally the EB-66. Pressure on specialist aircraft such as the standoff jamming aircraft would be a persistent problem that faced subsequent air campaign planners. Improvements in other areas helped to alleviate these problems. These improvements included advanced standoff weapons to take aircraft out of the range of SAMs and AAA. Improved Wild Weasel F-4Gs, and improved antiradar munitions such as the Shrike anti-radiation missile were also introduced with good results.

¹²² Martin Van Creveld, Technology and War From 2000 B.C. to the Present London: Brassey's (UK) Maxwell Macmillan Pergamon Publishing Corporation 1991, p.273.

¹²³ Summers, p.109.

¹²⁴ Cooling, p.541.

¹²⁵ Hallion, p.61.

Soviet conclusions¹²⁶ from the war in Vietnam provide an interesting and different perspective. These conclusions included the idea that the whole anti-aircraft defence system had to be integrated to maximise the use of SAMs and AAA. A fully integrated air defence system could not be completely neutralized and could influence aircraft deployment and interrupt control of the air. The efficiency and lethality of the air defence system grew as a result of the introduction of new types of SAMs and increased mobility and flexibility whilst retaining the integration and performance of the system. One of the most important factors that affected the outcome of the attacks on air defence systems was the achievement of a certain degree of surprise. That could 'compensate for lack of firepower or ECM.'¹²⁷ However, Vietnamese ESM activity coupled with the Route Package system enabled USAF and USN attack altitudes and aircraft type to be predicted.

The Soviets found that tactical air superiority depended upon the effectiveness of countermeasures. The expense of creating ECM and ECCM 'are paid back by the reduction in the number of aircraft lost.'¹²⁸ Uncoordinated strike packages and lack of co-ordination of countermeasures exposed assault aircraft. The greatest probability of survival for aircraft was by employing low flying, high speed, ECM and anti-SAM manoeuvring but USAF was prevented from flying low due to AAA activity. The Soviet defence systems found low-level penetration bombers such as the F-111 that were introduced during LINEBACKER II, the most challenging adversary.

Further Soviet conclusions were that rapid redeployment of air defence assets prevented fixing of locations by U.S. aircraft and provided an element of surprise for the U.S. aircraft on every raid. False signals indicating missile launch, induced evasive manoeuvres and possibly forced aircraft abort missions. Optically targeted non-radar guided AAA could be used to cover Route Package approach paths of bombers. The use of EW systems had to be timed to maximise their utility and minimise vulnerability. Successful ECCM

¹²⁶ Y. Bodansky, 'Air War Vietnam: What The Soviets Learned' Air University Review Vol. 34 No. 2 (January) 1983, p.87.

¹²⁷ Bodansky, p87.

included use of early warning systems to decrease the time radar stations needed to detect and track targets. Bi-static radar capabilities were a vital component of system redundancy. Activating radar only when targets are known to be in the area and periodic shut down was the most efficient defensive measure against Shrike anti-radiation missiles. Finally the Soviets concluded that the dynamic nature of EW did not permit either side to gain a final or long-lasting advantage.

The U.S. experiences in ROLLING THUNDER and LINEBACKER II air campaigns were conspicuously different, but the process had been incremental and developed over a period of seven years. Had the original doctrine of overwhelming destructive force been used, far fewer aircraft and aircrew would have been lost. LINEBACKER II operations showed that the air war was not unwinnable.¹²⁹ According to Nalty, LINEBACKER tactics and results were 'a vast improvement over Rolling Thunder.'¹³⁰ A different military and political strategy may have assured victory during the ROLLING THUNDER campaign. Keegan wrote that a LINEBACKER II type campaign 'could have brought the war to a close as early as 1965.'¹³¹ Although these were lessons that would not be lost on future air war planners, they did not represent a quantum leap forward in strategy or equipment that was indicative of a revolution. Rather these lessons represented a return to, or rediscovery of fundamental doctrine, strategy and tactics in a process that lasted seven years and culminated in LINEBACKER II.

¹²⁸ Bodansky, p.87.

¹²⁹ Nixon, p.18.

¹³⁰ Bernard C. Nalty, Winged Shield, Winged Sword A History of the United States Air Force Volume II 1950-1997 Washington: Air Force History and Museums Program United States Air Force 1997, p.321.

¹³¹ Thompson & Frizzell, p.143.

Chapter 4**The Arab/Israeli Wars 1967-1982**

On June 5th 1967 the Israeli air force (IAF) launched a pre-emptive strike against the Egyptian air force (EAF) to start the "Six-Day War." This was the first Middle East war in the missile age and represents another opportunity to study the development of electronic warfare. These wars provide a unique opportunity to consider and compare the development of electronic warfare in an environment and location distinctly different from Vietnam but occurring at approximately the same time. These wars provide an opportunity to gauge if electronic warfare developed differently in this environment and if different conclusions were reached. Although dissimilar in regards to geography there was symmetry in the weapons systems used. Some remarkably recurrent themes emerge, with outcomes replicating the experiences of U.S. forces in North Vietnam.

This chapter will examine the contribution of the Arab/Israeli wars, to the development of electronic warfare. It will consider the application of electronic warfare doctrine and the use of new technology to ascertain if electronic warfare in the Arab/Israeli wars meets the conditions of revolutionary application of new ideas and technology. This chapter will consider new capabilities and limitations of electronic warfare operations to establish if there is continuity and where departures and discontinuities exist. This chapter will examine themes that emerge from Arab/Israeli wars that include problems with doctrine and problems with planning. An initial reluctance to engage in electronic warfare is followed by reactive and incremental development. This is coupled with recurrent systems failure and inconsistent application of electronic warfare.

The Israeli air force (IAF) launched Operation "DAWN," a pre-emptive strike against the Egyptian air force (EAF) to start the "Six-Day War" on June 5th 1967. Operation "DAWN" followed the principle of overwhelming force in a rapid operation that alleviated the need for electronic countermeasures equipment. IAF Ouragans, Mysteres, Super Mysteres and Mirage aircraft attacked nine airfields simultaneously at Bir Gifgafa, Bir Themada, El Arish,

Gebel Libni on the Sinai peninsular and airfields in the Canal Zone, Nile Delta and the Cairo areas.¹ 'Excellent intelligence'² including ELINT and Signals Intelligence (SIGINT) enabled the Israelis to detect and isolate the entire order of battle of the Egyptian air force. Israeli intelligence assets and the use of EW detection had identified the location of individual Egyptian squadrons, their types of aircraft and their operational procedures. This enabled the IAF to select and strike the most dangerous Egyptian forces first, at a time when the Egyptians were least prepared for an attack.

The Egyptian Air Force and ground based missile defence system 'were initially caught unaware'³ and did not recover from the Israeli attack. The destruction of the Egyptian radar sites eliminated the Egyptian early warning system and missile system guidance source. Without guidance, missiles could only be used as very expensive unguided AA artillery. Subsequently during the Six Day war the Egyptians fired only 22 missiles from the 160 SA-2 launchers deployed in 24 batteries.⁴ In addition to losing their missile defences, 'the EAF was crippled'⁵ in the first three hours of the war. By nightfall on the first day the Arabs lost 380 aircraft and Israeli air superiority was assured.⁶ The destruction of the Egyptian radar sites also ensured Israeli control of the electromagnetic spectrum. The elimination of the threat of EAF aircraft and missile defences meant that EW equipment was not required. IAF aircraft could safely fly above the range of AAA and therefore ignore AAA radar systems.

Israeli success was the result of overwhelming force in a rapid operation that utilised 'near perfect intelligence, meticulous planning and innumerable rehearsals.'⁷ The Israelis timed their strikes in anticipation of the EAF defences being in a "stand-down" mode and all the EAF aircraft being on the

¹ Anthony Robinson 'Operation Dawn The Israelis Destroy The Egyptian Air Force' War In Peace Vol. 5 No. 5 1984, p.1094.

² Van Creveld, The Sword and the Olive, p.183.

³ Cooling, p.578.

⁴ Streetly, p.108.

⁵ Cooling, p.578,

⁶ Cooling, p.580.

⁷ Howard M. Sachar, A History Of Israel From The Rise Of Zionism to Our Time New York: Alfred A. Knopf Inc. 1979, p.640.

ground. The Egyptian aircraft, in accordance with their routine, were all lined up in neat rows for ease of servicing. This made them easy targets for the Israelis, who used cannon to strafe and destroy the aircraft. The timing of the attack was planned for 0845 Egyptian time, before Egyptian commanders and staff officers arrived at work.⁸ The Israelis did not follow the anticipated EW destruction/denial tactic of attacking early-warning radar first in order to suppress the air defences. Most of the twenty-three radar stations in the Egyptian network were not attacked until the afternoon of 5 June. By this time the decisive phase of the air strike was already over,⁹ and attacking radar sites assuaged the potential threat of SAMs to Israeli aircraft.

There were several reasons for bypassing the radar stations in the initial strike. Eliminating the EAF reduced the most significant threat and meant that Israeli aircraft could operate safely above the range of radar guided AAA. Even limited ECM activity or a pre-emptive attack on Egyptian radar sites would have indicated that an attack was imminent or underway. Also the Israelis lacked electronic countermeasures equipment. The Israelis used electronic denial, evading the Egyptian's Soviet-built radar systems by flying below the radar horizon. Aircraft attacking the Canal Zone, Nile Delta and the Cairo areas 'flew in low over the Mediterranean, maintaining radio silence to avoid detection.'¹⁰ Aircraft attacking airfields at Bir Gifgafa, Bir Themada, El Arish and Gebel Libni flew low, direct from their bases in Israel. This electronic warfare denial tactic was effective due to favourable short distances to targets and relatively flat desert topography.

Flying below the radar horizon meant that those Egyptian radars sites that were active could not distinguish between Israeli aircraft and "clutter" from dust and fixed objects such as hills. Also the window of opportunity to acquire an aircraft with radar was diminished because the aircraft were within range for only seconds. Flanking and bypassing the radar systems and destroying the main threat of EAF aircraft reduced the need for ESM and ECM

⁸ Moshe Dayan, *Story Of My Life* London: Weidenfeld and Nicolson 1976, p.281.

⁹ E.N. Luttwak, & D. Horowitz, *The Israeli Army, 1948-1973* Lanham: University Press of America 1983, p.227.

equipment. Destroying the radar systems totally alleviated the need for electronic surveillance and countermeasures but there were problems. Low flying increased fuel consumption and there was a reduction in maximum distances and payloads achievable. The aircraft payload deficiency was offset by not using ECM pods or fuel drop tanks. The planned use of cannon and not bombs against the EAF aircraft at the Egyptian airfields also reduced payloads. Another problem was the element of surprise would not be easily replicated in future campaigns. A more sophisticated EW campaign would be required.

Electronic warfare had been a minor concern for the IAF until 1967 and the events of the Six Day War did nothing to change the situation. IAF doctrine and strategy relied upon the skill and courage of pilots. These qualities were perceived to be critical factors in Israel's success, despite ELINT and SIGINT providing the Egyptian order of battle and details about Egyptian routines. IAF doctrinal ideas were reinforced by the lack of ECM equipment. Israel's lack of resources meant that the IAF did not even have the simplest of defensive detection such as radar warning receivers to alert their pilots of missile activity.¹¹ Lack of resources also precluded destruction or denial using specialist Wild Weasel flights, jamming support and chaff bombers. These were 'an unaffordable luxury.'¹² The Israeli response to missile threats therefore centred on evasive manoeuvres and hard-kill attacks on radar systems and missile batteries by non-specialist aircraft. As long as the Egyptian electronic order of battle was known and Israel could control the electromagnetic spectrum through the destruction of radar sites, such tactics were sustainable. These tactics would not be sustainable with the introduction of new technology.

By June 10 the Israelis had 'won a great victory,'¹³ without electronic countermeasures equipment. The Israeli air force had lost only 46 aircraft, of those 43 were to ground fire. The Six-Day War manifestly demonstrated the

¹⁰ Van Creveld, *The Sword and the Olive*, p.183.

¹¹ Luttwak & Horowitz, p.349.

¹² Streetly, p.109.

efficacy IAF doctrine of 'superior skills, training, equipment, leadership and strategy.'¹⁴ The capture of the Golan Heights and Sinai provided forward defence positions and locations for early warning radar. This raised the erroneous expectation that there was no possibility of a successful surprise attack against Israel. Victory in the Six Day War meant that there was no stimulus to re-examine doctrine or strategy. If there had been such an evaluation by Israel 'events six years later might have taken a different direction.'¹⁵

Egypt continued to contest the outcome of the Six Day War with military exchanges across the disputed border. The Egyptian President Nasser declared on November 23rd that there would be no peace for Israel.¹⁶ The objective was to turn Israel's quick victory into a protracted battle. The strategy was to inflict 'as many casualties as possible on the Israelis' limited manpower and military assets.'¹⁷ With Soviet assistance, Egypt embarked upon a protracted campaign to challenge Israel's control of the air and regain the advantage in the electromagnetic spectrum. During the subsequent War of Attrition Egypt relied heavily on surface-to-air defences (SAD) rather than aircraft. This policy 'originated in the ignominy of the EAF as a result of its annihilation in 1967'¹⁸ and the inability to counter Israeli air-to-air superiority. Avoiding quick military engagements that suited Israel, the War of Attrition was designed to sap the resources of Israel over a lengthy period and erode the advantages held by the IAF. The Egyptian understood that the key lay in neutralizing Israeli air power.¹⁹

In response to Egyptian requests for help,²⁰ the Soviet Union despatched 32 battalions of SA-3 missiles, two squadrons of SU-15 and squadrons of MiG-

¹³ Luttwak, & Horowitz, p.282.

¹⁴ Armitage & Mason, p.118.

¹⁵ Armitage & Mason, p.118.

¹⁶ Edgar O'Ballance The Electronic War in the Middle East 1968-1970 London: Faber & Faber Ltd. 1974 p.20.

¹⁷ Van Creveld, The Sword and the Olive, p.212.

¹⁸ Mason, p.71.

¹⁹ Korn David A. Stalemate The War of Attrition and Great Power Diplomacy in the Middle East, 1967-1970 Boulder: Westview Press 1992, p.269.

²⁰ Sachar, p.694.

21J interceptors in 1969. By late 1970 up to 20,000 Soviet military advisors were also deployed to Egypt.²¹ Profound changes were made to the Egyptian military, including modes of operation, organisation, a revision of selection and promotion of officers in conjunction with improvements in training.²² Israeli ECM techniques were studied and copied. This was part of 'a very objective and accurate assessment of [Egyptian] strengths and weaknesses'²³ by Egypt and their Soviet advisors.²⁴ Israeli electronic warfare, in contrast, remained in a primitive stasis.

Under Soviet guidance, Egypt constructed an anti-aircraft fortress²⁵ installing a system of overlapping high and low anti aircraft missiles, augmented by more than a one thousand A.A. guns.²⁶ In March 1970 SA-3 (Goa) anti-aircraft missile batteries, manned by Soviet technicians, were introduced into the Egyptian missile defence system.²⁷ The SA-3 was a medium to low-level missile that was designed as a compliment to the SA-2. The SA-3 was radio guided and had semi-active radar terminal guidance. For tactical air defence, it was 'a far more effective weapon than the [SAM-2] Guideline previously deployed in Egypt.'²⁸ To defeat the SA-3 it was necessary to jam the early warning radar, radio guidance links and the missiles radar terminal guidance. These were tasks beyond the IAF EW capabilities and the electronic order of battle advantage held by the IAF had disappeared. Egypt capitalised on Israel's EW weakness. The problem was compounded by the persistent Israeli belief that the solution 'lay with the fighting man, not with an instrument.'²⁹

The use of SAM systems such as the SA-2 by Egypt had many advantages over aircraft. They were relatively cost effective to operate, costing U.S.

²¹ Mason, p.73.

²² Korn, p.89

²³ Armitage & Mason, p.121.

²⁴ Chaim Herzog, The Arab-Israeli Wars War and Peace in the Middle East from the War of Independence to Lebanon London: Arms and Armour Press 1984, p.214.

²⁵ Sella Amnon, Soviet Political and Military Conduct in the Middle East London: Macmillan Press Ltd. 1981, p.40.

²⁶ Herzog, p.217.

²⁷ Korn, p191.

²⁸ Luttwak, & Horowitz, p.323.

\$8,000 in 1969, compared to \$250,000 for a MiG-21 or the \$1.2 million for an F-4 Phantom.³⁰ Training took only 10-12 weeks. By 1968 Egypt had committed more than 150,000 men,³¹ to what would become known as the War of Attrition. Nasser's government was prepared to sustain the effort and was supported in the campaign by Soviet military personnel who operated anti-aircraft defences and SAM batteries.³² These conflicts provided opportunities for the Soviets to introduce new equipment and tactics in a thoroughly testing environment. The improved Soviet-built, Egyptian air defence system 'seriously eroded the Israeli air of superiority,'³³ as intended by the Egyptians and their Soviet advisors.

