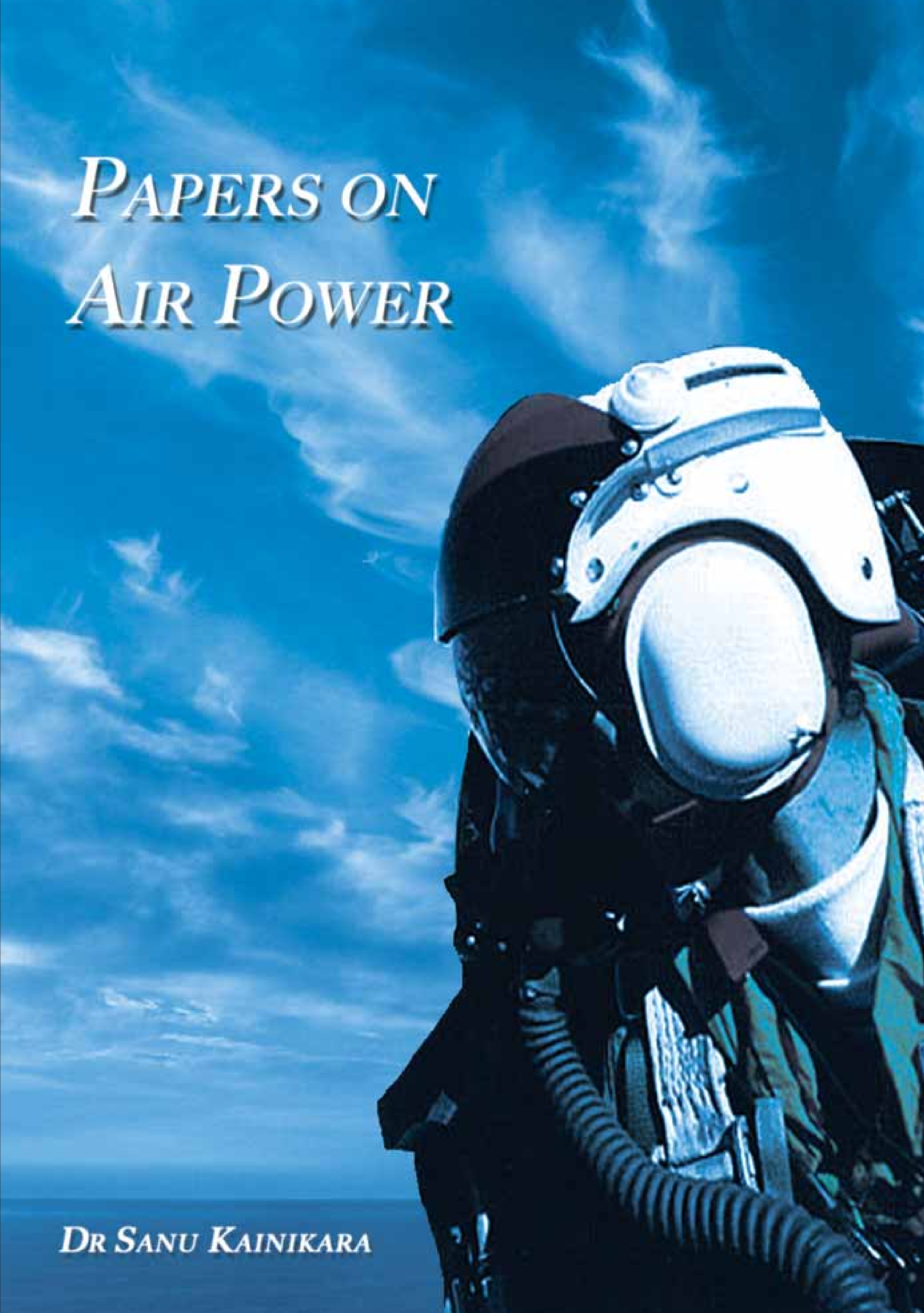
PAPERS ON AIR POWER



DR SANU KAINIKARA

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ON
AIR POWER

Dr Sanu Kainikara

Air Power Development Centre
Canberra

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He is a regular contributor to defence-related magazines and has published prolifically on air power and defence strategy in the *Asia-Pacific Defence Reporter, Fighter Tactics, Australian Defence Force Journal* and *The Leading Edge*. He is also a contributing editor to the *Asia-Pacific Defence Reporter.* He has also presented a number of papers on air power and defence strategy in various international professional forums.

Dr Kainikara is a graduate of the Indian National Defence Academy, Defence Services Staff College and the College of Air Warfare. He holds two Bachelors degrees and a Master of Science in Defence and Strategic Studies from the University of Madras. His PhD in International Politics was awarded by the University of Adelaide.

Preface

Between 1996 and 1998 I worked as a senior analyst in air power strategy, operations and tactics for a US-based private company. During this period I carried out a great deal of research and analysis into almost all facets of air power employment. This book is a collection of some unclassified, independent background analyses that I carried out as a precursor to detailed reports. It also contains few draft papers that I wrote during the same period. The drafts were mainly intended as dynamic initial working papers on which to base more detailed and at times classified reports as necessary. In their current form they have not been published or made available to the public, to the best of my knowledge. Further, only a few of the papers included in this collection finally eventuated in the form of a more detailed report.

Since most of the research was carried out almost a decade ago, the papers are also of the same vintage. Therefore, only those that have a definitive relevance to air power in the contemporary context have been included in the collection. Although all the papers relate to air power issues, ranging from the tactical to strategic, they analyse very disparate issues. Some of the research papers are purely analysis of equipment that have a direct bearing on the application of air power, a few are analysis of campaigns to distil lessons from them, there are two technically oriented papers on design of combat aircraft and some have been written at the philosophical doctrinal level. Because of the diversity of the topics covered it has been difficult to find a common theme and flow through the entire collection. However, in order to improve its cohesiveness, the book has been organised in four sections—air combat, air warfare concepts, aircraft design and weapon systems.