By 1970 the Israeli air force came under attack from more than a dozen missile batteries at any point in the defensive line. Improved SA-2 Guideline batteries were used for high-altitude interception and were protected against low-level strikes by SA-3 Goa missiles that were faster and more agile. Both missiles utilised co-located ground-based search and tracking radars.³⁴ Israeli losses mounted as the Egyptian forces were able to extend defences westward toward the Suez Canal and regain control of the air. The Israelis did not understand what was happening³⁵ and the IAF tried to counter Egyptian advances with attacks on SA-2 missile and radar sites.³⁶ 'Few Israeli military planners appreciated the vulnerability of tanks and aircraft-despite the American experience in Vietnam.'³⁷ Between 30 June and 7 August 1970 the Israelis lost five F4-E Phantoms despite their organic electronic deception, jamming and missile early warning systems. Such losses were unsustainable, representing over five percent of the total Phantom force of 96 aircraft. Changes had to be made by the IAF.

²⁹ Dayan, p.417.

³⁰ Mason, p.72.

³¹ Streetly, p.108.

³² Van Creveld, p.214.

³³ G.E. Rothenberg, The Anatomy of The Israeli Army London: Redwood Burn Ltd. 1979, p.163.

³⁴ Luttwak, & Horowitz, p.325.

³⁵ Richard A. Gabreil, Operation Peace for Galilee The Israeli-PLO War in Lebanon New York: Hill and Wang 1984.p.18.

³⁶ Bar-Siman-Tov Yaacov. The Israeli-Egyptian War of Attrition, 1969-1970 New York: Columbia University Press 1980, p.99.

Electronic warfare 'became a field of primary importance,'³⁸ for the IAF in reaction to the Egyptian implemented improvements to air defences and deployed new SAM systems. EW techniques had to be learnt from the most basic level by IAF. Israeli specialists trained and learnt EW skills under the constant pressure of the introduction of new Soviet missiles and new Soviet radars. New equipment had to be acquired from the U.S. and introduced into the Israeli Defence Force (IDF) service. The War of Attrition induced the United States to be more liberal in supplying Israel with new electronic countermeasures equipment.³⁹ The ECM equipment provided by the U.S. included equipment designed to warn pilots of missile activity and enable them to break away in time.⁴⁰ As the War of Attrition drew to a close, the Israelis began to receive American jamming pods '(believed to be AN/ALQ-101s) and AGM-45s tuned to the frequencies used by the Fan-Song-A and B SA-2 fire control radars.'⁴¹ The acquisition of 50 F-4E Phantoms with a ranges of 1,500 miles, speed of Mach 2.4 and capacity for seven tons of ordnance alleviated, to a degree, the weight/payload trade-off between bombs and ECM equipment. The F-4 allowed the IAF to carry ECM pods but even these had limited effectiveness and capabilities. The US provided only what were considered appropriate ECM pods but 'refused to sell its better ECM equipment - on security grounds.'⁴²

After 1970 U.S. and locally produced ECM systems, coupled with guided stand-off missiles, radar-homing Shrike and "smart" Maverick missiles, 'made suppression of Egyptian air defences [theoretically] possible.'⁴³ Standoff weapons potentially took aircraft out of the range of the missile defence system, but not early warning radar systems. The Shrike and ECM systems provided the opportunity to deal with early warning and missile guidance radars. Unfortunately equipment did not reconcile with existing Israeli air force doctrine, thus Egyptian radar sites were not systematically isolated and

³⁷ Gabriel, p.18.

³⁸ Luttwak, & Horowitz, p.332.

³⁹ Rothenberg, p.162.

⁴⁰ Van Creveld, p.214.

⁴¹ Streetly, p.109.

⁴² Luttwak, & Horowitz, p.351.

⁴³ Rothenberg, p.163.

destroyed. This indicated a reluctance to use EW because that required a change in doctrine and strategy by senior air force officers, planners and the pilots that flew the missions.

The equipment had the potential to redress the balance in the IAF's favour – if the IAF chose to use it. They did not. Doctrine remained unchanged by events or equipment acquisition because key Israeli figures believed that Israel's military advantage lay with the army.⁴⁴ Israeli commanders continued to believe that no substantial changes had taken place and the missile systems did not represent a problem for the IDF.⁴⁵ Part of this perception was based upon experience. On July 20th 1969 IAF aircraft had successfully neutralised the northern end of the Egyptian missile screen by attacking a single SA-2 site.⁴⁶ This opened up an air corridor through which IAF aircraft attacked Egyptian strategic positions in and around Cairo. Although success may have inspired false confidence, it also indicated a linear air defences key vulnerability. This key vulnerability would not purposely be exploited until the Lebanon invasion. This was a result of a reluctance to use EW because EW was not considered as important as the courage and skill of pilots.

The War of Attrition was a success for Egypt because as anticipated, Israeli losses could not be sustained. Losses were greater than necessary because the Israelis also did not know how to use the new EW equipment to its full advantage. An example was shooting down of Phantom squadron commander Chetz, who was under instructions not to try to evade missiles because the new ECM pods were expected to protect the aircraft.⁴⁷ This was indicative of equipment deficiencies and the deficiencies in Israeli electronic warfare doctrine. The depth of Egyptian resources meant that, as in North Vietnam, so many potential radar threats existed that they could not all be jammed with existing resources. Any radar in the Egyptian integrated system could detect and acquire an aircraft and activate the defence system. Although Israel acquired electronic warfare equipment and anti-radar missiles,

⁴⁴ Dayan, p.429.

⁴⁵ Bar-Siman-Tov, p.200.

⁴⁶ Korn, p.168.

'at great cost,' these measures could not eliminate the 'electronic summer'⁴⁸ forecast by Moshe Dayan.

Matching Israel militarily restored Arab pride for Egypt and a cease-fire was arranged to end the War of Attrition on August 7th 1970. The Israelis had lost control of the air and the electromagnetic spectrum but were unable to fix the problem due to existing doctrine. Not only was the surprise attack of the Six Day War no longer possible but the altitude and location at which Israeli aircraft could operate was dictated by the Egyptian air defence system and its location. The loss of the ability to operate low altitudes was critical for close air support operations and high altitude operations also reduced the accuracy of munitions. The War of Attrition was 'the first time since 1948 that the IDF had failed to achieve its objectives.'⁴⁹ It was indicative of future problems and may have provided the confidence needed for Egypt and Syria to launch the Yom Kippur War in 1973.⁵⁰

October 1973 – The Yom Kippur War

On October 6 1973, Egypt and Syria launched a surprise attack on Israeli occupation forces in the Sinai and in the Golan Heights. The outcome of the war that was subsequently known as Yom Kippur was an effective stalemate although both sides claimed victory.⁵¹ The Yom Kippur War proved to be a breaking point for Israeli electronic warfare. The Israeli doctrine and tactics used were disastrous and the subsequent heavy losses were the impetus for change. In the aftermath of Yom Kippur there was a revolution in electronic warfare for Israel, but this led to a discovery of principles and practices that had served the Allies well in World War II.

Yom Kippur marked the climax of Egyptian military preparations that began at the close of the Six Day War. Prior to the Yom Kippur War the Egyptians had

⁴⁷ Korn, p.231

⁴⁸ Luttwak, & Horowitz, p.325.

⁴⁹ Van Creveld, p.215.

⁵⁰ Herzog, p.229.

studied and absorbed the lessons of the Six Day War and the War of Attrition.⁵² In initial strikes on October 6th, 300 Egyptian air force aircraft flew '200 pre-planned sorties against Israeli airfields in Sinai, command posts, Hawk SAM batteries and radar installations.'⁵³ Egypt replicated the low flying radar avoidance tactics employed by Israel in 1967. The Egyptians tried to deliver the same kind of knock out blow that the Israelis achieved in the Six Day War. Without other electronic countermeasures the Egyptian losses were 5%.⁵⁴ Although the EAF failed to achieve its objectives, the Egyptian integrated air defence system proved to be more than a match for the IAF counter-offensive. On the northern front, sorties flown by the IAF played a critical role in halting Syrian armoured columns but in the south, at the Suez Canal, 'the IAF achieved little.'⁵⁵

Chaff and other ECMs acquired from the U.S. after the War of Attrition enabled IAF aircraft to make a contribution to the ground battles,⁵⁶ but on both fronts the losses were extremely heavy. During the first three days of Yom Kippur the Israelis lost 80 aircraft⁵⁷ of the total of 109 aircraft lost altogether during the war.⁵⁸ Countermeasures such as flares proved to be ineffective against SA-7 heat seeking missiles and the SA-6s were beyond the capability of Israeli electronic surveillance and countermeasures equipment. Hallion writes that 'overconfident from its performance in previous wars, the Israeli air force blundered into high-threat SAM areas, apparently under the presumption that SAMs would not be a problem.'⁵⁹ The problem was compounded by Egyptian efficiency, expending only 11 SA-2s per kill instead of the 110 expended by North Vietnam against U.S. forces.⁶⁰

⁵¹ Richard Goff, The Twentieth Century A Brief Global History New York: McGraw-Hill Publishing 1990, p.386.

⁵² Herzog, p.229.

⁵³ Mason, p.125.

⁵⁴ Armitage & Mason, p.134.

⁵⁵ Van Creveld, p.233.

⁵⁶ Trevor N. Dupuy, The Evolution of Weapons and Warfare New York: Da Capo Press 1984, p283

⁵⁷ Streetly, p.109.

⁵⁸ Hallion, p.60.

⁵⁹ Hallion, p.59.

⁶⁰ Armitage & Mason, p.127.

The heaviest Israeli losses were suffered in attacks against radar-controlled anti-aircraft guns and 'in attacks against static air-defences, [and] missile batteries firing salvos rather than single missiles.'⁶¹ Egyptian air defences, with Soviet technical assistance had utilised lessons from the War of Attrition to good effect. The Egyptian anti-aircraft defences were only disrupted by 'finally coming under ground attack by artillery and tank.'⁶² The Israelis used a combination of flank and penetration attacks to assault fixed air defences. Israeli missile boats attacked the north end of the Egyptian missile defence line from the Mediterranean end of the Suez Canal. Forces commanded by General Sharon 'crossed the canal'⁶³ and destroyed four batteries by ground attack on the night of October 15th.

Destroying the missile batteries opened safe air corridors for penetration into Egyptian territory by the IAF. This tactic was made viable by a linear Egyptian air defence system and replicated the July 20th 1969 operation. Israel had come across a solution to the Egyptian integrated air defence system by chance but did not exploit the advantage. The Israelis did not utilise the air corridor to attack strategic targets in Egypt, but instead focused on support for ground forces and thus wasted the advantage. Destruction of selected radars to open an air corridor was a significant development in post-World War II electronic warfare development and was a tactic that would be replicated in the Lebanon invasion and in the Gulf War.

Before the Yom Kippur war Egypt had installed 400 radars at 180 sites in an air defence system that ran the length of the Suez Canal. Air defence assets were built up to include 146 SAM batteries with an estimated 880 SAM launchers, with 80 SA-6s, 2,000 SA-7s, and a mixture of 2,600 AAA guns of various calibre and 150 ZSUs.⁶⁴ The Egyptian air defence system provided effective air cover down the entire length of the Suez Canal.⁶⁵ The Egyptian SA-2, SA-3, SA-6, SA-7 and ZSUs used in combination, 'provided a

⁶¹ Rothenberg, p.198.

⁶² Van Creveld, p.236.

⁶³ Warden, p.31.

⁶⁴ Cooling, p.587.

⁶⁵ Armitage & Mason, p.122.

comprehensive air defence umbrella up to a height of some 72,000 feet and out to a slant range of about 31 miles.⁶⁶ At the start of the Yom Kippur War the air defences over the Canal 'were the thickest and most effective ever deployed, notably superior to those of Hanoi at the time of the last American bombing offensive.'⁶⁷ Soviet technical advisors imported lessons from Vietnam, and utilised the principal of using an integrated system. The advances made by Egypt were not matched by Israel.

The surprise of the Yom Kippur War was the result of poor intelligence evaluation,⁶⁸ and inconsistent application of electronic surveillance. Israeli electronic surveillance practitioners had failed to maintain the standard of the Six Day War era. During May of 1973 Israeli intelligence had 'observed increased Egyptian activity on the west bank of the Canal.'⁶⁹ New SA-6 Gainful radar guided anti-aircraft missiles were distributed to Egyptian armoured divisions but Israeli electronic surveillance assets failed to recognise SA-6 activity and had no information on the Syrian SA-6s.⁷⁰ The mobile SA-6 batteries carried three ready to fire missiles and proved to be more effective than other Egyptian missiles because the IAF had no effective countermeasures to these missiles. 'Frequency agility and the combination of very high speed flight, continuous wave target illuminator, pulsed radar tracker and optional optical guidance'⁷¹ made the SA-6 very difficult to detect and avoid. IAF jammers were ineffective against the SA-6s 'Straight Flush' continuous wave acquisition/tracking and pulsed wave illumination radar.⁷²

An indication of Israeli electronic surveillance systems failure was the lack of knowledge about the search and tracking radar that incorporated frequency-hopping features. The SA-6 provided a complex electronic surveillance and subsequent countermeasure problem,⁷³ for which Israel was unprepared. SA-

⁶⁶ Cooling, p.586.

⁶⁷ Luttwak & Horowitz, p.351.

⁶⁸ Sachar, p.753

⁶⁹ Rothenberg, p.175.

⁷⁰ Mason, p.75.

⁷¹ Armitage, & Mason, p.127.

⁷² Streetly, p.109.

⁷³ Herzog, p.220.

6 missiles were guided by radar command from the ground and had an infrared homing device that was not easily decoyed by flares. The jamming and deception ECM equipment in service with the IAF could not deceive the SA-6 radar. One reason was the SA-6 featured a continuous wave radar signal that was not recognised by U.S. ECM equipment that was designed for pulsed transmissions.⁷⁴ The SA-6 'with its agile radar and the SA-7 with its sophisticated IR filters (in an otherwise simple weapon) came as a genuine surprise'⁷⁵ to the Israelis. The advantage of detailed knowledge of the Egyptian electronic order of battle that existed during the Six Day War had disappeared.

Another indication of Israeli electronic surveillance and countermeasures systems failure was the success of the SA-7 missiles. SA-2, SA-3 and SA-6 SAM batteries were augmented with the SA-7s Grail hand held heat-seeking weapon that acquired using infrared (IR). The SA-7s used by the Egyptians were newer versions than those used in Vietnam and could not be deceived by flares. The SA-7 deployments were enhanced through the use of eight barrelled launchers that fired in salvos of four or eight missiles. This meant missiles could be fired in barrages that enhanced the probability of a kill, through sheer numbers of missiles launched. The comprehensive and integrated missile system used in combination forced the Israeli aircraft to fly as low as possible, 'right into the lethal range of many anti-aircraft guns.'⁷⁶

The EW problems posed by the Egyptian system were beyond the Israeli EW capabilities. The Egyptian air defence system radars and guidance systems worked on a wide frequency spectrum and included frequency hoppers that produced a comprehensive ECM problem. The system had a high degree of inbuilt redundancy that meant that jamming, deceiving or destroying one or more radar sites did not eliminate the problem of detection by air defence assets. The SA-2 utilised a bi-static system that separated the transmitting aerial from the receiving aerial and enabled the one radar to feed another

⁷⁴ de Arcangelis, p.190.

⁷⁵ Luttwak, & Horowitz, p.350.

⁷⁶ Luttwak & Horowitz, p.350.

missile batteries radar. Thus the radar targeting an aircraft did not necessarily belong to the missile battery shooting at it. Once aircraft were detected, subsequent visual targeting was possible because air defence assets knew the direction, altitude and approximate time when IAF aircraft would be within range. Both sides routinely practiced jamming but there is no evidence to suggest that either was particularly effective against command and control.⁷⁷ This is yet another indicator of Israeli countermeasures systems failure.

On the northern front, Israel was more successful against Syria's air defences that included 360 missile launchers with 60 SA-6s, 1,000 SA-7s, 1800 AAA, 100 ZSUs and 275 combat aircraft.⁷⁸ Against Syrian missile defences the Israelis used fake and genuine attacks to draw as much fire as possible and exhaust the Syrian missile supply before attempting air interdiction. The result of fake and genuine attacks, was that the 'Syrians had used up all their stocks [of missiles]⁷⁹ by noon on Monday. With missile stocks exhausted, missile countermeasures were no longer needed. Using Shrikes, 27 of the 36 Syrian missile batteries 'were silenced by nightfall on the 7th.⁸⁰ The Shrike ARM was also used against surveillance radars.⁸¹ In the first anti-missile strike only two Syrian batteries were destroyed but a total of thirty Shrikes subsequently accounted for 18 SAM batteries.⁸² Reasons for the success included the relatively limited size of the problem and the ability to exhaust the Syrian missile stocks.

Against Egyptian forces significant problems arose. Although the use of Chaff combined with low altitude approaches by the IAF reduced the SA-6 threat, these tactics brought Israeli aircraft within range of the SA-7 and ZSU-23s.⁸³ Egypt's acquisition of ZSU-23-4 and ZSU-57-2 anti-aircraft systems, prior to the Yom Kippur war, proved decisive at low altitudes. The introduction of the ZSU-23-4, in late 1970, gave Egypt an integrated, self-propelled, low-level

⁷⁷ Armitage & Mason, p.137.

⁷⁸ Cooling, p.587.

⁷⁹ Cooling, p.592.

⁸⁰ Cooling, p.591.

⁸¹ Armitage & Mason, p.131.

⁸² Cooling, p.596.

⁸³ Streetly, p.109.

anti-aircraft system.⁸⁴ The Israelis had no countermeasures. The ZSU fire control radar had the capability to both acquire and track low-flying aircraft targets, with an effective anti-aircraft range of 2.5km. The high-frequency fire control radar emitted a very narrow beam that tracked aircraft and was difficult to detect or evade.⁸⁵ One solution was to use standoff anti-radar weapons that kept the aircraft out of range of the ZSU. Such standoff capabilities were 'simply not available, [with] the Israelis ARMs being ineffective in the frequency ranges of Straight Flush and the ZSU-23's Gun Dish radar.'⁸⁶ Chaff clouds may have been partially effective but could not give total protection against the integrated radar system that complimented the ZSU. The 2.5km limited radar range of the ZSU was overcome by linking the system to other long-range acquisition radars in the area. The ZSU could then be optically sighted with tracer rounds to correct fire and was capable of firing on the move because of its integrated radar and gun stabilization system. The ZSU was, like the SA-6, was an ECM problem that the IAF was not prepared for.

The Yom Kippur War indicated deficiencies in Israeli EW planning. Israeli electronic warfare specialists claimed that the Israeli electronic warfare community 'had indeed planned for advances in the Arab SAM capability, but had failed to foresee that it would come about so soon.'⁸⁷ The IAF encountered a Soviet-made Egyptian missile systems of 'unexpected quantity and effectiveness. Before dark [on the first day] the Israelis lost more than 30 aircraft.'⁸⁸ Losses generated by SA-2, SA-3 and SA-6 forced attackers down into lower altitudes where they encountered SA-7s and ZSU-23-4. The SA-6 and ZSU-23 use and performance 'came as a complete technical surprise'⁸⁹ to the Israelis. The highly regarded Israeli ELINT capability 'failed to give adequate warning of Egyptian preparations.'⁹⁰ The frequency of the Straight Flush radar associated with SA-6 was unknown and neither 'apparently was

⁸⁴ <http://www.bharat-rakshak.com/LAND-FORCES/Army/ZSU-23-4.html>

⁸⁵ <http://www.bharat-rakshak.com/LAND-FORCES/Army/ZSU-23-4.html>

⁸⁶ Streetly, p.109.

⁸⁷ Streetly, p.109.

⁸⁸ Streetly, p.109.

⁸⁹ Armitage & Mason, p.129.

⁹⁰ Armitage & Mason, p.136.

its heavy dependence on acquisition information from other radars at regimental level.⁹¹

An indication of the magnitude of the Israeli EW failure was the loss rate of fifty aircraft⁹² or 4.1%⁹³ in the first three days of the war. The Israelis lost aircraft faster than they could be replaced. The employment of countermeasures such as Chaff 'regained on a slight measure of air superiority for the Israelis.'⁹⁴ The Egyptian missile defence system was so intense 'that sheer numbers negated most types of evasion tactics. The number of missiles launched during the first three days is supposed to have equalled the total NATO inventory.'⁹⁵ In the following days Egyptian mobile SA-6 missiles and self-propelled ZSU-23-4 'claimed many Israeli planes.'⁹⁶ Mobility of air defence assets provided a complex and changing ESM and countermeasures problem because the Israelis could not know where ZSUs or SA-6s were positioned. The Israelis could not avoid the mobile missiles or know where to deploy countermeasures such as Chaff or directional jammers for greatest effect.

The Israelis failed to exploit the weaknesses of the Egyptian air defence system, concentrating on support for the pre-eminent ground forces instead. The Egyptian air defence weaknesses included a lack of independent mobility and the interdependence of its component parts. These weaknesses were exposed but not taken advantage of when Israeli ground forces crossed the Canal and opened a radar safe air corridor.⁹⁷ The Egyptian missile screen lacked mobility because SA-2 and SA-3 sites were concentrated in concrete bunkers with only the radar antennas exposed. Four or six launchers were sited and dug in, in a precise symmetric relationship to the control center. The missile sites were thus susceptible to ground attack, but when combined with mobile ZSUs SA-6s and SA-7s they were virtually immune to air attack. The

⁹¹ Armitage & Mason, p.137.

⁹² Herzog, p.311.

⁹³ Hallion, p.59.

⁹⁴ Dupuy, p.283.

⁹⁵ Rothenberg, P.198.

⁹⁶ Dupuy, p.283.

⁹⁷ Dayan, p.511.

ZSUs, SA-6s and SA-7s did not however, 'provide adequate protection on the move and once outside the range of their static air-defence envelopes.'⁹⁸

Problems with planning, a reluctance to use EW and inconsistent application were experienced. The strategy and tactics used against Syrian forces were not replicated against Egyptian forces. Egyptian air defences were not comprehensively attacked. The key to defeating the radar controlled air defences was to take out a vital component of the integrated system such as the early warning radars that alerted and activated air defences. Eliminating the early warning radar system could seriously degrade the air defence system. Destroying early warning radars were an obvious target because the SA-6, with limited search and altitude discrimination relied upon the early warning.⁹⁹ Another vulnerability included the system's total coverage capability, which could be degraded by breaching the defensive line at a given point. Breaching was possible because the SA-2 and SA-3 were at fixed sites. The lack of mobility meant the system could be flanked, particularly from the Mediterranean end, as the Six Day War indicated. Instead of exploiting the Egyptian weaknesses, the Israeli air force concentrated on support for ground forces, in adherence to doctrine and expectations but not successful EW strategy.

Egyptian air force activity further illustrated Israeli EW failure. On October 23rd 1973 the EAF attacked three airbases and airfields, ten Hawk SAM sites, three major command posts and electronic jamming and monitoring centers as well as radars stations. Using 25 Kelt air-to-ground missiles with 1,600-pound high explosive warheads, two Israeli radar stations were hit and destroyed.¹⁰⁰ The EAF achieved another minor technical surprise with the launching anti-radiation versions of the Soviet supplied AS-5K (Kelt).¹⁰¹ The EAF flew some 1500 offensive sorties, often using low flying for electronic

⁹⁸ Rothenberg, p.198.

⁹⁹ Sella, p.91.

¹⁰⁰ Cooling, p.589.

¹⁰¹ Armitage & Mason, p.134.

denial and unsupported by electronic countermeasures equipment. The EAF lost 75 aircraft to Hawk batteries and AA artillery, for a loss rate of 5%.¹⁰²

In reaction to the losses, both superpower allies' airlifted supplies to rearm the combatants. In operation "NICKEL GRASS" the U.S. supplied the IAF with ECM equipment and vital aircraft spares and replacements. The first aircraft into Israel carried ECM AN/ALQ-119 and AN/ALQ-101-V(B) under wing pods for use against the radars of the SA-2 and SA-3. The radar acquisition and tracking frequencies 'were well known [to the U.S.]. They were followed by Chaff dispenser and pods.'¹⁰³ The new ECM equipment 'greatly reduced SAM effectiveness and thus increased Israeli aircraft survivability'¹⁰⁴ against SA-2s and SA-3s, but the damage had already been done, through heavy aircraft losses. Significantly the new electronic countermeasures equipment meant the IAF could regain altitude and operate outside the ZSU and SA-7 threat area. New equipment included "Smart" munitions such as the AGM-65A Maverick missiles¹⁰⁵ to improve standoff capabilities and put greater distance between aircraft and the air defence system.

The doctrine of relying upon the traditional and expected initiative, aggression and bravery by individual pilots that had served the IAF up until the Yom Kippur War, failed. It was an inadequate substitute for a systematic attack on air defences.¹⁰⁶ The Yom Kippur War demonstrated for a second time that the IAF could not support the ground forces to the degree that they were accustomed to,¹⁰⁷ due to intact enemy missile screens. Yom Kippur marked the end of close air support, counter-air operations and interdiction against an intact co-ordinated SAM system.¹⁰⁸ Doctrinally it was clear that air defence capabilities, 'based very largely on electronics had seriously diminished the value of aircraft in some tactical environments.'¹⁰⁹ The IAF was 'unable to

¹⁰² Armitage & Mason, p.134.

¹⁰³ Armitage, & Mason, p.131.

¹⁰⁴ Hallion, p.62.

¹⁰⁵ Hallion, p.62.

¹⁰⁶ Mason, p.75.

¹⁰⁷ Cooling, p.592.

¹⁰⁸ Armitage & Mason, p.120.

¹⁰⁹ Cooling, p.598.

operate with the accuracy or efficiency'¹¹⁰ that had been displayed until the War of Attrition.

Yom Kippur 'sparked a great deal of controversy about the impact of surface-to-air defences on tactical air operations.'¹¹¹ Cooling for example concluded that electronic detection capabilities and missiles were 'demonstrably changing the nature of war in many ways.'¹¹² Armitage and Mason saw the Yom Kippur war as 'a further stage in a well-rooted [electronic] evolution.'¹¹³ The reality was different. Despite ECM equipment the Israelis lost approximately 104 aircraft in about 10,000 sorties, for a loss rate of around 1.3 percent. The total number of aircraft lost was critical, representing approximately 25 percent of the total force in less than 20 days. Of the 87 combat aircraft lost to ground-to-air fire, only 36 of them were lost to ground-to-air missiles of all kinds.¹¹⁴ 32 of the aircraft lost were A4 Skyhawks that had the limited ECM carrying capacity.¹¹⁵

The Egyptian air defence system dictated the altitude of aircraft and therefore the IAF lost total control of the sky. The IAF had also lost control of the electromagnetic spectrum. To regain control the IAF would have to use the full range of EW equipment, techniques and tactics. Thus one result of the Yom Kippur War was that electronic detection assumed a greater importance. Electronic detection enabled Egyptian air defence systems to be activated and ready to engage IAF assets. Electronic detection capabilities extended into space, even if in a limited capacity, with at least four Soviet Cosmos satellites in orbit over the battlefields.¹¹⁶ The IAF, on the other hand, no longer enjoyed an electronic advantage, particularly in regard to the SA-6 and the ZSU, and no longer knew the Egyptian electronic order of battle. Another result of the war was that air superiority was no longer 'an automatic result of

¹¹⁰ Dayan, p.510.

¹¹¹ Mason, p.71.

¹¹² Cooling, p.594.

¹¹³ Armitage & Mason, p.136.

¹¹⁴ Cooling, p.597.

¹¹⁵ Hallion, p.60.

¹¹⁶ Sella, p.95.

superior effectiveness in the air'¹¹⁷ as had been the case for Israel since the War of Independence. Ground based assets assumed a vital role in controlling air space. Neutralizing more lethal, sophisticated and numerous missiles and ground-based defences therefore became a priority for Israel following the Yom Kippur War.

The shock of the Yom Kippur War motivated Israeli leaders 'to amend and reinterpret the principles underlying essential national-security policies.'¹¹⁸ The "Agranat Commission" was set up to investigate the failures of Israeli intelligence community.¹¹⁹ Yom Kippur provoked a radical change in IDF doctrine and electronic warfare strategy. New tactics were introduced with the new equipment. The Israelis recognised the potential of Operation GAZELLE¹²⁰ in breaching linear air defence systems using a flanking attack across the Suez Canal. The idea that destroying early warning radars was critical to success became evident. A focus on destroying selected air defences and enemy electronic assets, as a primary objective emerged to provide a blueprint and effective EW battle plan for future conflicts. Military operations were to be directed at destroying enemy forces rather than seizing terrain.¹²¹

By 1980 the Israelis had undergone a relative electronic warfare revolution. The Israelis acquired and developed systems to counter Arab anti-aircraft defences. The Israeli attack on Iraq's Osirak nuclear reactor in Operation BABYLON¹²² on June 7th 1981 provided impetus and an opportunity to analyse air defences. Israeli analysis indicated that during the Vietnam War and Yom Kippur War, 70% of losses were from AAA. Almost all losses were in the 1500-4500 feet altitude and within 25 miles of the target air defences.¹²³ Operation BABYLON was conducted with an ingress altitude of 100 feet and

¹¹⁷ Dupuy, p.283.

¹¹⁸ Eliot A. Cohen, Micheal J. Eisenstadt, Andrew J. Bacevich, 'Israel's Revolution in Security Affairs' *Survival*, Vol. 40 No. 1. (Spring) 1998. p.48.

¹¹⁹ Sella, p.173.

¹²⁰ Frank Aker, *October 1973 The Arab-Israeli War* Connecticut: Archon Books 1985. p.100.

¹²¹ Cohen, Eisenstadt & Bacevich, p.62.

¹²² Dan McKinnon, *Bullseye One Reactor* St. John's Hill: Airlife Publishing Ltd. 1988. p.3.

¹²³ McKinnon, p.116.

an egress of 38,000 feet. The Israelis avoided the Iraqi early warning radar by exploiting a gap in radar coverage that went 'all the way to Baghdad.'¹²⁴ The radar coverage weakness at the same location would be exploited by the Coalition during the Gulf War.

The specific EW systems were acquired, including flares to seduce heat-seeking missiles such as the SA-7, and electronic jammers for ground to air missiles such as the SA-2 and SA-3.¹²⁵ The IAF acquired a variety of U.S. standoff systems. Israel was supplied with Shrikes ARMs in 1974 and again in August 1978, the latter delivery totalling 200 rounds.¹²⁶ America was also 'reported to have supplied Israel with 100 Walleye II TV guided glide bomb kits in 1978, 600 TV-guided AGM-65 Maverick air-to-surface missiles and 200 extended range Data Link Walleye IIs in 1980.'¹²⁷ These standoff weapons took aircraft out the range of the air defence system, thus reducing the need for comprehensive countermeasures.

Another Israeli acquisition that would prove to be vital was the development of unmanned aerial vehicles (UAVs). Expendable remotely piloted UAVs 'replaced the IAF over contested battlefields.'¹²⁸ Israel developed both Mastif and Scout RPVs that were designed and built in Israel.¹²⁹ The UAVs had many advantages over manned aircraft. UAVs were relatively inexpensive, costing a few thousand dollars compared to the \$1.2 million for an F-4. The UAVs were 'simple, robust and well adapted for use under field conditions; owing to their off the shelf components.'¹³⁰ UAVs could be configured to produce a radar signature that replicated an aircraft and thus activated air defences and drew missile fire. This not only disclosed the presence of the missile system and its associated radar but the smaller physical profile of the UAVs made them a harder target to hit, thus increasing the missiles fired to kill ratio.

¹²⁴ McKinnon, p.135.

¹²⁵ Van Creveld, *The Sword and the Olive* p.276.

¹²⁶ Streetly, p.109.

¹²⁷ Streetly, p.110.

¹²⁸ Van Creveld, p.277.

¹²⁹ Gabriel, p.98.

¹³⁰ Van Creveld, p.277.

Although at an early stage of development, the UAV was a significant electronic warfare development. Early models carried TV cameras but later developments included laser range finders, radar-jamming equipment and RPVs that carried out 'kamikaze strikes against enemy radar stations.'¹³¹ Before the introduction of the UAVs the missile system had the advantage of being easier to man and more cost effective to operate than a manned aircraft. UAVs reversed this advantage because they were more expendable and less expensive than the missiles that were trying to shoot them down. The true benefits of the RPV and other innovations in EW equipment and tactics would manifest themselves in operation "Peace for Galilee."

Peace for Galilee – The Invasion of Lebanon 1982

On June 6 1982 the Israeli Defence Force launched Operation "Peace for Galilee" and invaded Lebanon. The operation was ostensibly intended to destroy the PLO in southern Lebanon. Preparation of the operation was code named 'Pine Tree' and began eighteen months before the invasion. There were three plans considered with the "Big Plan," including war against the Syrians.¹³² The "Big Plan" was rejected by the Israeli government three times, the last being June 8th 1982¹³³ but was executed on June 9th. The Israeli government did not want war with Syria and Damascus 'turned itself inside out to avoid an all-out war.'¹³⁴ Syria's lack of preparation and restraint were a major factor in Israel's military success in Lebanon. Syrian inactivity allowed Israeli forces to move artillery into range of the Syrian missile defence system. Syrian inactivity also meant that there was no suppression of air defences until three days into the campaign. Once executed, the destruction of the Syrian missile system was the turning point of the war. From that point the outcome of the war was a foregone conclusion.¹³⁵

¹³¹ Van Creveld, p277

¹³² Gabriel, p.61.

¹³³ Evron Yair War and Intervention in Lebanon London: Croom Helm 1987, p.134.

¹³⁴ Schiff, Ze'ev & Ya'ari, Ehud. Israel's Lebanon War New York: Simon and Schuster 1984, p.155.

¹³⁵ Gabriel, p.120.

The Syrian missile system was attacked in force with a two-hour systematic and comprehensive EW operation on June 9 1982.¹³⁶ The attack was the result of IAF's new doctrinal thinking. This was, 'the best response to an integrated air defence system is to destroy it.'¹³⁷ This reflected a doctrinal change that accompanied the electronic warfare developments. The Israeli attack was the result of nine years of exercises, meticulous planning and an enormous investment in electronic warfare weapons systems.¹³⁸ The Israelis had worked through and solved the electronic warfare problems encountered in the Yom Kippur war. Preparatory work for the attack was undertaken with the destruction of two key radar sites at Damour and Rayak on June 7th. An indication of the lack of Syrian preparation was the Syrian surprise 'that the Israelis even knew about the radar at Damour.'¹³⁹ The Syrians were also caught with some missile batteries not fully deployed.