The air combat section contains four papers that cover; planning to obtain air supremacy, the importance of training, the role of situational awareness and the impact of stealth on air combat. These form part of a six-paper study series that covered aspects outside the purely tactical and operational level of air combat, but analysed factors that have a profound if indirect influence on the conduct of air combat *per se*. Two of the six research papers have almost no relevance to air combat as practised today and therefore I have excluded them from this compilation.

The section on air warfare concepts contains preliminary work that I did in establishing the planning primacy of gaining air superiority in a campaign, the role of air power in offensive military doctrine, lessons in air power from limited armed conflicts and the concept of employment of Russian military aircraft.

Perhaps by virtue of my background, I have always had an enduring interest in the use of air power in limited armed conflicts. The research for the papers in this section was carried out more as a personal quest to understand certain aspects of air warfare, especially when employed by 'smaller' air forces. The research paper on the concept of employment of Russian aircraft formed the core of the keynote address that I delivered to the Air Warfare Conference held at RAAF Base, Williamtown in June 1999 under the combined sponsorship of DSTO and the RAAF. More importantly, it led me to further study of the Soviet/Russian Air Force, culminating in my choosing 'Russian Concept of Air Warfare: The Impact of Ideology on the Development of Doctrine' as my thesis topic for the PhD that the University of Adelaide awarded me in 2006. I feel that the papers in this section have great relevance today because they analyse the concepts of employment of air power from an overarching strategic level, with a particular emphasis on small air forces.

The third section, on aircraft design, contains two research papers dealing with the design features that enhance performance characteristics of fighter aircraft and the development of tailless designs for combat aircraft. Most of the conclusions that were drawn are still pertinent today and some of the issues highlighted have yet to be solved. There is relevance in looking at the performance characteristics of traditional fighter aircraft, especially with the current global push to improve the performance of Uninhabited Aerial Vehicles (UAVs). The fourth section has a follow-on role to the third in that the first two research papers look at UAVs in terms of their impact on air warfare and the changes that would come about at the higher operational level of air warfare when the full potential of Uninhabited Combat Aerial Vehicles (UCAVs) is realised and they are finally employed autonomously. The third paper in the section is a generic appreciation of the developments in Battlefield Air Defence, concentrating on technological developments that have been instituted to improve the efficiency of guns in providing an all-round mobile air defence capability. This assumes greater importance today as more and more world air forces are adopting an expeditionary construct in support of national security requirements and therefore acquiring more sophisticated organic surface-to-air capabilities.

I have not attempted to update the analysis of any of the papers since no outdated research papers have been included in the collection. However, I am aware that there may be certain conclusions drawn based on information available at the time of the research that may not now hold true. But such cases are very few. The papers cover research into a number of disparate issues that continue to constrain and impact the employment of air power. They also discuss some fundamental doctrinal and philosophical issues that have been debated since the beginning of air power theory. To a student of air power, the papers have a great deal of relevance and I feel confident that they will add value to the available literature and analysis of existing as well as emerging air power issues.

Dr Sanu Kainikara
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May 2007

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Section I

Air Combat

PAPER 1

Planning for Combat
The Primacy of Air Superiority

War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied.

Sun Tzu, *The Art of War*

Any Air Force which does not keep its doctrine ahead of its equipment, and its vision far into the future, can only delude the nation into a false sense of security.

Hap Arnold

INTRODUCTION

War is the most complex of human endeavours and therefore the most difficult to study and understand. Centuries of land warfare were conducted before philosopher warriors like Sun Tzu laid down the basics for success in war. However, it only took decades for air power exponents to synthesise the essence of aerial combat and lay down in basic terms the optimum employment of air power in the pursuit of overall victory. The principles of war are essentially the same for both army and air forces. But the speed, range and flexibility of air forces pose special problems and also offer special advantages that centre around the principles of mass and concentration, and their corollary, economy of force .[1]

Planning an air campaign is an art and the product of logical thinking. In any war, the air commander will have the choice between offence and defence. But the basic dictum, that can only be disregarded at the cost of defeat, is that whatever the choices available, no air campaign can succeed until air superiority is achieved. It is possible for an air force to have absolutely superior forces—numerically and qualitatively—and lose not only the air war but the entire war!

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[1] General Charles L. Donnelly, Jr (USAF, Ret.), Introduction to Colonel John A. Wardon III, *The Air Campaign,* Washington D.C: National Defense University Press, 1998, pxxxiii.

PERSPECTIVE ON THE AIR CAMPAIGN

In order to plan and direct operations, war can be broken down into parts that are related to decreasing levels of responsibility. The four levels of war are grand strategic, strategic, operational and tactical. Of these the strategic levels and the tactical level have been adequately explored and a large number of publications are available for their study. Surprisingly, very little has been written about the theory and practice of war at the operational level.[2]

Operational Level of War. The operational level is primarily concerned with how to achieve the strategic goals of the war with the forces allotted. It is the level at which plans are made for the actual employment of land, sea and air forces and the level where these forces are employed in the course of a campaign. Generally, a theatre commander is concerned with operations, as opposed to strategy. Operational thinking remains essential and a genuine understanding of it is vital for the conduct of a successful campaign. A lack of coherent doctrine on the utilisation of the various armed services, individually and collectively, in an operational campaign to secure some strategic goal leads to a host of problems that thwart the achievement of even limited objectives.