The entire Syrian radar network was attacked by UAVs, followed by F4 Phantoms and F16 Eagles using radar homing standoff missiles to destroy active missile batteries. UAVs were also used to draw fire from SAM batteries. Activity exposed the SAM radars to improved Shrike anti-radiation missiles that were launched from about 22 miles (35km) out. Mavericks and laser-guided bombs also destroyed the radars 'while multi-frequency jamming protected Israeli aircraft.'¹⁴⁰ Long-range artillery and 19 surface-to-surface missiles engaged SAM batteries in the Beka Valley. Two SA-2, two SA-3 and 12 SA-6 batteries deployed 'were subjected to a rolling attack.'¹⁴¹ Within two hours the Israelis wiped out 19 batteries and severely damaged four others, without the loss of any aircraft.¹⁴² The elimination of the missile system and subsequent elimination of the Syrian air force gave the Israelis complete mastery of the air.¹⁴³

¹³⁶ Evron, p.136.

¹³⁷ Streetly, p.111.

¹³⁸ Schiff & Ya'ari, p.166.

¹³⁹ Schiff & Ya'ari, p.155.

¹⁴⁰ Cooling, p.599.

¹⁴¹ Streetly, p.111.

¹⁴² Cooling, p.599.

¹⁴³ Herzog, p.348.

Upon completion of the missile suppression, the Syrian air force was engaged in a comprehensive EW operation. Israeli airborne detection was undertaken with the use of U.S. supplied Hawkeye E-2Cs early warning aircraft. The Israelis used early warning capabilities to manoeuvre their aircraft into position to attack Syrian MIGs from side on, where MIGs had no radar acquisition capability. The Syrian air force was rendered ineffective by airborne early warning, jamming of air-to-ground communications links and jamming of airborne navigation systems.¹⁴⁴ Due to jamming and attacks from radar blind spots, Syrian aircraft were electronically blind. On June 9 and 10 in a series of massive air-to-air battles, 90 Syrian aircraft were shot down and only one Israeli plane lost.¹⁴⁵ The IAF eliminated approximately 15 percent of Syria's air force and 25 percent of its fighters in one day.¹⁴⁶ The ninety-to-one kill ratio achieved was better than that in 1967 thirty-to-one and 1973 fifty-to-one ratios¹⁴⁷ and validated the change in electronic warfare doctrine and acquisition of electronic warfare equipment. The lessons gained from the Lebanon campaign were 'eagerly sought by American and NATO intelligence agencies in the hope of improving their offensive and defensive capabilities.'¹⁴⁸

During the preparation for the invasion, thorough Sigint and Elint had detected and isolated ground control, fire control, acquisition and every other ground-based and air borne Syrian radar system. In the year prior to the attack on the Beka valley air defences, the IAF had mapped out Syrian batteries and acquired all the Syrian radar operating frequencies.¹⁴⁹ The ELINT advantage that had existed prior to the Six Day War had been restored. The IAF 'had revised its lessons and comprehensively removed any doubts about its supremacy.'¹⁵⁰ A systematic approach to the process of the elimination of Syrian air defences in the Beka Valley was adopted.¹⁵¹ Having breached the

¹⁴⁴ Streetly, p.111.

¹⁴⁵ Van Creveld, p.295.

¹⁴⁶ Gabriel, p.100.

¹⁴⁷ Van Creveld, p.295.

¹⁴⁸ Gabriel, p.99

¹⁴⁹ Van Creveld, p.295.

¹⁵⁰ Armitage & Mason, p.139.

¹⁵¹ Warden, p.50.

integrity of the missile defence system by destroying the key early warning radar sites at Damour and Rayak, the IAF gained control of the air, based upon domination of the electromagnetic spectrum. The IAF was then able to support ground forces and carry out retaliatory raids in Southern Lebanon as required. Although the Beka Valley campaign was an EW and military success, it did not overcome the long-term Syrian or PLO threat. That required a political peace settlement.

Arab/Israeli War Conclusions

The Israel/Arab conflicts between 1967-1973 confirmed the electronic warfare lessons that developed in Vietnam. These included the reality that mobile air defences and radar guided AAA in particular constrained air activity.¹⁵² There was reluctance by Israel to acquire and use EW equipment and practices in the early engagements. This reluctance continued with regard to the engagement of AAA with electronic warfare assets. The density of threat from AAA, SAMs and fighters subsequently resulted in the deployment and use of EW equipment and tactics. This included EW support aircraft accompanying strike aircraft.¹⁵³ With this EW support the ability of the SAMs to engage and destroy Israel's American made aircraft was 'seriously degraded.'¹⁵⁴ New equipment included advanced standoff weapons to take aircraft out of the range of SAMs and AAA, standoff jamming aircraft and improved anti-radar munitions such as the AGM-88 HARM to destroy radar. Although each conflict subsequently resulted in the use of more sophisticated equipment, in general 'none seems to have brought to light any revolutionary principles in electronic warfare.'¹⁵⁵

Israel's doctrine until the Yom Kippur War focused on the skill and courage of Israeli pilots and the belief in their inherent superiority. It took the loss of significant numbers of aircraft and the inability of the IAF to support ground forces, to induce change. The change in electronic warfare between Yom

¹⁵² Hallion, p.61.

¹⁵³ Hallion, p.61.

¹⁵⁴ Hallion, p.61.

Kippur and the Peace For Galilee operations in particular represented a quantum leap forward for Israel. The IAF discovered practices and techniques that had served the Allies well in World War II and that were eventually practiced in Vietnam. The Lebanon and LINEBACKER II campaigns indicate that Israel and the United States had arrived at the same solution to electronic threats. The contrast between the earlier campaigns and the doctrine applied in LINEBACKER II and Lebanon would manifest itself again when the U.S. went to war with Iraq, and lead some observers to conclude a revolution had taken place in electronic warfare.

¹⁵⁵ Van Creveld, p.273.

Chapter 5

Gulf War 1990-91

The war in Persian Gulf from 1990 to 1991 provides an important opportunity to evaluate and compare the progress of developments in electronic warfare in response to new technological opportunities, in a combat environment. The air campaign launched on January 17th 1991, as part of the DESERT STORM campaign to evict Iraqi forces from Kuwait,¹ marked the zenith of airpower and electronic warfare development in the twentieth century. The Gulf War was 'the apotheosis of twentieth-century air power,'² but was it also the apotheosis of an electronic warfare revolution?

This chapter will examine the Gulf War's contribution to the development of electronic warfare. It will appraise the application of electronic warfare doctrine, strategy and the use of new technology to see if electronic warfare in the Gulf War meets the conditions of revolutionary application of new ideas and technology. This chapter will consider new capabilities and limitations to establish if there is continuity with earlier conflicts and where departures and discontinuities exist. This analysis will thus demonstrate whether the use of electronic warfare in the Gulf War was revolutionary or a rediscovery of fundamental doctrine.

When compared to the minimalist beginning of electronic warfare in both the Vietnam War and the Middle East, the execution of an electronic warfare strategy in the Gulf War appeared radically advanced from the very beginning. The Coalition dominated the electromagnetic spectrum.³ The Gulf War seems to have reflected the best contemporary practice and epitomised lessons learnt from the previous conflicts covered in this thesis. The prime concern was to gain and maintain air superiority.⁴ There was a transformation in the technology used, with comparative quantum leaps in speed, accuracy and

¹ John McCausland, 'The Gulf Conflict: A military analysis' Adelphi Paper no. 282 November 1993, p.3.

² R.A. Mason, 'The Air War in the Gulf' Survival vol.33 No.3 May/June 1991, p.138.

³ Mason, p.156.

⁴ Keaney & Cohen, p.12.

destructive power compared to earlier conflicts. Closer examination however, reveals that the doctrine, policy, strategy and tactics used in the Gulf War were not as revolutionary as first imagined. They can be described as incremental refinements based upon experience and lessons from the earlier conflicts. The same problematic electronic warfare themes that beset the earlier conflicts can be identified as the Gulf War progressed.

The constant themes that emerge from the Gulf War include the recurrence of doctrinal problems. The planning problems and lack of EW protection at low levels that were evident in the initial engagements in Vietnam and the Middle East, whilst not apparent at the beginning of the Gulf War, emerge in the later stages. An initial reluctance to engage in electronic warfare is evident to a lesser extent in comparison with the earlier conflicts, but in the Gulf War there is a reluctance to prosecute electronic warfare to its logical conclusion. Again there are recurrent systems failures and inconsistent application, particularly in electronic surveillance and subsequent countermeasures. A critical difference in the Gulf War was however, that U.S. military strategy 'had come the full circle, and in many important respects was back to World War II again,'⁵ particularly in regard to electronic warfare.

There are inherent problems with studying the Gulf War because it was such a one sided affair that identifying themes consistent with earlier conflicts is more difficult and conclusions may appear more tenuous. Generally only one side was intent on battle and victory was seemingly complete so it is difficult to draw conclusions that may be of value. But closer inspection of areas where Iraq chose to engage, specifically with SCUD ballistic missiles in particular, provide strong evidence of the deficiencies identified in the earlier wars. Closer inspection provides the continuities that make a consideration of the Gulf War a worthwhile exercise with regard to electronic warfare progression.

⁵ Summers, p.155.

To prosecute the air war against Iraq the U.S. led Coalition aircraft flew 109,876 sorties over 43 days at an average of 2,555 sorties per day. 84,200 tons of munitions were dropped in 44,145 combat sorties - 67 percent flown by USAF, 19 percent by Marines and 14 percent by the U.S. navy.⁶ The aircraft loss rate was .00132 percent or one-tenth of one percent for Coalition aircraft.⁷ These loss rates are the lowest in the history of air warfare and the progress in electronic warfare is a primary reason for this success. Such a reduction in loss rates is the principal reason for conducting electronic warfare operations. A-10 Warthogs, however, suffered a total of four percent loss rates as a result of low flying operations.⁸ Tornados attacking airfields suffered a total 13 percent loss rates or 6 aircraft, also due to their low flying operations. These kinds of loss rates reflected pre-electronic warfare loss rates experienced in World War II, and indicate a consistent electronic warfare failure in coverage and capabilities, particularly at low altitudes.

Planning for the DESERT STORM air campaign was the responsibility of the staff at "Black Hole," a basement storage area of the Royal Saudi Air Force HQ in Riyadh. Planners elaborated, refined, and expanded the basic strategic air campaign to meet CENTCOM's [Central Command] needs, after carefully analysing Iraq's strengths and weaknesses.⁹ Detailed planning before the action was a significant departure from the Vietnam experience and the overall success of DESERT STORM 'can be traced to years of planning and generous funding for preparation.'¹⁰ An example was the July 1990 command post exercise called "Internal Look 90" that specifically targeted Iraq as a potential aggressor.¹¹ Just as the Israelis were able to test their tactics, equipment and planning with operation BABYLON, the U.S. was able to draw upon the success of EL DORADO CANYON in 1986¹² as an indicator of how to evade missile defences. The U.S. also had the added advantage of being

⁶ Hallion, p.188.

⁷ Hallion, p.196.

⁸ Hallion, p.211.

⁹ Joseph S. Nye Jr. & Roger K. Smith, After The Storm Lessons From The Gulf War New York: Madison Books 1992. p.206.

¹⁰ Phyllis Bennis & Micheal Moushabeck, Beyond The Storm A Gulf Crisis Reader New York: Olive Branch Press 1991, p.91.

¹¹ Keaney & Eliot, p.25.

¹² Nalty, p.423.

able to observe and assess Iraqi military efficiency during the Iran/Iraq war. The U.S. provided electronic intelligence to Iraq from 1982 and this 'functioned as a kind of practice run,'¹³ for U.S. intelligence assets in the Gulf War.

Electronic detection, deception, denial and destruction were fundamental elements of DESERT STORM planning. Phase one of the plan was the achievement of electronic spectrum control, air superiority and attacks on Iraqi military strategic capabilities, in a seven to ten day period. Phase two was the suppression of surface-to-air defences in Kuwait. Phase three was the attack on the Iraqi army in Kuwait and phase four was the direct air support for the land offensive.¹⁴ The greatest challenge for Allied forces was 'seizing of air superiority'¹⁵ This meant the destruction of Iraqi fighters and interceptors, suppression of SAM and AAA sites, and the electronic jamming and destruction of Iraq's air defence network that included early warning and air surveillance radars. Against the latter was ranged F-117s Nighthawk stealth fighters, EF-111A Ravens and EA-6B Prowler electronic warfare aircraft, F-4G Wild Weasel radar killers, and the various electronic attack aircraft such as F-14s, F-15s, F-18s, F-111F, and A-6E.¹⁶

According to Builder, the air strategy and plans 'were not immediate or axiomatic consequences of Air Force doctrine, but had to be improvised and "pushed" by the few who had thought beforehand about theatre air campaigns.'¹⁷ The strategic campaign followed Warden's concept of attacking Five Strategic Rings that represented key military command and control assets. The strategic objectives included 'the seizing and retention of air superiority, the isolation and incapacitation of the Iraqi leadership ... and the elimination of Iraq's offensive and defensive military capabilities.'¹⁸ The plan

¹³ Bennis & Moushabeck, p.101.

¹⁴ I. Irving, 'The Gulf Air Campaign - An Overview' Royal United Services Institute Journal February 1992, p.12.

¹⁵ Hallion, p.154.

¹⁶ Hallion, p.154.

¹⁷ Carl H. Builder, The Icarus Syndrome The Role of Air Power Theory in the Evolution of the U.S. Air Force New Brunswick: Transaction Publishers 1998, p.11.

¹⁸ Hallion, p.151.

was an attempt to 'dismember Iraq and at the same time attack targets across the entire spectrum of strategic target sets.'¹⁹ The basis of the Coalition air plan was the dominance of the electronic spectrum, air defences to be rolled back, air superiority won, and both strategic and tactical targets attacked repeatedly and subsequently. Unlike Vietnam there would 'no respite for targets in Iraq or Kuwait.'²⁰ Prerequisites for success included a rapid overwhelming operation that was focused and intensive. The offensive air campaign envisaged was symbolically called "INSTANT THUNDER."²¹

The preparation for the type of war fought in the Gulf War, 'began in the mid-1970s as the US air force began a detailed analysis of the years of combat in Vietnam.'²² LINEBACKER II indicated a successful strategy and tactics for neutralising electronic air defence systems.²³ The plan for an air war would be the antithesis of early U.S. operations in Vietnam. DESERT STORM would involve the use of maximum force and begin with full-scale air attacks designed to win control of the electromagnetic spectrum, win control of the air and disrupt Iraqi command, control and communications. In contrast with Vietnam, initial targets would include radars and airfields, 'making full use of electronic warfare, cruise missiles, fighters using stealth technology and stand-off precision munitions.'²⁴ Command of the air was to be gained by attacks on Iraq's strategic air defence system.²⁵

Colin Powell eloquently summed up the philosophy for the air campaign. 'First, we're going to cut it off, and then we're going to kill it.'²⁶ The rhetoric conveyed the essence of a well-executed strategic plan and the U.S. intention, but the reality left something to be desired. Unlike Vietnam and the

¹⁹ Keaney & Cohen, p.11.

²⁰ Ian Bickerton & Michael Pearson, 43 Days The Gulf War Melbourne: The Text Publishing Company 1991, p.187.

²¹ Andrew Leyden, After Action Report Gulf War Debriefing Book Oregon: Hellgate Press 1997, p.187.

²² Charles A. Horner, 'The Air Campaign' Military Review vol. 71 no. 9 September 1991, p.17.

²³ Summers, p.113.

²⁴ G. Kemp, 'The Gulf Crisis: diplomacy or force?' Survival vol. 32 no.6 November/December 1990, p.511.

²⁵ Keaney & Cohen, p.33.

²⁶ Quoted in R.A. Pape, Bombing to Win Air Power and Coercion in War Ithaca: Cornell University Press 1996, p.224.

Middle East wars, electronic warfare doctrine and planning coalesced but strategy still failed to meet expectations with less than optimum outcomes. Reasons include a lack of sufficient preparation, deficiencies in EW training, personnel²⁷ and particularly a lack of vital equipment such as specialist jamming and radar destruction aircraft. One result was that after 40 days of the air campaign, targets still had not been neutralised that should have been neutralised in the initial air campaign.²⁸ Some of these targets were the ground-based air defences that were the main threat to Coalition aircraft.²⁹

There had been doubts about the efficacy of air campaigns before DESERT STORM, particularly by the U.S. military.³⁰ The performance of the Egyptian air defences against Israel in the 1970s had led some to conclude that the struggle of aircraft against missile had been decided in favour of the missile.³¹ The reality was however, that the Iraqi air defence system was not in the same league. There were 'vast differences in technological sophistication, training and morale'³² between the Iraq and the Coalition. As a result Iraqi resistance was 'slight, fragmented and largely absent.'³³ Yet, Iraq controlled the electronic spectrum below 10,000 feet and imposed air superiority below 10,000 feet. Iraq also successfully engaged Coalition forces with SCUD missiles. Despite the most comprehensive and technologically advanced EW campaign in history, Iraq's forces could still electronically acquire and engage targets. In terms of human life, the loss of a C-130 Spectre gunship and crew at Khafgi on the 31st of January 1991 was the most costly example of EW failure.³⁴

²⁷ Colvard, p.142.