All kinds of operations that might influence the campaign must be considered. In today's context, if the air campaign is to be waged against a modern, highly resilient industrial power, there may not be a single target that holds the key and so a number of targets would have to be attacked. These targets would have to be chosen to affect the enemy's centre of gravity.

Centre of Gravity. The term 'centre of gravity' describes that point where the enemy is most vulnerable and the point where an attack will have the best chance of being decisive. The term indicates a point against which a level of effort will accomplish more than that same level of effort could accomplish if applied elsewhere. Clausewitz called it the 'hub of all power and movement.'[3] Every level of warfare has a centre, or centres, of gravity. The most important responsibility of a commander is to identify correctly and strike appropriately enemy centres of gravity. Theatre operations must be planned, coordinated and executed with the idea of defeating the enemy by striking decisive blows.

The theatre commander will normally have air, sea and land forces at his disposal. Depending on the identified centre of gravity of the enemy, he must decide which, or which combination of available forces must be used. Historically, it is seen

[2] Richard E. Simpkin, *Race to the Swift: Thoughts on Twenty-First Century Warfare, Brassey's* Defence, London, 1985.
[3] Carl von Clausewitz, *On War*, translated and edited by Michael Howard and Peter Paret, Princeton University Press, Princeton, NJ, 1976, p. 595.

that single arms can prevail, if employed optimally. But a prerequisite for the success of any single arm (or a combination) is the need to achieve and maintain air superiority.

THE CONCEPT OF AIR SUPERIORITY

In any war air superiority is a necessity. Since the German attack on Poland in 1939, no country has won a war in the face of enemy air superiority, no major offensive has succeeded against an opponent who controlled the air, and no defence has sustained itself against an enemy who had air superiority. Conversely, no state has lost a war while it maintained air superiority, and attainment of air superiority consistently has been a prelude to military victory.[4]

Air superiority could be defined as a situation wherein own air forces are able to operate without any hindrance, while denying the same to the enemy and ensuring that own surface forces are not constrained by enemy air activity. Although propounded as the cornerstone of the employment of air power, in actuality, complete and unopposed air superiority is very rarely achieved. There are varying degrees and categories of air superiority that would prevail in any war. These could be classified as listed below.

- **Favourable Air Situation**. This is defined as a situation wherein friendly air forces are capable of operating in the theatre of interest without undue interference by the opposing air element. It does not mean that the enemy air force is completely neutralised, and it may also be that they have the independence to oppose effectively certain missions of one's own forces. A Favourable Air Situation (FAS) can also be fluctuating between the contending forces. In essence, FAS has to be defined both in time and space and is not all-encompassing. However, FAS is the bare minimum of control of the air that is necessary for surface forces to proceed with their plans. A regional air force, fighting a limited war should first aim at achieving FAS before trying to establish air superiority. Depending on its strength, operational priority and the time that is available, it may also become necessary for an air force to accept a 'Tolerable Air Situation' at the beginning of a conflict. However, it must be ensured that this situation is only accepted in case other factors are of such overriding concern that the surface campaign can not be delayed.

- **Air Superiority.** This can be defined as a situation wherein the air force has complete freedom of movement and operation in a limited area for a finite

[4] John A. Warden III, *The Air Campaign: Planning for Combat,* National Defense University

period of time. At times this situation is also referred to as local air superiority. The concept of air superiority has always got to be qualified geographically and in terms of time frame which must extend to at least a few days or till the culmination of a particular operation by the surface forces. Theatre air superiority means that friendly air can operate at any place and time within the entire combat theatre.

- **Air Supremacy.** Air supremacy means the ability to operate air forces anywhere without opposition. This situation can be achieved by regional air forces only at great cost to itself or if the opposing forces have been defeated conclusively at the beginning of the conflict.

The contention that air superiority is a necessity to ensure victory or avoid defeat is based on theory as well as on an analysis of the last half century of warfare. Theory alone would suggest that surface warfare cannot possibly succeed if the surface forces and their support elements are constantly under attack by enemy aircraft.[5] This theory is copiously supported by historical examples, a few of which would amply illustrate and reinforce the point.

- Germany destroyed Poland's air force in the first days of the campaign. From then on, the Germans were able to use their air forces to interdict, attack ground troops, and soften positions for subsequent rapid movement of surface forces.[6] Nine months later, Germany repeated the operation in France, when the Luftwaffe won air superiority in two days.[7]

- On the other side in World War II, the Western Allies achieved air superiority before German Field Marshal Erwin Rommel's last offensive at Alam Halfa. Rommel observed:

  Anyone who has to fight, even with the most modern weapons, against an enemy in complete control of the air, fights like a savage against a modern European army.[8]

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5 Ibid., p. 14.

6 Cajus Bekker, *The Luftwaffe War Diaries*, translated and edited by Frank Ziegler, Ballantine Books, New York , 1969, p. 31.

7 Williamson Murray, *Strategy for Defeat: The Luftwaffe* 1933-45, Air University Press, Maxwell Air Force Base, Ala, 1983, p. 36-37.