²⁸ David P. Dilegge, 'Soviet Lessons Learned: Operations DESERT STORM' Marine Corps Gazette February 1992, p.38.

²⁹ Pape, p.228.

³⁰ Summers, p.198.

³¹ E. Karsh, 'The Iran/Iraq War: A Military Analysis' Adelphi Paper No. 220 Spring 1987, p.40.

³² Alberto Bin, Richard Hill, & Archer Jones, Desert Storm A Forgotten War Westport CT: Praeger Publishers 1998, p.251.

³³ Mason, p.137.

³⁴ Leyden, p.273.

The electronic warfare plan for the Gulf War was a significant part of operations called INSTANT THUNDER.³⁵ INSTANT THUNDER sought to use maximum force in a comprehensive, rapid and overwhelming operation to dominate the electronic spectrum. The aim was not to use incremental EW operations. The priority was to reduce and confuse the enemy's early warning system, thus delaying the arrival of fighters by knocking out as many of the radar stations as possible. Destruction was also designed to prevent the enemy obtaining early warning of, and accurate plots on approaching forces for ground based air defences. Further objectives included interfering with enemy fighter radio communications, thus affecting both the movement of fighters into the area of operations and the direction of intercepting fighters. The final objective was to produce diversionary threats, thereby dividing the enemy's available fighter effort.³⁶

The USAF Electronics Security Command and Electronic Warfare Center at Kelly AFB Texas provided the electronic warfare preparatory work. ELINT collected by satellites, specialist SIGINT and EW aircraft such as RIVET JOINT and COMPASS CALL provided the details of the Iraqi electronic order of battle.³⁷ In late 1990 intelligence collectors monitored Iraqi communications, signals and radar 'assessing potential threats and locating targets.'³⁸ Digital maps were overlaid with the collected intelligence data to show the locations and effective radius of Iraqi air defence radar. This enabled aircraft such as the F-117 to subsequently avoid known air defence radar. Precedents for using this method of electronic denial included the U.S. navy attack on North Vietnamese targets in the Gulf of Tonkin on August 4th 1964,³⁹ the Israeli preliminary attacks during the opening phase of the Six Day War, and the Egyptians attacks during the Yom Kippur war.

Gathered intelligence data enabled computer simulations of the attack plan to be run ten times over. The simulation effort allowed planners to 'explore a

³⁵ Keaney & Cohen, p.30.

³⁶ Price, p.116.

³⁷ Kearny & Cohen, p.163.

³⁸ Hallion, p.156.

range of strategies, unit level tactics and aircraft type deployments before the commencement of hostilities.⁴⁰ This was an unprecedented effort in computer modelling,⁴¹ and can reasonably be described as revolutionary. Intelligence data also enabled accurate pre-programming of allied aircraft radar warning receivers, jammers and accurate tasking of air defence suppression aircraft.⁴² The preparatory work reflected Israeli endeavours prior to the Lebanon campaign, and contrasted the lack of USAF preparation in Vietnam. The key flaw in the U.S. system was that electronic mapping and computer simulations were only effective against known active targets. The electronic order of battle was not complete and unexpected contingencies could not be planned for. Thus planning problems continued to be a feature of EW operations.

³⁹ Edwin E. Moise, Tonkin Gulf and the Escalation of the Vietnam War: The University of North Carolina Press 1996, p.219.

⁴⁰ Carlo Kopp, 'Desert Storm - The Electronic Battle' Australian Aviation, June/July/August, 1993, p.3.

⁴¹ Kopp, p.3.

⁴² Mason, p.216.

In contrast to previous confrontations the Soviet Union and China did not assist their client (Iraq) with air defence personnel or expertise. The Soviet Union instead 'passed to the Coalition technical information on Soviet-supplied air-defence electronics [and] communications systems.'⁴³ This complimented information already gained and enhanced knowledge about the Iraqi electronic order of battle. Also in direct contrast to earlier conflicts the Soviet Union and China cut military aid and ended all arms sales to Iraq with the adoption of U.N. Resolution 661 on 6 August 1990.⁴⁴ A direct consequence of Iraq's isolation was that 'no recovery, no resuscitation, no reinforcement was coming.'⁴⁵ Thus there would be no resupply of air defence ordinance to replace expended missiles or assets. The Coalition could theoretically exhaust Iraqi missile supplies, as the Israelis had done to Syria in 1982, but AAA would continue to provide difficulties and highlight an EW systems failure.

The execution of Instant Thunder represented a coalescing of the best ideas and practical experience of Vietnam and Arab/Israeli wars but with faster and more accurate equipment. Offensive air operations in the Gulf War began at 6:36 A.M. on January 16 1991 when seven B-52s lifted off from Barksdale AFB in Louisiana, carrying AGM-86C Tomahawk cruise missiles. Being the first into action was a fitting tribute to the venerable B-52, and provided continuity with LINEBACKER II. The direct attack on Iraqi electronic assets was another continuity from LINEBACKER II. Unlike Vietnam however, the B-52s utilised long-range standoff missiles and did not enter enemy airspace for the air strike. Only one B-52 was lost in the Gulf War, and that was due to a crash. 74 B-52s subsequently flew 1,624 sorties and dropped 25,700 tons or 42 percent of USAF bombs.⁴⁶ In coordination with the B-52s, USS *San Jacinto* and USS *Bunker Hill* launched Tomahawks synchronised to arrive in Baghdad at H hour.⁴⁷ 106 Tomahawk land attack missiles (TLAMs) were launched. 54 of these were against electronic and strategic targets in

⁴³ Mason, p.144.

⁴⁴ Bickerton & Pearson, p.55.

⁴⁵ Summers, p.173.

⁴⁶ Hallion, p.218.

⁴⁷ Leyden, p.130.

Baghdad such as the Iraqi main communications exchange and the Iraqi Ministry of Defence main building.

In operations that were the antithesis of ROLLING THUNDER, high tempo, high intensity operations were used to seize the advantage and overwhelm air defences. Maximum force was used in the opening operations against Iraqi electronic and air defence targets. In combination with F-117 Nighthawks, Tomahawk missiles destroyed Iraqi radar, command and control, and air defences assets. This attack replicated LINEBACKER II, with simultaneous high and low level attacks by Tomahawks and Nighthawks reflecting B-52 and F-111 attacks. The initiative was seized with Tomahawk attacks against the nerve center of Iraq's air defence system. The arrival of the Tomahawks 'stimulated transmissions by Iraqi surveillance radars and SAM guidance radars, thereby disclosing their positions to air launched anti-radiation missiles.'⁴⁸

Task Force Normandy formed part of the co-ordinated and comprehensive EW operation. Utilising MH-53J Pave Low pathfinders and nine AH-64 Apache helicopters attacked and simultaneously destroyed two Iraqi frontier early warning radar sites at 0100 am on January 17th.⁴⁹ This opened up a ten kilometre wide air corridor in the southern Iraqi integrated radar system. Immediately after the attack, in a replication of operation GAMORAH, 100 allied aircraft poured through the "radar black corridor" en route to Baghdad.⁵⁰ The full 'orchestration' of Allied air power was then able to attack Iraqi air defence and electronic targets. Destruction or jamming of long-range surveillance and early warning radar allowed attacking aircraft to approach undetected.⁵¹ Other EW assets used included EF-111A Ravens, EA-6B Prowler electronic warfare jammers, F-4G HARM-firing Wild Weasels and F/A-18 SAM hunters. F-4G Wild Weasel and Navy F/A-18 SAM-killers 'fought

⁴⁸ Mason, p.215.

⁴⁹ Thomas Houlahan, Gulf War The Complete Story New London: Schrenker Military Publishing 1999, p.24.

⁵⁰ Mason, p.215.

⁵¹ Mason, p.157.

a merciless electronic war, identifying Iraqi radars, locking onto them, and shooting them with missiles.⁵²

As part of the co-ordinated EW attack F117As struck the Nukhayb air defence operations center in southern Iraq and the centers at AL Taqaddum and Al Taji.⁵³ The Iraqi Air Defence Headquarters and three of the four air defence Sector Operations Centers were destroyed. Also targeted was the main telecommunication center. F117As shattered the Iraqi air defence network integrity.⁵⁴ C-130 Compass Call standoff jamming aircraft and EF-111 Raven escort jamming aircraft engaged Iraqi radar and fighter control communications. This added to the paralysis of the Iraqi air defence system. EF-111's ability to escort attack aircraft into high threat areas alleviated standoff jamming problems associated with the EB-66 in Vietnam. Continuous monitoring of remaining Iraqi frequencies by Compass Call and Rivet Joint aircraft provided target information for F-4 air defence suppression aircraft.⁵⁵ This kind of targeting information and level of co-ordination had been unavailable during Vietnam era IRON HAND missions.

Iraq air defences were decimated by an electronic and firepower offensive unparalleled in scale and intensity since OVERLORD operations in 1944. The Iraqi integrated air defence system was rendered inoperable within the first 48 hours due to the destruction of command and control facilities and the degradation of radar assets. In the first four hours, Iraqi air force radar transmissions were reduced from over 100 to 15 as a result of air attack. Radar activity had decreased by 90 percent after 48 hours of the air campaign.⁵⁶ This overwhelming electronic combat attack formed the basis for the subsequent Coalition military success. With the degradation of the Iraqi air defence system and subsequent lack of threat from Iraqi aircraft, General Powell was able to declare air superiority and the objectives of Phase One were met.

⁵² Hallion, p.173.

⁵³ Hallion, p.169.

⁵⁴ Houlahan, p.27.

⁵⁵ Mason, p.157.

⁵⁶ Mason, p.218.

The Iraqi air force's ability to co-ordinate defensive or offensive missions was effectively ended within the first 24 hours of conflict by the destruction of its command, control and communications system.⁵⁷ On the first day, Iraq's integrated air defence network 'had collapsed'⁵⁸ and SAM sites and interceptor airfields were no long under centralized control. The strategic objectives had been achieved and planner's expectation met. This part of the EW operation worked well, as experience in LINEBACKER II and Lebanon indicated that it should.

Problems with inconsistent EW application and lack of electronic protection became evident however. Four Tornado aircraft were lost attacking airfields at low level in the first week of the air campaign. Low-level attacks by all aircraft were abandoned.⁵⁹ Coalition aircraft were limited to altitudes of above 10,000 feet and night operations to avoid infrared SAMs and AAA that were targeted independently.⁶⁰ The ZSU-23 continued to be a problem and was 'very effective in clear weather.'⁶¹ Despite the massive effort and resources available the Coalition was unable to overcome the low altitude threat. The enforced medium-level activity imposed operational constraints.⁶² Problems with operational height restrictions arose because sorties using 'unsophisticated F-16 fighters, flying at 10,000 feet, proved ineffective.'⁶³ When low-level sorties were reintroduced over the battlefield, four aircraft were lost to ground fire on the first day of the offensive.⁶⁴ This was indicative that Coalition aircraft did not control the air and represented unsustainable losses.

⁵⁷ Mason, p.219.

⁵⁸ Hallion, p.176.

⁵⁹ Mason, p.218.

⁶⁰ Mason, p.141.

⁶¹ Nye & Smith, p.251.

⁶² Mason, p.150.

⁶³ J. Pay, 'The US Navy and its Carriers, 1974-1993' *Journal of Strategic Studies* vol. 17 no. 1 March 1994, p.137.

⁶⁴ Mason, p.150.

Iraq's strategy and capabilities 'must bear a significant portion of the responsibility for the speed and thoroughness of its defeat.'⁶⁵ Saddam Hussein expected to survive and win a political victory despite the expected military defeat.⁶⁶ Iraq could not however, withdraw without a military engagement. A U.S. military victory over Iraq was never in doubt⁶⁷ because Iraq chose a defensive posture with inadequate defences. Poor quality Iraqi air defences lacked coverage and depth, and were further degraded by politically imposed constraints. Iraq relegated air defence to a minor role in its military hierarchy. Air defences were further undermined as a result of the Iranian war, after which less competent officers were often posted to air defence units.⁶⁸

Despite the limitations, the air defence network was designed to contend with a sophisticated attack and provided a significant challenge. Due to political imperatives of the Baathist system Iraq had a well-equipped air force and air defences but 'with leaders who had absolutely no idea of how to run it.'⁶⁹ Iraq possessed high altitude cover ability provided by SA-2 and SA-3 SAMs. Medium and low level cover was provided by SA-6, SA-8, SA-9, SA-13 and French Roland SAMs, interspersed with light and heavy calibre radar guided AAA. Iraq had about 20 SA-2 (120 launchers), 25 SA-3 (150 launchers), 25 SA-6 batteries and some 60 Roland fire units.⁷⁰ Iraq's air defence system was based upon Soviet equipment and Soviet style integrated air defence management. Despite the large number of missiles the coverage of the air defence system was not comprehensive. Large parts of Iraq were only covered by early warning radars and thus Coalition aircraft were under threat for only part of the time.

⁶⁵ N. Cigar, 'Iraq's Strategic Mindset and the Gulf War: Blueprint for Defeat' Journal of Strategic Studies vol. 15 no. 1 March 1992, p.1.

⁶⁶ J.G. Stein, 'Deterrence and Compellence in the Gulf, 1990-91' International Security Vol.17 No. 2 Fall 1992 p177

⁶⁷ Bennis & Moushabeck, p.133.

⁶⁸ S. McKnight, 'The Forgotten War: The Iraqi Army and the Iran-Iraq War' Small Wars and Insurgencies vol.2 No. 1 April 1991, p.95.

⁶⁹ Hallion, p.130.

⁷⁰ Mason, p.212.

Iraq's air defence system based upon the French KARI air defence net that was centrally controlled from Baghdad. It comprised of surveillance radars and mobile units linked by duplicated voice and digital communications system.⁷¹ Iraq's communications systems were duplicated and layered to prevent severing of key nodes.⁷² The French built KARI was an excellent "layered" air defence system⁷³ consisting of centralised air defence headquarters and sector centers. The air defence network was designed to detect intruders through radar and optical surveillance. Intruders were then tracked and targeted with radar and/or optical fire control.⁷⁴ The U.S. EW operation attacked and neutralised the vital components of the KARI systems and destroying key nodes such as sector HQ. This unhinged the system.

Iraq's first counterattack consisted of seven SCUD long-range ballistic missiles that were launched at Israel on January 17th and 18th, as Saddam Hussein had promised.⁷⁵ The SCUD exposed problems with EW planning, inconsistent application and highlighted EW systems failures. The SCUD became a priority target for the air campaign 'not so much because of the military threat posed, but the political and psychological value of the weapon.'⁷⁶ SCUD missiles were a simple derivative of the German V2 rocket used in World War II and were not very effective military weapons. However, the SCUD missiles posed unexpected electronic detection and destruction difficulties for the Coalition.⁷⁷ The use of the SCUD missiles and subsequent intensive operations to attempt to find and destroy SCUD mobile launchers exposed electronic detection shortcomings. An example was the unsuccessful attacks made against communications links thought to be transmitting SCUD launch authorization.⁷⁸

⁷¹ Mason, p.212.

⁷² Hallion, p.131.

⁷³ Hallion, p.147.

⁷⁴ K.J. Kennedy, 'Stealth A Revolutionary Change in Air Warfare' Naval War College Review vol. 46 no. 2 Spring 1993, p.120.

⁷⁵ Bennis & Moushabeck, p.66.

⁷⁶ Leyden, p.57.

⁷⁷ Bin, Hill & Jones, p.227.

⁷⁸ Kearny & Cohen, p.15.

Iraq possessed 108 SCUD launchers, two thirds of which were truck mounted mobile units.⁷⁹ The problems associated with the detection of mobile targets that was apparent in Vietnam had not been resolved. Iraq launched 93 SCUD missiles of its 800 plus inventory, with 42 fired at Israel, 48 at Saudi Arabia, and 3 fired at Bahrain. There were no Coalition plans in place for the search and destroy mission required for dealing with mobile SCUD launchers. Coalition planners assumed, incorrectly, that launch set up would take several hours and that launch procedures would produce distinctive electronic signatures that Coalition forces could exploit. Planners also assumed that decoys would not greatly complicate the problem of dealing with SCUDS.⁸⁰ Despite efforts to halt SCUD launches and destroy launch sites and mobile launchers there was 'no direct evidence of the destruction of mobile launchers by aircraft.'⁸¹

Iraqi strategic missile forces practised good electronic warfare discipline, particularly when deploying SCUD missiles. Iraqi missile forces avoided pre-launch electromagnetic emissions and increased electronic denial and deception by dramatically cutting pre-launch set-up times, firing at night and seeding the launch areas with decoys.⁸² Mobile SCUD teams could fire their missiles and be hidden within five minutes.⁸³ Detection problems were increased because launch sites and hiding places were not identified by the Coalition before the start of the air campaign.⁸⁴ The Iraqis indicated their capabilities with a test firing on December 28th 1990. This indicated that SCUDS were protected by dispersion, moved mainly at night and concealed using buildings or camouflaged earth covered trenches.⁸⁵ Iraqi radio silence was maintained, and 'very little electronic or infrared emissions were generated by either the refuelling or launch sequence.'⁸⁶ The extent to which Iraq was able to protect SCUDS 'through concealment, deception, dispersal,

⁷⁹ Bickerton, p.182.

⁸⁰ Kearny & Cohen, p.69.

⁸¹ McCausland, p.35.

⁸² Kearny & Cohen, p.75.

⁸³ Bin, Hill & Jones, p.103.

⁸⁴ Kearny & Cohen, p.73.

⁸⁵ Kearny & Cohen, p.232.

⁸⁶ Mason, p.217.

redundancy and mobility does not appear to have been fully appreciated until after the war's end.⁸⁷

The SCUD was a very simple but effective missile in relation to countermeasures, and presented a complex EW problem for Coalition forces. There was no terminal guidance system that could be disrupted, so once fired the SCUD could not be diverted from its target with existing tactics and technology. Iraqi modifications to the SCUD created unintended but effective countermeasures. The missile often broke up on re-entry, thus presenting multiple targets to the U.S. Patriot missile defence system.⁸⁸ Damage was still inflicted upon the target area, even if Patriot intercepted the incoming missiles because debris from SCUD and Patriot missiles crashed to earth at speeds of two thousand miles an hour.⁸⁹ Infrared sensors on U.S. satellites could only detect launches and from telemetry information designate and relay early warning to intended targets.⁹⁰ Targets could then be warned of imminent attack.

Coalition land based anti-missile defences were non-existent except for the Patriot system. The Raytheon MIM-104 Patriot missile provided the only hard-kill option for SCUDs. Patriot was deployed in batteries of five launchers, each with four missiles. The system's phased-array radar could detect incoming SCUDs at 70 miles (100km) and engage targets from 10 to 20 miles (16 to 30km).⁹¹ The Patriot missile was the primary response to the Scud Missile threat,⁹² but problems were experienced because of the fire and forget nature of SCUD missiles. Terminal guidance was preset and therefore could not be jammed or decoyed. Patriot 'appeared to have worked as planned the first time it had been used in earnest,⁹³ but there was contention over Patriots

⁸⁷ Kearny & Cohen, p.118.

⁸⁸ Joseph S. Nye & Roger K. Smith, After The Storm Lessons From The Gulf War Lanham Madison Books 1992, p.258.

⁸⁹ Bin, Hill & Jones, p.101

⁹⁰ Bin, Hill & Jones, p.99.

⁹¹ Mason, p.281.

⁹² McCausland, p.35.

⁹³ Bin, Hill & Jones, p.100.

total effectiveness as a SCUD countermeasure. 'In retrospect, it is clear that Patriot was misperceived as an "unqualified success."'⁹⁴

Electro-magnetic pulse weapons represented an electronic destruction opportunity that were not used against Iraq's missiles but were deployed against static targets in Baghdad. USAG AGM 86C air-launched cruise missiles (ALCM) carried a non-nuclear electro-magnetic pulse (EMP) generator. This was powerful enough to produce a burst of microwave energy strong enough to disable unprotected electronic components on radars, guidance systems, communications, computers and vehicles.⁹⁵ The theoretical underpinnings of EMP weapons were established by Nikola Tesla in 1905⁹⁶ and developed at the end of World War II. Research indicated the feasibility of disrupting the German V1 and V2 missile guidance systems. The electronic charge from the EMP weapon would stop all electrical activity, thus the missile would lose its guidance and propulsion. An EMP weapon was not used during World War II because the war ended before development could be completed. The Gulf War was the first recorded operational deployment of an EMP weapon.⁹⁷ The potential of EMP weapons remains unfulfilled, but the importance cannot be understated. The implications of EMP development and deployment are revolutionary because EMP represents the ultimate electronic warfare weapon.

Key equipment such as satellites played an important part in the success of INSTANT THUNDER but satellites highlighted problems with inconsistent EW application. Although the Gulf War was described as the first space war,⁹⁸ satellites were first used in combat during the 1982 Falklands War. Also the Soviet Cosmos system was used for intelligence collection during the Yom Kippur war. The satellite systems deployed in the Gulf War extended the capabilities of Coalition aircraft and were significant in electronic detection because of the unprecedented time over target. Geo-stationary satellites gave

⁹⁴ Bin, Hill & Jones, p.101

⁹⁵ Mason, p.154.

⁹⁶ <http://www.wealth4freedom.com/wns/1/specialreport/34.htm>

⁹⁷ Houlahan, p.27.

continuous coverage.⁹⁹ The satellite systems with EW capability included the Lacrosse low elliptical orbit (LEO), Key Hole (KH-11) LEO, KH-12 LEO and Magnum geo-stationary satellites. The five Key Hole-11 satellites provided unprecedented visual and thermal infrared digital imagery. However, satellites suffered technical difficulties that beset other EW equipment. Coverage problems were encountered with KH-11 being impeded by cloud and the Lacrosse radar satellite could track surface movements but not provide minute details.¹⁰⁰ Also with the destruction of Iraq's command, control and communications system the Lacrosse and KH11/12 ELINT satellites 'may have been left little to do.'¹⁰¹

The Iraqis used no countermeasures against satellites despite the Coalition's vulnerability, with a heavy reliance on satellites for communications, command, control and intelligence. Iraq could have, for example, disabled the satellite ground station in Kuwait city that carried a large proportion of Coalition communications traffic. Other countermeasures available were 'meaconing, interference, jamming and intrusion.'¹⁰² With 15 satellites carrying between 700-1100 voice grade channels per satellite, jamming was a substantial EW problem for Iraq. A reluctance to jam satellites may have resulted from Iraq's own utilisation of satellite technology for photo intelligence provided to Iraq by a French firm. This reluctance to use satellite countermeasures is reminiscent of the initial uses of chaff, where neither the Germans nor the Allies in World War II, wanted to open the Pandora's box of chaff use.

Satellite capabilities were enhanced by use of airborne assets like Airborne Warning and Control System (AWACS). The U.S. AWACS E-3A was the most advanced airborne early warning (AEW) system deployed in the Gulf War. These aircraft were incremental improvements on the COLLEGE EYE and

⁹⁸ P. Anson, & D. Cummings, 'The First Space War' Royal United Services Institute Journal Winter 1991, p.51.

⁹⁹ Bickerton, Pearson & Wilesmith, p.186.

¹⁰⁰ Mason, p.222.

¹⁰¹ Anson, & Cummings, p.51.

¹⁰² T.G. Siegel, 'The Application of Space to Military and Naval Operations' Naval War College Review vol. 47 no. 1 Winter 1994, p.119.

RIVET TOP AEW aircraft used in Vietnam, although some Western analysts identified systems such as AWACS as 'the most important air power innovation.'¹⁰³ An AWACS is a modified Boeing 707 that uses thirty-foot-wide rotating Westinghouse APY-1 radar.¹⁰⁴ The radar has a range of 235 miles and was able 'to distinguish objects against background clutter, using a pulse-Doppler signal linked to a computer.'¹⁰⁵ The crucial advantage that the AWACS airborne radar offered lay in its ability to see "over-the-horizon" beyond the range of ground-based radar. Unhindered by the curvature of the earth the extended horizon of radar surveillance was 'vital for early warning against low-level attacks'¹⁰⁶ and is a key electronic denial asset. Two of the five AWACS were in the air at all times and could cover the whole of Iraq and Kuwait.¹⁰⁷

Another significant incremental development was the use of UAVs to reduce air defence threats. USN A6 and USMC aircraft launched a substantial number of tactical air launched decoys (TLADS) in the first hours of the air campaign on January 17th, 'to deceive and saturate radar controlled air defences.'¹⁰⁸ The Coalition's use of UAVs to draw missile fire and overwhelm the air defence system was a tactic that had proved extremely successful in Lebanon in 1982, and worked extremely well in against Iraq. Drones such as the BQM-74 were employed 'in various electronic warfare roles, for direct attack, to launch weapons on command, in standoff attack, and as decoys, in addition to well-proven surveillance and reconnaissance roles.'¹⁰⁹ The BQM-74 drones were launched from two sites in Saudi Arabia and were programmed to arrive in target areas at the same time as Tomahawks and F-117s.

¹⁰³ Mason, p.155.

¹⁰⁴ C. Cook, & J. Stevenson, The Atlas of Modern Warfare London: Weidenfeld and Nicolson 1978, p.169

¹⁰⁵ Cook, & Stevenson, p.168.

¹⁰⁶ Cook, & Stevenson, p.166.

¹⁰⁷ Bin, Hill & Jones, p.220.

¹⁰⁸ Mason, p.147.

¹⁰⁹ Mason, p.236.

BQM-74s loitered over target areas, 'simulating the radar signatures of bombers.'¹¹⁰ In addition to drawing missile fire and assisting in the rapid expenditure of Iraqi missile stocks, UAVs exposed SAM acquisition and guidance radars to HARM missiles.¹¹¹ UAVs enabled HARM missiles to be effectively employed by undetected launch platforms.¹¹² 200 anti radiation missiles were fired on the first night and a total of 3,039 were used during the war.¹¹³ Attacks involving UAVs and HARMS were launched against Baghdad and other areas where Iraq's radar guided AA missiles were concentrated.¹¹⁴ The use of UAVs may have been the reason for Iraq's claim to have shot down nearly eighty Coalition aircraft on the first day, 'when in reality they were simply crashing decoys.'¹¹⁵ UAVs were used in Vietnam and by Israel but not against strategic targets and not in conjunction with another unmanned systems. OVERLORD in 1944 was the last time such a comprehensive use of unmanned aircraft was used.

The General Dynamics BGM 109 Tomahawk Land Attack Missile (TLAM) was another significant incremental development in EW deception and destruction. Tomahawk was the ultimate standoff weapon system that could be used in high threat areas without danger to aircrews. Tomahawk missiles were based upon the same principle as the German V1 rockets, but with accurate guidance that ensured a high probability of hitting targets. Tomahawks were difficult for Iraqi air defence units to electronically detect and engage because of their low radar signatures and their high-speed, low-level approach. With a maximum range of 1,100 miles carrying 700lb warhead, Tomahawks 'contributed greatly to the success of the air campaign'¹¹⁶ by attacking and destroying vital targets. The Tomahawks' major contribution was against hard targets such as command, control and communications, and air-defence assets. However, Tomahawks lacked organic countermeasures and were

¹¹⁰ Bin, Hill & Jones, p.86.

¹¹¹ Kearny & Cohen, p.12.

¹¹² M.P. Grissom, 'Stealth in Naval Aviation' Naval War College Review vol. 44 no. 3 Summer 1991 p10

¹¹³ Leyden, p.280.

¹¹⁴ Leyden, p.49.

¹¹⁵ Leyden, p.133.

¹¹⁶ Hallion, p.250.

unable to take evasive action or cope with contingencies.¹¹⁷ Tomahawks could also only hit the targets they were programmed to hit and could not be redirected.

Specialist electronic warfare aircraft made a vital contribution to the air campaign. The aircraft used were updated versions of aircraft used in Vietnam, indicating incremental development. An example of a typical strike package was four A-6Es and four Tornado attack aircraft. They were protected by four F-4G Wild Weasels, five EA-6B radar jammers, and twenty-one F/A-18C Hornets carrying radar homing missiles. This produced a support to strike ratio for 5:1 and a typical aircraft to target ratio of 38:1.¹¹⁸ EF-111A Ravens, USN EA-6B Prowler and USAF EC-130H Compass Call stand-off jamming aircraft jammed surveillance radars, communications between ground controllers and fighters, the guidance systems of medium and high-level SAMs and the airborne radars carried by Iraqi air force interceptors.¹¹⁹ The problems with standoff jamming that were inherent with the EB-66 Destroyer in Vietnam, were evident with standoff jamming EC-130H Compass Call aircraft, but was alleviated to some extent by EF-111A Ravens that could escort aircraft throughout the entire mission. The problems with insufficient specialist EW aircraft and therefore inconsistent coverage continued to apply.

General electronic warfare equipment was available to all USAF aircraft at the start of the campaign, in contrast to Vietnam. The lessons derived from the Vietnam and the Arab/Israeli wars contributed to the level of preparation. Aircraft had not collectively been this well electronically protected since World War II. Most USAF planes carried older generation external Westinghouse ALQ-119 and ALQ-131 ECM pods. Radar warning receivers used included the ALR-56C installed on all F-15Es. F-15Cs carried ALR-56As. Radar warning receivers and other ECM systems were re-programmable, which meant new threat characteristics could be added to the equipment's memory.

¹¹⁷ J.M. Collins, U.S.-Soviet Military Balance Concepts and Capabilities 1960-1980 Washington: McGraw-Hill Publications Co. 1980, p.148.

¹¹⁸ Hallion, p.249.

¹¹⁹ Mason, p.215.

Equipment took just seven minutes to reprogram.¹²⁰ Missile warning systems (MWS) were carried by B-52s and F-111s and were designed to detect all kinds of missiles, including those using infrared and electro-optical sensors.¹²¹ Tornado aircraft were updated with upgraded radars, chaff and flare dispensers prior to deployment to the Gulf.¹²²

The Walleye TV guided bombs and laser-guided bombs were also updated versions of those used in Vietnam. Without PGMs it would have been even more difficult and dangerous for air defences to be rolled back, air superiority won, and both strategic and tactical targets attacked repeatedly and sequentially. A single strike aircraft carrying two "smart" bombs could function as effectively as 108 World War II B-17 bombers carrying 648 bombs and crewed by 1,080 airmen.¹²³ One bomb, one hit results reduced the time over target and reduced the vulnerability of aircraft to air defences. Targets such as bridges could be dropped in one sortie, thus nullifying the rationale of installing AA defences around these vital communications and supply assets. Precision-guided munitions (PGMs) were important electronic denial weapons because of high levels of mission accomplishment with minimum collateral damage. PGMs resulted in fewer sorties to destroy targets and thus reduced 'exposure and, therefore, reduces the potential for aircraft losses.'¹²⁴

Although PGMs were credited with 75% of damage inflicted on Iraqi targets,¹²⁵ problems with inconsistent application and technical difficulties existed. Despite the apparent success of precision-guided munitions there were not enough available to cover requirements. Pentagon statistics that were subsequently released showed that 93% of the bombs dropped 'were unguided free-fall bombs and 75% of these missed their targets.'¹²⁶ This

¹²⁰ J.W. Canan, 'The Electronic Storm' Air Force Magazine (June) 1991, p.31.

¹²¹ Canan, p.31.

¹²² I. Irving, 'The Gulf Air Campaign - An Overview' Royal United Services Institute Journal February 1992, p.13.

¹²³ Hallion, p.192.

¹²⁴ Horner, C.A. 'The Air Campaign' Military Review vol. 71 no. 9 September 1991p26

¹²⁵ Keaney & Cohen, p.292.

¹²⁶ Bennis & Moushabeck, p.278.

meant that targets had to be re-visited, thus exposing aircraft to electronic acquisition and air defences.

F-117 Nighthawk stealth fighters were specifically designed to reduce aircraft radar detection and complimented the electronic denial achieved with PGMs. Stealth capabilities enhanced aircraft survivability through increased electronic denial. Low radar signatures degraded air defence capabilities by making aircraft harder to detect electronically. Flying high and fast, escorted by EF-111A Raven electronic jamming aircraft, F-117s were invulnerable to Iraqi air defences and none were lost during the Gulf War, despite attacking the most heavily defended targets. Stealth capabilities resulted in mission completion and aircraft survival.¹²⁷ F-117s Nighthawk stealth fighters flew 1,270 combat sorties and dropped 1,616 bombs, with a 79 percent successful hit rate.¹²⁸ One F-117 with two bombs could destroy a hardened target which 20 years previously would have required 95 F-105s dropping 190 bombs.¹²⁹

Stealth aircraft encountered problems with inconsistent EW application and was vulnerable. Stealth technology reduces radar systems effectiveness by reducing radar detection ranges through reduced radar cross-sections.¹³⁰ However, low-frequency ground-based radars have a limited capability to detect stealth platforms. During the Gulf War this weakness was not exploited. It was necessary however to individually destroy Iraq's 12 older radars that could have apparently detected stealth aircraft.¹³¹ Hallion notes that 'proponents of stealth have never said that it invisible-only that it is so difficult to detect and track,'¹³² using contemporary equipment. Paradoxically the Soviets believed that stealth technology was operating against old Soviet equipment that had reached the end of its operational life. Modern Soviet equipment could operate through current jamming and 'can presently detect

¹²⁷ Bick, p.187.

¹²⁸ Hallion, p.177.

¹²⁹ Mason, p.225.

¹³⁰ K.J. Kennedy, 'Stealth A Revolutionary Change in Air Warfare' *Naval War College Review* vol. 46 no. 2 Spring 1993, p.120.

¹³¹ Kopp, p.4.