8 Ronald Lewin, *Rommel: As Military Commander,* Ballantine Books, New York, 1972, p. 275.

Rommel subsequently made a similar comment about the situation in Sicily and in Italy:

Strength on the ground was not unfavourable to us. It's simply that their superiority in the air and in ammunition is overwhelming, the same as it was in Africa.[9]

- In recent times, the Israeli's have illustrated the power of air superiority. In 1967, the Israelis destroyed the Egyptian and Syrian Air Forces on 5 June and then proceeded to lay waste the Egyptian Army in the Sinai, where Israeli command of the air had made life intolerable for the Egyptian soldier.[10] Six years later the very same Israeli Defence Force paid a terrible price for not gaining air superiority in the first phase of the war. Only after recognising the need to suppress enemy missile systems—their primary barrier to air superiority—were they able to turn the tide of battle.[11]

The weight of historical evidence overwhelmingly suggests that air superiority is crucial to success and therefore, must be accepted as the first goal in any conflict. All other operations must be subordinated—to the extent contextually possible—to its attainment. This does not mean that no other operation must be commenced until air superiority is obtained, but that no other operation must be undertaken if it is going to jeopardise the primary mission or is going to utilise forces that should be used to attain air superiority. The only conceivable exception to this would be when no other choice is available but to commit all resources in an effort to buy time or to save some strategically important entity, brought on perhaps by a surprise attack. **It has to be reiterated that under normal circumstances, air superiority remains the first and most compelling task of any air force**.

THE AIR SUPERIORITY CAMPAIGN

Attaining air superiority is not simple in either concept or execution. The air battle can be joined under different contexts and a variety of circumstances. The context within which the engagement takes place must be very clearly considered and understood before the actual campaign because fighting even a well–planned battle under the wrong circumstances could prove to be disastrous. The following three factors assert the maximum influence on an air superiority campaign and combined together determine the framework of the options available:

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9 ibid.

10 Randolf S. and Winston S. Churchill, *The Six Day War*, Houghton Mifflin Company, Boston, 1967, p. 86.

11 The Insight Team of the London *Sunday Times, The Yom Kippur War*, Doubleday & Company, Inc., Garden City NY, 1974, p. 161.

- Material. Encompasses aircraft, surface-to-air weapons, and infrastructure necessary for their direct support as well as manufacturing facilities for both.

- Personnel. Primarily means the very highly skilled people who man the combat systems, who have special talents to begin with and who require extensive training before becoming useful in battle. Pilots and other aircrew are the most obvious component of this category.

- Position. Summarises the relative location and vulnerability of air bases, missile fields, ground battle lines and infrastructure.

Attaining air superiority, in simple terms, means eliminating by one means or the other, enemy forces that can interfere with own air operations. In very general terms, two categories of systems can interfere with air operations, i.e. stop the attainment of air superiority—airborne platforms and ground based weapon systems. Detection and electronic countermeasure systems are directly connected to combat and would have to be considered as combat systems. Depending on the situation, winning air superiority would be possible in a number of ways, ranging from precision attacks on military targets to all-out attacks on the enemy infrastructure. However, it has to be borne in mind while planning an air superiority campaign that the best way to achieve this goal may not always be the most direct. It is necessary to conceptualise the problem and then develop the appropriate action necessary to obtain and retain air superiority.

At the onset of hostilities, a number of situations could arise, as far as the air campaign is concerned. The spectrum of possibilities can spread from one side having overwhelming superiority on the one end, to a situation wherein both sides have parity in the beginning of the campaign, at the other end. In the case of regional conflicts, for the purpose of analysis, the case of parity between the opposing air forces could be taken as most probable. In this mutually vulnerable scenario, which ever side wins air superiority first would reap significant and perhaps war-winning advantages. It is also to be realised that almost all regional air forces would be 'conventional and tactical' in nature. The task for these forces were clearly defined as under:

> *The primary purpose of tactical air forces is to provide the necessary protection and support to ground and sea forces to allow them to control their environment. The classic missions remain air superiority, close air support and interdiction.*[12]
>
> General. John D. Ryan, Chief of Staff USAF

[12] Gen. John D.Ryan, *United States Strategic and Tactical Air Forces: Today and Tomorrow,* NATO's Fifteen Nations, August–September 1972, p. 17.

The Choice Between Offence and Defence

Air superiority, even when not an end in itself, accomplishes two things:

- it permits offensive air operations against any enemy target at a reasonable cost, and

- it denies the same opportunity to the enemy.

In broad terms two approaches to winning air superiority exists. The first is to concentrate on defending against enemy air and the second is to emphasis offensive operations aimed at reducing and neutralising the enemy's air capability directly so that he is forced to devote more of his resources to defence.

Problems of Defence. A purely defensive stance has in-built problems that may make the option less than attractive.

- Normally more than one aircraft is required to destroy one enemy in aerial combat. It is seen that the most effective form of air defence is provided by aircraft itself. Ground–based systems are effective, but are susceptible to neutralisation early in the war and also suffer from the disadvantage of being far less mobile than air-based defences. At best, these defences only help to channel enemy air operations for a limited period of time.

- Defence tends to pass the initiative to the enemy. This has inherent drawbacks in that, the force that has managed to seize the initiative will be able to dictate the time, pace and location of attacks, thereby tying down a disproportionately large component of the defending forces.

- Even aircraft that are kept in readiness to counter enemy attacks do not achieve anything. They can not put any pressure on the enemy and are assets that are being completely frittered away.

- The most serious drawback of a defensive concept is that it is basically negative and can never lead to a victory of any sort. At best it will only produces a stand-off situation with no clear winners.[13]

Advantages of the Offensive. An all-out offensive to gain air superiority means utilising all air assets in an optimum manner to crush the enemy's air power capability. This may also necessitate suppression of air and ground based defences at the outset. An offensive approach has many distinct advantages.

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[13] Adolf Gallant, *The First and the Last*, Ballantine Books, New York, 1963, p. 137.

- It retains the offensive, thereby forcing the enemy to react as opposed to initiating independent action. This situation instinctively denies the enemy one of the greatest qualities of air power — flexibility.

- The war is carried to the enemy keeping him off balance at all times.

- Utilisation of air assets are optimised and pressure is continuously asserted on the enemy. If it is ensured that the offensive is against the appropriate centre of gravity, then it is possible to inflict far greater damage to secondary capabilities which would in any case have to be neutralised at a later date.

- Offensive action is a positive measure that will lead to positive results. Victory in any operation can only be achieved as a culmination of concerted offensive action.

Although the defensive option may seem the safer one, specially to leaders who are unschooled in the offensive utilisation of air power, it is seen that the effects of offensive operations itself provide good defence faster than purely defensive operations. **In planning for combat, therefore, the offensive course should always be selected as the optimum course of action available to an air force.**

Offensive Operations

> *Future weapons will be able to strike enemy forces at great distances. In mid- or high-intensity combat, it may not always be necessary to physically occupy key terrain on the ground, vital airspace, or critical choke-points at sea in order to control them. While wars will still be won only when soldiers occupy the enemy's territory, it may not be necessary in every case to 'close with' the enemy in order to destroy him.*
>
> Admiral David Jeremiah, USN, 1993

Offensive in its purest state exists when every thought can be devoted to the offensive without concern for defence. A commander should undertake offensive air operations to carry the battle to the enemy and to achieve political objectives. The offensive must be directed against the enemy's centres of gravity and the proper identification and selection of these centres is crucial. If the initial choice is incorrect there may not be another opportunity to win air superiority.

Centre of Gravity. The enemy's centre of gravity may lie in any or a combination of the factors listed below:

- Equipment: number of planes, missiles and other warfighting material.
- Logistics: the quantity and resilience of supply support.
- Geography: location and number of operational and support facilities.
- Personnel: numbers and quantity of aircrew, operators and specialist technicians.
- Command and Control: Importance and vulnerability.

Logistic Chain. The selection of the centre of gravity that would prove to be the most vulnerable and yet provide the maximum disruptive effect in the quest for air superiority must be done after careful examination of the logistic chain that leads to the fighter aircraft being in the air. Under ideal conditions the destruction of aircraft on the ground would yield spectacular results. For example, the Germans destroyed more than 4000 Russian aircraft on the ground between 22 and 30 June 1941 while deploying only 1400 bombers and fighters on the entire Russian front during the period.[14] The Israelis had similar results from their attacks on Egyptian and Syrian air forces in 1967. With 196 operational combat aircraft, they destroyed almost 400 aircraft on the ground in two days.[15] It is historically apparent that it is cheaper to destroy aircraft on the ground than in the air. Whether circumstances will permit such success would, however, be the function of surprise, the state of enemy defences and the physical protection given to aircraft in the field.

Vulnerable Links. Choosing the correct point in the logistic chain as the most vulnerable centre of gravity is a difficult task. Almost always the most obvious one would be the least effective. It is important to note that in a campaign that is likely to be of extended duration, from an air campaign perspective, enemy logistics would be the real centre of gravity, with fuel being the most promising link. C4I facilities are true centres of gravity and worth attack in any circumstances if they can be reached. It is vital to remember that results may not be immediately evident unless the enemy is under severe pressure. The destruction of a command element may not immediately be evident on the battlefield, simply because inertia, if nothing else, will allow subordinate units in the field to continue operations for some time. Patience and perseverance is imperative under these circumstances. Attacks on the decision element of the C4I system are limited only by imagination.

Doctrine. A very careful analysis of enemy doctrine is necessary to arrive at the appropriate emphasis in the quest for air superiority. In doing so, avoiding ethnocentricity is especially important; one must not assume that one's own Service priorities are also what the enemy will consider as logical and necessary. Really decisive success can be achieved by adapting new doctrinal concepts to

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14 Bekker, *The Lufrwaffe War Diaries* p. 312.

15 Ezer Weizman, *On Eagle's Wings*, Macmillan Publishing Co., Inc., New York , 1976, p. 223 and Churchill, *The Six Day War*, p. 88.

which the enemy is unable to respond. War through the ages has been a battle of doctrines and examples abound from World War II to the present day of air doctrine, for good or ill, playing a decisive role in the outcome of battles and wars. Strategy, doctrine and equipment have to be developed in conjunction with each other and should never be mismatched.

- **Example.** The classic example of air doctrine achieving political objectives is the unconditional surrender of Japan immediately after the two atom bombs were dropped on their cities. At the time of surrender, the Japanese had over 2 million men and 9000 aircraft in the home islands alone. The need or otherwise of dropping the atom bomb is not being debated here, but what is clear is that the Japanese had lost air superiority over the home islands. As the Strategic Bombing Survey of the United States concluded, ‘It seems clear that, even without the atomic bombing attacks, air supremacy over Japan could have exerted sufficient pressure to bring about unconditional surrender and obviate the need for invasion.’[16]

Reach and Penetration. One of the major attributes of air power is its reach and penetration, which if used to provide concentration, can win the battle. This could take the form of a mobile screen when the enemy is also likely to adopt an offensive air doctrine. However, to counter an enemy who is seen to be adopting a defensive stance, fighter escort of close support and interdiction aircraft would be sufficient. When enemy ground forces are being attacked, enemy air would *per force* have to respond or *de facto* relinquish air superiority. Assuming that the enemy would come up to battle for control of the air, even while on the defensive, escort operations can be conducted in two basic ways: the fighter sweep and close escort.

- **Fighter Sweep.** The fighters precede the attacking aircraft (bombers, ground attack fighters) and engage and neutralise enemy aircraft found en route and in the flanks, thus sanitising the route for the attack craft. This package may also include SEAD aircraft depending on the perceived threat.