¹³² Hallion, p.248.

stealth aircraft, but at a shorter range.¹³³ In reality some older Soviet equipment could detect stealth aircraft unless operating with an escorting EF-11A or EA-6B noise jamming aircraft. These aircraft can reduce the enemy 'radar receiver's sensitivity to the point where the otherwise detectable F-117A vanished from the screen.'¹³⁴

The susceptibility of stealth aircraft to detection by older radar systems was not the only electronic detection problem associated with the Gulf War. Another of the criticisms of stealth technology was that it was not really tested because every other aircraft performed as well and had survival rates that were comparable with stealth aircraft. Once air superiority was obtained and Iraq's air defences were suppressed, stealth aircraft were unnecessary. For example no F-15C aircraft were lost in 5,674 combat sorties flown.¹³⁵

In Desert Storm the acquisition, interpretation and timely and appropriate distribution of tactical intelligence was a weakness that impeded the flexibility and success of air operations.¹³⁶ The intelligence failures of the Gulf War 'were a direct result of the failure of operators to have trained realistically with their intelligence assets before the war.'¹³⁷ This was true in regard to electronic warfare operations. The lack of tactical intelligence training 'led to numerous problems throughout Desert Shield/Storm and the ensuing complaint of inadequate tactical intelligence.'¹³⁸ The problems were associated with 'inadequate training to personnel shortages to equipment shortfalls,'¹³⁹ replicated the experience of the Vietnam War.

Gulf War Conclusions

The Coalition supremacy in electronic warfare destruction and deception 'from start to finish was a big reason-maybe the biggest reason-for the stunning

¹³³ Dilegge, p.39.

¹³⁴ Kopp, notes.

¹³⁵ Keaney & Cohen, p.274.

¹³⁶ Mason, p.275.

¹³⁷ C.E. Colvard, 'Unfortunately, We Fought Like We Trained' Marine Corps Gazette vol. 75 no. 9 September 1991, p.20.

¹³⁸ Colvard, p.20.

success of the allied coalition's air campaign.¹⁴⁰ One of the cornerstones of the electronic warfare campaign was the preparatory work and planning that occurred before the air campaign. This had not happened in Vietnam until the LINEBACKER II operation and in Israeli until the Lebanon campaign. In the Gulf War, however, planning was not automatic or preordained but was improvised. In a campaign that was to be the antithesis of Vietnam, electronic targets were the first priority. Operations were intended to be overwhelming and were intended to offer no respite from attack. The Gulf War was unique in the context of the period and conflicts covered because of the Iraqi strategy of focusing on defensive actions, except SCUD missile attacks. Another unique feature was the lack of ongoing Soviet technical and material assistance to its client.

Significant equipment deployed in the Gulf War included satellites, cruise missiles, UAVS, HARM and ALARM anti-radiation missiles, AWACS and Hawkeye airborne early warning aircraft, and PGMs. Each system represented an incremental improvement over Vietnam era equipment but tactics and practices replicated earlier conflicts. Satellites replicated and enhanced the services provided by aircraft, but satellites were unique in the ability to remain continuously on station. Cruise missiles were an effective improvement on the German V1 rockets.¹⁴¹ The UAVS used were based upon unmanned aircraft used in Vietnam and Lebanon. AWACS, Hawkeye and JSTARS were derivatives of College Eye and Rivet Top early warning aircraft used in Vietnam, as were the precision-guided munitions.

The importance of electronic warfare 'should be so self-evident as to remove the need for explanation.'¹⁴² However, the allocation of resources suggested otherwise. The problems that beset aerial electronic warfare in Vietnam were still evident in the Gulf War. There was a shortage of electronic warfare aircraft that caused problems with mission completion and the use of standoff jammers reduced efficacy of electronic warfare campaign. There were further

¹³⁹ Colvard, p.21.

¹⁴⁰ Canan, p.26

¹⁴¹ <http://www.accessweb.com/users/mconstab/v1.htm>

continuities from the Vietnam War in the lack of control of airspace below 10,000 feet. After the loss of two F-16Ds on January 19th, daylight attacks against Baghdad ceased.¹⁴³ There were continuities in the lack of contingency planning. The mobility of targets caused problems in Vietnam and this was evident in the Gulf War with the detection of SCUD missiles.

There are other indications that the air campaign and the EW campaign were not as successful as indicated. Air defence assets were not neutralised and the Iraqi regime and military survived as a coherent organisation. After the Gulf War, despite the seemingly crushing defeat, the Iraqis had significant numbers of tanks, APCs, artillery pieces and multiple rocket launchers intact.¹⁴⁴ Targets of the air campaign such as power stations were back in operation within a week of the end of the war. Israeli analysis indicated that much of the Iraqi army had survived intact and up to 80% of equipment and 130 brigades was still intact.¹⁴⁵ Despite the air campaign specifically targeting electronic command and control, the Joint Chief's battlefield assessments indicated that 75 percent of national command telecommunications and 30 percent of military communications 'were still "operational" and that communications from Baghdad to Kuwait were continuously available.'¹⁴⁶ Overwhelming airpower also 'did not resolve the enduring regional problem posed'¹⁴⁷ and Saddam Hussein 'survived the "most successful" air campaign in history.'¹⁴⁸

The conduct of the aerial campaign in the Gulf War suggested to some observers that a revolution in military affairs had occurred. Much of the enthusiasm for the idea of a revolution in military affairs 'seems to have developed in the euphoric aftermath of the Gulf War.'¹⁴⁹ Such military

¹⁴² Mason, p.270.

¹⁴³ Keaney & Cohen, p.32.

¹⁴⁴ Houlahan, p.430.

¹⁴⁵ C.J.D. Thomas, 'How Israel Saw Iraq During the Gulf War' Royal United Service Institute Journal Winter 1991, p.42.

¹⁴⁶ Pape, p.240.

¹⁴⁷ Builder, p.11.

¹⁴⁸ J. Record, 'Defeating Desert Storm (and Why Saddam Didn't)' Comparative Strategy vol. 12 no 2. April/June 1993 p137

¹⁴⁹ Thomas, p.57.

revolutions 'are generally understood to be changes in military technology, concepts of operation, and military organisations which ... transform the conduct of war and make possible order-of-magnitude gains in military effectiveness.'¹⁵⁰ An RMA occurs when technological change combined with organisational and operational change, 'result in a transformation in the conduct of warfare.'¹⁵¹

The Gulf War did not indicate an order of magnitude change and did not represent a transformation of warfare. During the Gulf War, there were generally no new operational concepts for the use of airpower.¹⁵² The Gulf War 'bore a striking family resemblance'¹⁵³ to air campaigns as far back as World War II. The Gulf War air campaign was part of the incremental development of electronic warfare and experienced planning problems, inconsistent application of electronic warfare and systems failures that were not consistent with a revolution. According to Thomas, the Gulf War 'is not viewed as a revolution in military affairs but rather ... hinted at what was to come later.'¹⁵⁴

¹⁵⁰ Thomas, p.3.

¹⁵¹ Thomas, p.28.

¹⁵² Keaney & Cohen, p.209.

¹⁵³ Keaney & Cohen, p.201.

¹⁵⁴ Thomas, p.28.

Chapter 6**Conclusion**

This thesis has studied the development of electronic warfare to ascertain whether electronic warfare meets the conditions of revolutionary change in the second half of the twentieth century. These conditions are changes in technology, concepts of operations, and military organisation that transform the conduct of war and make possible order-of-magnitude gains in military effectiveness. This is a contemporary question that gains impetus from the current transformation in military affairs that is commonly called the RMA. This thesis proposes that there has not been a revolution in electronic warfare but rather a return to the principles and practices established during World War II. The catalyst for this return to the basic principles and practices of airborne electronic warfare was the introduction and development of radar guided surface to air missiles in an integrated air defence system.¹

This final chapter will examine the conclusions that this thesis has reached on the development of aerial electronic warfare since the introduction of surface to air missiles in the 1960s. This chapter will consider conclusions from the Vietnam air war, the Arab/Israeli wars and the Gulf War to establish if there is continuity between the conflicts and where departures or discontinuities exist. The methodology used, consistent with previous chapters, will consider electronic warfare doctrine, planning, strategy, equipment, operations and analysis of outcomes to establish continuities. This analysis thus establishes whether the use of electronic warfare in the period covered was revolutionary or a rediscovery of fundamental doctrine.

This thesis began with the establishment of definitions of electronic warfare and doctrine to establish a common language to be able to consider EW operations, principles and practices. Changes in doctrine, strategy and tactics as a result of the introduction of surface-to-air missiles were examined to consider if there has been a subsequent revolution in the development of electronic warfare. The application of EW doctrine and the use of new technology were appraised to observe if electronic warfare meets the

conditions of the revolutionary application of new ideas and technology. Consistent themes emerged. These included problems with doctrine and planning. A reluctance to use EW and incremental development is accompanied by systems failures and a persistent lack of electronic protection at low altitudes. These themes, particularly incremental development and systems failures are not consistent with revolutionary development. A revolution, by definition, involves rapid and fundamental changes, not repetition and not failure of vital component parts.

Problems with the application of doctrine were evident in the Vietnam War. The gradual escalation of the air war was the antithesis of contemporary USAF doctrine. USAF doctrine and effective electronic warfare practice called for overwhelming force in a rapid and decisive operation. Gradual escalation and lack of organic electronic warfare equipment enabled North Vietnamese air defences time to develop and overcome American electronic countermeasures until the LINEBACKER operations. In a return to doctrine that espoused overwhelming force, LINEBACKER II successfully destroyed electronic targets, whilst presenting a constantly changing electronic detection problem for the defenders.

A divergence of doctrine from strategy was not apparent in Israel's case until the 1973 Yom Kippur War. The Israeli air force doctrine successfully focused upon the courage and skill of Israeli pilots as the critical factor in Israeli success in the Six Day War. Israeli aircraft depended on electronic denial by flying in pre-plotted radar blind spots and below the radar horizon of Egyptian defenders to attack airfields at the start of the Six Day War. Once the Egyptian air force was eliminated, the Israelis attacked the early warning radar system and tried to systematically eliminate ground based air defences.

This doctrine was practical until the introduction of new anti-aircraft technology by Egypt and Syria. A change to the doctrine was then forced upon Israel by the losses of the Yom Kippur War. A post Yom Kippur war

¹ Price, p.253.

reappraisal of doctrine resulted in a change to EW strategy. The subsequent changes fully utilised the EW equipment acquired by the Israeli air force. Comprehensive and systematic EW practices and techniques were also introduced. The new doctrine was evident when Israeli aircraft, UAVs and ground forces systematically overwhelmed Syrian air defences during the invasion of Lebanon.

Problems with doctrine were not evident at the beginning of the Gulf War but became apparent particularly in regard to the anti-SCUD missile campaign. The full range of Allied air assets was used in a rapid and overwhelming campaign at the start of offensive operations. An air corridor was opened in the Iraqi air defence perimeter by the destruction of two early warning radars. This simple strategy enabled non-stealthy aircraft to operate with near impunity, when accompanied by electronic countermeasures jamming aircraft. At the same time F-117 stealth aircraft and cruise missiles were dismembering command and control. Problems subsequently arose with the execution of the EW campaign. Objectives were not met and strategy was unable to adapt to meet new contingencies such as the SCUD missile campaign by Iraq. Although the Iraqi integrated air defence system was shattered, individual air defence sites continued to operate autonomously and enabled Iraq to control the airspace below 10,000 feet. The resulting Coalition strategy of flying mainly at night and above 15,000 feet was not consistent with a doctrine of controlling the air.

Recurrent planning problems at the start of the Vietnam conflict highlighted an issue that was inimical to good electronic warfare operations. Planning problems were also apparent in the subsequent conflicts studied. Planning problems in Vietnam were a direct result of policy based upon political imperatives. Planning problems were compounded by a doctrinal belief that pilot's skill could overcome most difficulties. Planning was also uncoordinated and inconsistent with electronic denial used in some operations and then not others. Although the planning for ROLLING THUNDER was inadequate, the planning and execution for LINEBACKER II set a standard and provided a model for future electronic warfare operations.

Israel's forces based their strategic plan for the Six Day War in 1967 upon information provided by electronic surveillance. However, the success of the Six Day War contributed to a lack of contingency planning that became apparent with the Yom Kippur War. An example was the failure to systematically exploit the air corridor opened by ground forces at the northern end of the Suez Canal and either attack strategic targets or degrade the Egyptian air defences. The losses incurred during the Yom Kippur resulted in an increased focus on detailed and extensive electronic surveillance and planning. This was evident in the execution of the 1982 Lebanon EW campaign. This campaign saw the full use of electronic detection, deception and destruction practices and principles that would form the basis of the Gulf War electronic battle.

The Gulf War saw electronic warfare planning reach a level comparable to the OVERLORD electronic warfare plan of World War II. However, the process was not automatic or preordained and had to be promoted by key people such as air force Colonel Warden. Gulf War planning was the antithesis of the early years of the Vietnam War. ROLLING THUNDER became INSTANT THUNDER, with systematic and detailed electronic warfare planning to win the air war. Plans and scenarios were tested in computer simulations. Planning in the initial stages was focused on gaining superiority of the electromagnetic spectrum by dismembering the Iraqi air defence system from the top down. There were problems however, with unexpected contingencies. One result was the problems associated with the anti-SCUD missile campaign and another was the less than optimum attrition of the Iraqi air defence system. These problems indicated an inconsistent application of planning with emphasis on systematic and comprehensive planning at the beginning of the campaign but ad hoc and reactive planning as the campaign progressed. Planners failed to answer the question of what to do when the master plan did not work.

Problems associated with a reluctance to use electronic warfare were exacerbated by gradual escalation against North Vietnam. Limits on aircraft

such as restricting B-52s use and restrictions on targets resulted in the inability to deceive or destroy electronic threats. These problems were compounded by the Route Package system of allocating targets to specific U.S. armed services. This degraded electronic denial and countermeasures through repetitive practices and failure to eliminate potential electronic threats. The clear communications and repetitive attack patterns that characterised ROLLING THUNDER were eliminated during LINEBACKER operations. In direct contrast to ROLLING THUNDER, the LINEBACKER II campaign used the full range of ESM, ECM and ECCM equipment tactics and equipment available. Enciphered communications and varied attack patterns were coupled with high and low level attacks carried out both during the day and at night. This ensured no rest or respite, particularly in LINEBACKER II.

A reluctance to use EW and inconsistent application was the result of a number of factors. These included electronic warfare equipment not being available until mid 1966 for the fighter/bombers. These aircraft undertook the majority of bombing missions against North Vietnam until LINEBACKER operations in 1972. Paradoxically the B-52s that did have electronic countermeasures systems were used for the first time during the LINEBACKER operations. Until then they had been employed in close air support in South Vietnam and against targets on the Laotian border. The main countermeasure employed against radar controlled AAA, until the introduction of SAMs, was simply to fly above the range of AAA. Another indication of the reluctance to use EW was introduction of Chaff in 1972. Chaff was not used in the first seven years of the Vietnam War because there were no Chaff dispensers provided for fighter/bomber aircraft.

Reluctance to use EW was also evident in the Six Day War. This was a result of a lack of equipment and a belief that the skill and courage of Israeli pilots could overcome any difficulty. The subsequent War of Attrition did not change a reluctance to use EW practices and techniques even though EW equipment was acquired. Reluctance to use EW and inconsistent application continued into the Yom Kippur War and was one of the significant contributors to the heavy Israeli losses. An example of reluctance was the breaching of the

Egyptian air defence system integrity by ground forces. This opened an air corridor through which attacking aircraft could tackle the air defence system but was not exploited. Egyptian strategic, command and control assets were also not attacked, despite these targets being a priority during the Six Day war and the War of Attrition. Ground forces again attacked SAMs in the Lebanon campaign and opened an air corridor that was exploited. Significantly the idea of using an air corridor would be a critical component of the Gulf War electronic battle.

A reluctance to use EW and inconsistent application became apparent in the Gulf War as the air campaign progressed. The abandonment of low altitude operations and a reversion to night flying are two significant indicators of a reluctance to use EW. Despite the absolute necessity for control of the air and the electromagnetic spectrum the Coalition chose not to electronically engage and overcome low altitude threats. Another sign of the reluctance to use EW was the anti-Scud missile campaign that provided an indication of electronic surveillance and countermeasures deficiencies. The principle method of dealing with SCUD missiles was to try to shoot them down at the end of their flight. No provision or effort was made to use electro-magnetic pulse weapons (EMP) against SCUDS in the launch phase or whilst in flight. EMP weapons were available and were used against static targets in Baghdad. The provision of specialised EW aircraft and crew are another indicator of a reluctance to use EW and the lack of sufficient aircraft and crew was a feature of the whole campaign.

The introduction of SAMs induced the incremental development of electronic countermeasures equipment and tactics in Vietnam after 1966. Key systems deployed included Wild Weasel SAM suppression aircraft, EB-66 Destroyer specialised standoff jamming aircraft, College Eye and Rivet Top air early warning aircraft. Organic electronic countermeasure equipment such as ECM pods, Shrike anti-radiation missiles and standoff weapons such as Walleye TV guided bombs were also introduced. The use of standoff weapons such as the Walleye enhanced electronic denial by enabling aircraft to operate out of range of air defence weapons. Standoff weapons would develop from the

Walleye to culminate in Tomahawk cruise missiles in the Gulf War. Wild Weasel aircraft equipped with specialised equipment such as the Shrike radar homing missile enhanced electronic destruction and provided a guide for the future suppression of electronic threat operations.