- **Close Escort.** The fighters stay in close proximity to the strike package and drive off the enemy when he attacks. This tactic essentially denies the fighters flexibility and is useful only when the target for the strike is of such overwhelming importance to the overall outcome of the war. This also has a long history of failure.[17]

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[16] US Strategic Bombing Survey, *Summary Report* (Pacific War), US Government Printing Office, Washington DC, 1946, pp. 25–26.

[17] Bekker, *The Lufwaffe Diaries*, p. 242.

Planning

The air campaign may be primary or supporting in a theatre. In either case, an air campaign plan is a necessity. The plan should describe air centres of gravity, phasing of operations and resource requirements. It must also provide general guidelines for division of effort, in terms of priority and quantum, between air superiority missions and the rest of the roles of the air force. It should also explain how other arms will support or be supported by the air campaign. Similar to the overall theatre plan, it must carry through to the conclusion of the war. Certain critical concepts are crucial to comprehensive planning.

- **Enemy Plans**. The nature of the enemy must be studied and his plan of action anticipated. This is critical in all planning where straight attrition is not being resorted to. The enemy must be categorised and then the way he would react in a given situation can be predicted with reasonable accuracy. History would provide some help in assessing the enemy, but it would be foolhardy to expect that straight line projection of past behaviour is going to be completely valid.

- **Own Capabilitie**s. The other side of knowing the enemy is knowing one's own capabilities. Plans must be made according to the training that has been imparted and must take into account the emphasis that has been laid on certain tactics etc. The most important part of assessing one's own side is complete honesty. The fact that in the short term very little can be changed in the human resources that are available must be explicitly accepted and everything else must be built around this reality and not on hypothesis or wishful thinking.

- **Integration**. At the outset of the campaign the integration of different elements of the air effort must be accomplished. It is reiterated that a war cannot be won if the enemy has air superiority. Indeed, no nation enjoying air superiority has ever lost a war by the sheer force of enemy arms alone. Therefore, a commander who tries to win—or at least not lose—without air superiority is trying to achieve what no–one else has done before! Thus it is prudent to do what is necessary to become superior in the air at the earliest after carefully considering where one stands with respect to the enemy.

Theatre vs Local Air Superiority. There is active debate regarding the necessity as well as the capability of a force to attain theatre air superiority which is considered too ambitious. In its stead, local air superiority is advocated. 'Local air superiority' can have two definitions. Normally it means establishing cover for a surface operation for the duration. In a few circumstances, it suggests a phase in an air campaign similar to a break-through operation on the ground that establishes the base for further moves. This merely recognises the reality that achieving absolute theatre air superiority is rarely a possibility. In practice, a kind of compromise between local and theatre air superiority exists with one or the other being predominant depending on the circumstances. It is also seen that the side that takes the initiative will be able to retain the advantage of offence which is the only way to achieve all objectives.

Targeting Priorities. Targeting priorities will be a function of perceived enemy air centres of gravity. Defensive considerations may dictate the neutralisation of certain targets that may not effectively be the final objectives. But these may be necessary to ensure that the campaign progresses as planned. The air superiority campaign must not be waged by air assets alone but should have naval and ground forces playing active roles wherever possible. The overriding need for air superiority must be understood and pursued with intrepid and innovative decisions. There are three particularly involved problems that face the planning and execution of an air campaign:

- The use of air power in emergency situations, such as a fast progressing enemy ground offensive, to the detriment of other missions.

- The desirability of carrying out air superiority, interdiction and close air support simultaneously.

- The division of relative effort to be allocated to the three key elements and further division between interdiction and close air support.

Concentration. Concentration probably is the most important principle of air war. Therefore, all missions should be chosen in such a way that concentrated application of air power would bring it to fruition. In this decision, it must be clearly appreciated that no other mission can succeed unless air superiority has been achieved. Also worth emphasising is the fact that air power has been more effective when used for interdiction as compared to close air support. Given the critical importance of air superiority and the historical success of interdiction, a compromise solution to carrying out all three missions simultaneously must be worked out. Clearly, air superiority must be the air priority because everything else—ground operations, interdiction, close air support—is heavily dependent on it.

CONCLUSION–AIR SUPERIORITY IN RETROSPECT

The purpose of this paper has been to outline briefly the problems that confront the planning and execution of an air superiority campaign and to suggest possible optimum solutions to them. But like so many other aspects of air power, the problems are multifarious and therefore, the solutions are equally variable. A successful campaign clearly is contingent on a good plan and construction of a good plan requires an intimate understanding of the aims of the forthcoming action. **Central to this understanding is the concept of the primacy of air superiority, that it is crucial, that a campaign will be lost if the enemy has it, that in many circumstances it alone can win a war and that its possession is needed before other actions on the ground or in the air can be undertaken**.

The situation at the beginning of a conflict could at worst be one in which own bases are under air attack from the enemy while one has no capability to respond in kind. This would leave no option but to engage in a purely defensive air war. At the other end of the spectrum is the situation wherein the enemy's bases become subject to attack while own bases are safe. In between these two extremes are the situations that have both the sides vulnerable to some extend. It is seen that an air force forced on the defensive has little or no chances of victory. It is suggested that a defensive doctrine should never be adopted if there is even the slightest chance of moving towards an offensive option.

Of all mankind's activities, war is the most baffling and intriguing. It brings out the best in men; and it uncovers the worst. War demands from its participants the coldest calculation, the most rational yet precise thought and a clear understanding of the dear price of failure. Methods of war change, but the principles of war—the essence of war—have not changed from the most primitive times to date. Since war affects every person and nation that it touches, the only way to mitigate its effects is to understand it thoroughly.

Thus, what is of supreme importance in war is to attack the enemy's strategy.

Sun Tzu, *The Art of War*

PAPER 2

Training for Victory in Air Combat

It's not the crate, but the man who flies it!
Manfred von Richthofen

INTRODUCTION

The basic essence of air combat has remained the same since the advent of fighter aircraft, but technology has wrought phenomenal changes in the conduct of what is perhaps the last form of personal combat in warfare. Fighting in the air is seen as clean, exciting and even glamorous; it is individual combat with man against man and machine pitted against machine. There is a discernible thread of continuity between the duels fought above the trenches of World War I and the fast-action engagements that have taken place during the Gulf War. Although it has now become possible to launch homing missiles at a target which is only a tiny speck on a radar screen, the pilot has also got to be fully prepared to oppose the enemy face to face in combat. The aces of yesteryear may be astonished by the awesome sophistication of modern jet fighters, but they would not be baffled by the fundamentals of the tactics that are still used. For they would understand that the dogfight remains a trial by combat in which the skill and determination of the pilots often determine the outcome, and where a single lapse could prove fatal.

The Gun – Here to Stay

At the dawn of the supersonic age, in the late 1950s, air combat theoreticians decreed that close-in, 'one-on-one' dogfights were a thing of the past. The increased speed of the aircraft and the advent of air-to-air missiles reaffirmed the concept that future engagements would all be fought and concluded at distances beyond visual range. This new idiom spawned a generation of air superiority fighters armed only with guided missiles: the F-4 Phantom in the West and the Soviet MiG-21 'Fishbed'. There are no front lines in the sky to distinguish friend from foe and air combat in Vietnam revealed the extreme shortcoming of this concept when launching a missile without eye contact was seen as a formula for disaster. The internal guns were reintroduced and since then no air superiority fighter has been designed, anywhere in the world, without the quintessential weapon of the dogfight—a gun! The gun remains a hallmark of the air superiority fighter with even the F-22 carrying it.

VIETNAM – ADVENT OF JET AGE AIR COMBAT

The long-drawn Vietnam War provided the first opportunity for jet fighters to oppose each other in aerial encounters. During the 1950s and early 60s, changes had taken place in the tactical appreciation of air combat. It was thought that in the engagement of high-speed aircraft, there would be no use for guns or cannons and that guided missiles would relegate close-in combat to the history books. The Vietnam War, while driving technology to find solutions to complex problems, comprehensively disproved certain fallacies that had been built up regarding the nature of aerial combat.

- The so-called supremacy of the guided missile in air-to-air engagements was completely negated for two primary reasons:
  - the need for positive visual identification of the target in a multi-aircraft environment, and
  - uncertain reliability of the missiles.
- Tactics that were once thought to be infallible did not always prove to be successful, necessitating a more flexible approach to tactical solutions. For example, the objective of the Vietnamese Air Force was to ensure that the bomb load of the strike formation did not reach its intended target. This was achieved by carrying out ‘one-pass, high-speed’ attacks from a position of advantage under close ground control even without being able to shoot down any attacking aircraft. The corollary was that these tactics did not have any long-term effect on the opposing air force.
- It was seen that speed alone did not contribute to a winning solution. Performance characteristics of the aircraft, like turn rate and radius, rate of climb and weapon aiming aids, far outweighed the maximum speed criteria in all encounters. In fact, acceleration was far more important than capability to reach high mach numbers.

This is not to diminish the effect of technological breakthroughs that took place during the same time, some of which revolutionised aerial combat. The primary innovations, which had far reaching effects, were:

- the fielding of air-to-air guided missiles in combat for the first time,
- the carriage of powerful air intercept radar by fighter aircraft, and
- great improvements in the aiming and guidance systems for weapon delivery.

Lessons Learned. Certain lessons with universal applicability emerged from the Vietnam conflict. Some of them did not have a direct bearing on the conduct of air combat, but were generic in nature.

- Fighters with two seats made their maiden appearance during this conflict. Although initially manned by two pilots, it was soon realised that controls of a high performance aircraft in two hands was a mistake, and the second seat was given over to a Weapon System Operator. This proved more cost effective than training two pilots. Undeniably, in combat, two pairs of trained eyes are better than one.
- Technological superiority alone was not sufficient to guarantee victory.
- While individual initiative and mutual support were important for victory, training was judged as the single most important factor in being successful in air combat.
- All aerial actions eventually led to close-in dogfights, especially when large numbers of aircraft were involved.

AIR COMBAT TRAINING

It is a truism of air combat that every victory demands a victim. What is surprising is that in every air war fought to date, a tiny minority run up high scores. These are the ‘aces’, less than five per cent of the fighter pilots, who have historically accounted for more than forty per cent of the total victories claimed. It is generally accepted that all these pilots were better led than their victims and definitely better trained. The old military adage ‘you fight like you train,’ has universal applicability in all aspects of military action, and in no form of warfare more so, than in air combat. Sharpening air combat skills, in all its variations, is the single most important factor in ensuring that fighter pilots are trained to achieve victory in all encounters with the enemy. The necessity for focused training was dramatically brought out during the Vietnam War. At the beginning of the conflict, both the US Navy Fleet Air Arm and Air Force had almost the same exchange rate of 3.7 to 1 in air combat. The US Navy concentrated on training with the establishment of what is now referred to as the 'Top Gun' school and by the end of the war was achieving a 12 to 1 exchange ratio, while the US Air Force continued to have the same ratio of 3 to 1 till the end of the war.