Another component of the incremental development of the electronic warfare system was the College Eye and Rivet Top aircraft that were introduced in late 1967. These aircraft were supplemented with the RED CROWN radar picket ship. These assets enabled early warning of threats and allowed U.S. aircraft to initiate simple electronic denial countermeasures by avoiding threats. The principle of early warning would develop from Rivet Top and College into Rivet Joint and AWACS. College Eye and Rivet Top provided airborne early warning that was indispensable and provided the basis for future AEW aircraft practices and tactics. Specialised airborne early warning aircraft was an innovation based upon advanced technology but followed the practices used for airborne electronic surveillance in World War II.

The development of electronic warfare during the period of conflict in the Middle East was also incremental, starting from minimalist tactics and equipment and concluding in the full range of electronic warfare equipment and practices. The process of measure and countermeasure was not as evident as in the Vietnam air war. However, the War of Attrition induced Israel to acquire ESM, ECM and ECCM equipment. Six-Day War operations had adhered to the tenets of rapid overwhelming force but this type of operation could only be successful for limited time. The Six Day War did not prepare Israel for the protracted War of Attrition that followed, and did not prepare Israel for missile combat or the electronic battles that followed. Israel acquired some of the requisite EW equipment but not the doctrine and strategy to utilise the equipment.

The Yom Kippur War raised the level of Israeli consciousness regarding electronic warfare. The losses of the Yom Kippur War induced a significant re-evaluation of principles and practices that resulted in a period of evaluation and significant EW development. Following the Yom Kippur War Israel

acquired more sophisticated electronic warfare systems from the United States. The electronic warfare acquisitions focused on electronic countermeasures including Chaff, flares and electronic jamming pods for aircraft. Boeing 707 aircraft were acquired to provide ELINT and E-2C Hawkeye airborne early warning aircraft were acquired for electronic detection and surveillance. These were critical for success. Standoff weapons such as the contemporary laser guided bombs for electronic denial removed the need for Israeli aircraft to enter high threat areas. Specialist electronic warfare destruction and denial was assigned to the ubiquitous F-16 Eagles armed with Shrike anti-radiation missiles. The Israelis also acquired and developed remotely piloted aircraft to deceive and decoy Syrian SAM systems. The result was the full use of electronic warfare in the successful invasion of Lebanon.

The Lebanon campaign, like Linebacker II, provided a guide for future electronic warfare air operations. The Lebanon campaign was the culmination of years of development and the lessons learnt from unsustainable losses to air defence assets. Syrian air defences were neutralised by a systematic and overwhelming attack that denied Syrian electronic surveillance, destroyed Syrian electronic targets and Syrian air defences. Simple but extremely effective electronic detection methods such as air borne early warning aircraft had a devastating effect. Israeli aircraft could attack Syrian aircraft undetected whilst Syrian aircraft were denied ground control communications and the ability to electronically acquire Israeli aircraft. The result was the loss of only one Israeli aircraft for one hundred Syrian aircraft destroyed. Although the equipment was new and advanced in terms of capabilities, size and accuracy, the Lebanon campaign was, like Vietnam, a rediscovery of some of the World War II practices and principles used by the Allies. The air war in the Middle East arrived at the same conclusions that were reached in Vietnam, especially in regard to using EW in overwhelming force and in a rapid operation.

Incremental development was not as immediately evident in the Gulf War as had been the case in the earlier wars. However, the key EW systems deployed represented incremental developments from the earlier conflicts.

The equipment used in the Gulf War was faster, smaller and more accurate than in previous wars but the essential objectives and targets were remarkably similar to the earlier conflicts. All the equipment except satellites were descendants from systems used in Vietnam and the Arab/Israeli Wars. Specific equipment in the Gulf War, such as AWACs was an improvement upon COLLEGE EYE and RIVET TOP aircraft. Standoff weapons such as the contemporary Walleye and laser-guided bombs were improved versions of those weapons used in Vietnam. Specialist electronic warfare destruction and denial aircraft such as the F-4C Wild Weasel and EF-111 Raven were also improved Vietnam era aircraft. Unmanned aircraft that played a pivotal role in electronic deception, detection and denial were also direct improvements of those used in Vietnam and Lebanon.

Recurrent systems failures were evident with EW systems such as the EB-66 Destroyer specialist electronic warfare aircraft used in the early years of the Vietnam War. The EB-66 was not effective because they were susceptible to the missiles systems that they were supposed to provide protection against. Operations were conducted outside the effective range of the EB-66. This problem would not be resolved until the reintroduction of ubiquitous escort electronic countermeasures aircraft that could accompany the bombers for the whole of the mission. Another persistent problem was the limited number of EW aircraft available. There were not enough aircraft to provide sufficient electronic protection and therefore only partial coverage existed, instead of the requisite systematic and comprehensive coverage. The subsequent use of organic ECM pods provided limited protection, and these limits would continue to be an issue. Organic countermeasure equipment had a limited effect in the initial stages of the Vietnam War and could not make up for shortcomings imposed by planning and strategy deficiencies. Equipment such as countermeasure pods had to be utilised with the full range of EW equipment and practices that was evident in the LINEBACKER II operation. The electronic warfare equipment available performed at maximum efficiency when used systematically and as part of an operation that was designed to totally overwhelm and destroy electronic threats.

Electronic warfare systems failures were evident with the elimination of the electronic surveillance and denial advantage that Israel enjoyed before the Six Day War. During the subsequent War of Attrition, Egypt successfully sought to degrade Israeli advantages by a systematic and protracted extension of Egypt's integrated air defence system. With Soviet assistance, Egypt was successful in introducing new electronically guided equipment that eliminated Israel's ESM advantage and consequently degraded ECM capabilities. Israeli forces did not have the comprehensive Egyptian electronic order of battle that existed prior to the Six Day War. Thus electronic countermeasures did not work against the SA-6 missile that was introduced by Egypt during the Yom Kippur War. Electronic countermeasures equipment and tactics were also ineffective against the ZSU and SA-7 missiles.

Recurrent systems failures were evident in the Gulf War, particularly in regard to electronic surveillance, detection of targets and electronic protection at low altitudes. Electronic surveillance failures resulted in electronic countermeasures failures. The result was that after a 40 day air campaign, targets still had not been neutralised that should have been neutralised in the initial stages of the campaign. These targets included ground based air defence systems that provided a threat to Coalition aircraft and continued to extract heavy casualties at low altitudes. Despite the most comprehensive and technologically advanced electronic warfare campaign in history, Iraqi forces could still electronically acquire and engage a range of targets.

The air war in North Vietnam does not seem to have brought to light any revolutionary principles or practices in electronic warfare. However, LINEBACKER II did set a contemporary standard and an example for future developments. LINEBACKER II also approached a level of systematic and comprehensive EW operations that was evident in World War II OVERLORD operations. The Arab/Israeli Wars also provided another interesting opportunity to study electronic warfare operations and development under combat conditions. These conflicts are significant because the equipment used by the protagonists was consistent and the outcomes were similar to U.S. experiences in Vietnam. Although the details are different, significant

operations such as LINEBACKER II and Peace for Galilee shared common EW objectives and outcomes. The Gulf War marked the high point of EW development with the lessons of the Vietnam War and Arab/Israeli War absorbed and utilized to produce a largely successful electronic warfare campaign.

The electronic warfare equipment, practices and strategies in the Gulf War have been used as the basis for an argument that there has been a revolution in military affairs. There is evidence in some areas of electronic warfare that this may be substantiated. These include the utilisation of remotely piloted vehicles, computer simulations for planning and the use of electro-magnetic pulse weapons. These particular areas have the potential for revolutionary development that may see a transformation in the conduct of warfare. Development in these areas may result in order of magnitude gains that may produce an entirely new form of warfare and destroy the existing military order. A case could also be made that Israel underwent an electronic warfare revolution, particularly in regard to doctrine, as a result of the Yom Kippur war. However, the Israeli 'revolution' arrived at the same conclusion that was reached by the U.S. in the Vietnam air war.

This thesis proposes that in general, the changes in electronic warfare technology, concepts of operations and organisation have not transformed the conduct of warfare in general or electronic warfare in particular. There have not been orders-of-magnitude gains in military effectiveness or changes to military operations that have introduced a new orders or new forms of military elites. The introduction of the surface-to-air missiles in an integrated air defence system has instead provided an impetus for development of electronic warfare that has led to a rediscovery of basic principles and practices. The loss of aircraft and more importantly pilots has raised the collective level of consciousness and electronic warfare standards but has not produced a revolution.

Glossary

AA	Anti-aircraft
AAA	Anti Aircraft Artillery
A-4	Skyhawk U.S. ground attack aircraft
A-7	A single-engine, all-weather, light attack aircraft
AC-130	A C-130 cargo aircraft modified with sensor equipment and armament making it suitable in the surveillance and attack role.
AFB	Air Force Base
Agranat Commission	A commission to investigate Israeli Intelligence failures associated with the Yom Kippur War in 1973
AGM-45	Shrike U.S. air to ground anti-radiation missile
AGM-65	Maverick air to ground missile
AGM-86C	Tomahawk U.S. air/surface to surface land attack missile
ALARM	Air Launched Anti-Radiation Missile
ALO	Air Liaison Officer
APC	Armoured Personnel Carrier
AS-5K	Kelt Soviet air launched anti-radiation missile
ATO	Air Tasking Order
A-10	Warthog anti-tank airplane
BABYLON	Code name for the attack on Iraq's Osirak nuclear reactor in 1981
BARREL ROLL	Code name for air operations in central and northern Laos
BDA	Bomb Damage Assessment
Bi-Static Radar	Radar system that may operate with transmission and reception aerials in separate locations, or using passive radar reception.
Black Hole	Code name for Desert Storm planning HQ
BOLO	Code name for MIG suppression operations (1967)
Boozer	British passive Radar Homing and Warning equipment (1944)
BQM-74	U.S. remotely piloted unmanned aerial vehicle
BULLET SHOT	Code name for deployment of U.S. to Vietnam February 1972
B-52	Strategic Bomber
C-130	Four engine, turbo-prop, medium-range cargo aircraft.
CBU	Cluster Bomb Unit
Call Sign	Identifying words assigned to an aircraft, ship, unit etc. for the purpose of radio communications.
CAP	Combat Air Patrol
CEP	Circular error probable, distance from aiming point with which half the bombs or projectiles are expected to strike.
CENTCOM	Central Command
Chaff	U.S. radar reflecting material used to deceive and draw missile fire
CINC	Command In Chief
CTV-77	Commander Task Force 77 on station off Vietnam 1972

DAWN	Code name for Israeli operations to start the Six-Day War 1967
DESERT STRIKE	1964 exercise to test U.S. aircraft in a SAM environment
DESERT STORM	Code name for U.S. offensive operations to liberate Kuwait in 1991
DMZ	Demilitarised Zone separating North and South Vietnam near 17 degrees north
EAF	Egyptian Air Force
EA-6	Prowler Navy electronic warfare jamming aircraft
EB-66	Destroyer U.S. specialised EW aircraft (1965)
ECM	Electronic Counter Measure
ECCM	Electronic Counter Counter-Measure
EC-121	COLLEGE EYE U.S. airborne early warning aircraft (1967)
EC-121	Rivet Top U.S. airborne early warning aircraft (1967)
EC-130H	Compass Call U.S. electronic warfare surveillance/jamming aircraft
EF-111	Raven U.S. electronic warfare jamming aircraft
EL DORADO CANYON	Code name for an air operation against selected targets in Libya on April 14 th 1986
EOGB	Electro-Optical Guided Bomb
EOB	Electronic order of battle
ESM	Electronic Surveillance Measures
EWO	Electronic Weapons Officer
E-2C	Hawkeye U.S. radar early warning aircraft
E-3	AWACS U.S. Airborne Warning and Control System
FAC	Forward Air Controller - an officer who controls aircraft engaged in close air support
Ferret	Name adopted and associated with SAM radar detection aircraft/missions.
FFZ	Free fire zone
FIRECAN	NATO designation for radar controlling AAA
FOB	Forward Operating Base
FREEDOM TRAIN	A air operation against North Vietnam in April 1972
F-4	Wild Weasel twin-engine, all-weather, tactical fighter aircraft designed for air defence suppression
F-15	Eagle general purpose air combat aircraft
F-16	Falcon fighter/attack aircraft
F-18	Hornet Navy/Marine fighter/attack aircraft
F-111	A twin-engine, all-weather, tactical fighter aircraft
F-117	Nighthawk stealth fighter primarily used for deep penetration
GABRIEL	Code name for the Israeli ground offensive that opened a radar free air corridor during the Yom Kippur War.
GAMORAH	Code name for British operation against Hamburg July 24 th 1943, and first operation to use Window (Chaff)
GCI	Ground Control Intercept
GPS	Global Positioning System
HARM	High Speed Anti-Radiation Missiles
HAS	Hardened Air Shelter

HAWK	U.S. anti-aircraft missile
IAF	Israeli Air Force
IDF	Israeli Defence Force
IFF	Identification Friend or Foe
IGLOO WHITE	Code name of the program for developing electronic battlefields.
INSTANT THUNDER	Code name for strategic air war against Iraq in 1991
INTERNAL LOOK 90	Code name for U.S. command exercise targeting Iraq in 1990
IR	Infrared
IRON HAND	Code name for suppression of air defence missile missions.
JCS	Joint Chiefs of Staff
JSTARS	Joint Surveillance and Target Attack Radar System
KARI	French built integrated air defence system used by Iraq
LGB	Laser Guided Bomb
LINEBACKER I	Code name for the strategic air campaign against North Vietnam May 10 – October 23 rd 1972
LINEBACKER II	Code name for the strategic air campaign against North Vietnam December 18-29 1972
LOC	Lines of Communication
Loran	Radio navigation aid
LZ	Landing Zone
MAC	Military Airlift Command
Mandrel	British organic bomber jamming system (1943)
MAP	Master Attack Plan
Mastif	Israeli remotely piloted vehicle
MEF	Marine Expeditionary Force
MEL	Mobile Erector Launcher used for mobile missiles
MIG	Soviet built fighter aircraft
MIGCAP	Combat Air Patrol for protection against MIGs
MIM-104	Patriot U.S. anti-missile missile
MLRS	Multiple Launch Rocket System
Monica	British airborne radar early warning system (1943)
NATO	North Atlantic Treaty Organization
NICKEL GRASS	Code name for the U.S. operation to resupply Israel with military equipment to replace losses during the Yom Kippur War in 1973
NVA	North Vietnamese
P-3	A four-engine, turbo-prop, all-weather, long-range antisubmarine aircraft.
PEACE FOR GALILEE	Code name for Israeli invasion of Lebanon in 1982
PGM	Precision-Guided Munitions
PINE TREE	Code name for Israeli military operations of Lebanon in 1982
Psyops	Psychological operations
RAF	Royal Air Force
RED CROWN	Code name for USS Pelez radar early warning ship (1970)

Real Time	computer operations that provide essentially instantaneous output.
RHAW	Radar Homing and Warning equipment
ROE	Rules of Engagement
ROLLING THUNDER	Code name for air operations against North Vietnam 1965-1968
Rolland	French surface to air missile
ROUTE PACKAGE	Code name for the system of allocating attack zones in Vietnam to specific U.S. services
RPV	Remotely Piloted Vehicle
SAC	Strategic Air Command
SAD	Strategic Air Defences
SAM	Surface-to-Air Missile
SA-2	Guideline Soviet radar/radio controlled surface to air missile
SA-3	Goa Soviet radar/radio controlled surface to air missile
SA-6	Guideline Soviet radar/radio controlled surface to air missile with infrared terminal guidance
SA-7	Grail Soviet shoulder launcher heat-seeking anti-aircraft missile
SA-9	Soviet-made surface-to-air missile
SA-13	Soviet-made surface-to-air missile
SCUD	Soviet-made surface-to-surface missile
SEAD	Suppression of Air Defences
Scout	Israeli remotely piloted vehicle
SIGINT	Signals Intelligence
SIDEWINDER	U.S. heat-seeking anti-aircraft missile
STINGER	U.S. shoulder launched anti-aircraft missile
Spectre	Call sign for AC-130 gunship
TAC	Tactical Air Command
TEABALL	Code name for U.S. GCI radar capability (1972)
TALD	Tactical Air-Launched Decoy
TEL	Transporter Erector Launcher for missiles
TLAM	Tomahawk Land-Attack Missile
TOT	Time Over Target
TOW	Tube-launched, optical-tracked, wire-guided anti-tank missile
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force
USN	United States Navy
Wall Eye	U.S. TV guided glide bomb
Wild Weasel	Name adopted and associated with SAM suppression aircraft/missions.
Window	British name for Chaff - radar-reflecting material used to deceive and draw missile fire
Yom Kippur	Israeli name for the October 1973 war with Egypt, also known as the Ramadan War
ZSU	Soviet self propelled four barrelled radar guided anti-aircraft gun system

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