The modern fighter pilot is a highly skilled technician, trained to get the utmost out of his machine, weapons and also the tactical situation in which he finds himself. In order to do this he needs to be trained constantly to seek to expand his own limits vis-à-vis that of the aircraft envelope.

Pilot Qualities. The dominant factor in aerial warfare has always been pilot quality. Although aircraft and weapon systems may continue to improve dramatically in the future, the most essential ingredient for success in air combat will remain the pilot. This irrefutable fact obviously means that training of the fighter pilot is of greater importance and significance than the means of warfare, the weapon systems and technological innovations. All training, therefore, must be oriented towards inculcating and nourishing the three qualities a fighter pilot must possess to be victorious:

- leadership,
- flexibility, and
- initiative to improvise

Training Methodology. Sharpening air combat skills is a complex and abstract art and has to be done by a judicial combination of class room study and aerial work outs. The class room study should aim at strengthening the pilot's knowledge level of his own and the adversary's aircraft performance as well as tactical doctrines. The pilot should be able to master his aircraft to such an extent that the pure flying of it becomes totally automatic and he is able to give his undivided attention to using the machine as a weapon of war. The actual combat training should be done by pitting the trainee against aircraft of comparable performance as the enemy, and using the same tactics as them. This would amount to Dissimilar Air Combat Training (DACT).

Air Combat Manoeuvring (ACM). It is now recognised in military flying all over the world that, whatever the armament a fighter carries, air combat manoeuvring—the art of the dogfight—should remain the cornerstone of fighter pilot training. These skills are as crucial in the supersonic age as they have been in the days of wood and fabric biplanes. The primary objective of ACM training should be to encourage and enable the pilot to take full advantage of his aircraft's performance characteristics without slipping beyond them into the regime of structural failures or departures. To ensure victory in air combat, a pilot must be capable of flying at such levels of risk that only success should differentiate the risk from recklessness. As a corollary, it has to be acknowledged that highly complex but spectacular air show manoeuvres are too elaborate, extremely difficult to master and perform adequately and, perhaps most important, very rarely applicable in combat.

One Versus One. 1 vs 1, with similar aircraft, progressing on to DACT should become the basic training platform from which the trainee is taken progressively to more advanced exercises. If a pilot really learns to fight 1 vs 1, he will develop the skill and confidence in the aeroplane to survive and prevail in multi-aircraft engagements. However, it also has to be emphasised that modern air-to-air engagements or encounters do not take place in isolation, but are part and parcel of a campaign with much wider and all encompassing objectives than the mere shooting the enemy out of the sky.

Dissimilar Air Combat Training. The aim of DACT is to expose the squadron pilot to the nearest simulation of actual warfare. Analysed data from air wars have shown that each pilot goes through a 'decisive combat'phase—one in which a pilot is either shot down or shoots down his opponent—with marginal chances of coming out the victor in the initial phase of a war. But after surviving five 'decisive combats,' the chance of surviving the sixth encounter increases by a factor of twenty. Since pure flying ability could not have improved to such an extent as to make this difference, it can be concluded that the dominant factor in this change is rigorous training. DACT takes fighter pilots through a close approximation of 'decisive combats' in which experience levels grow rapidly.

Tactics. Air warfare does not occur in isolation, but is always part of a much bigger pattern and consequently air combat must be viewed as part of a general conflict. Blind adherence to rigid doctrine and tactics is total anathema to success in air combat. The pilot has to be trained to be a thinking warrior, capable of recognising changing trends in the battlefield and initiating such actions as are necessary to ensure the success of the mission. It is a historically proven fact that innovative changes in operational tactics, which could be brought on by any number of factors, has almost always led to success. The importance of mastering the established tactics (both own and enemy) in its entirety, and the development of skills to improvise from them at short notice can not be overemphasised. Tactical development is the cutting edge of aerial technology.

Realistic Training. Air combat is an art that improves with constant practice. The more air combat that a pilot is involved in, the better he gets and after a while air combat becomes second nature to him. In the heat of battle precious seconds are not wasted in thinking an appropriate response to an emerging situation as it would come as second nature. However, even excellent training is not good enough if it stops short of preparing a pilot for actual war. Realistic combat experience, without a shooting war, is an essential ingredient in preparing a pilot to master the techniques vital to prevail against a skilled and determined enemy. Realistic combat training must be oriented towards exposing a pilot to:

- enemy fighter characteristics and performance, and
- capabilities of enemy radar and weapon systems.

This exposure should be the beginning of a comprehensive training package aimed at teaching him how to:

- exploit the weaknesses and counter the strengths of the enemy, and
- understand the adversary's tactics and their level of training.

In the past decade, the phenomenal improvements in electronic C3I—Command, Control, Communications and Intelligence—have changed the face of war in the air. Coupled with the advent of the all-aspect, infra-red, air-to-air missile capable of killing from any angle, technology has dictated the training patterns which are essential for the successful completion of any campaign. In this light, realistic training becomes the cornerstone of the overall training philosophy.

Situational Awareness. Situational Awareness (SA) and airmanship are two sides of the same coin. SA is a combination of many things, but in essence it is the ability of a pilot to keep track of events and foresee occurrences in the fast moving, dynamic scenario of air warfare. It demands that a pilot detect and keep track of all aircraft that pose a threat. This has to be achieved in fluid situations and circumstances where survival depends on not being surprised by the unexpected. Development of SA is once again the by-product of constant practice and coherent training. This prime requirement also indicates the necessity to adopt as realistic a training pattern as possible to ensure aerial victory.

He who can handle the quickest rate of change survives.

Major John R. Boyd, USAF
Briefing, 'New Conception for Air to Air Combat' 1976

Making the correct decision in combat is directly related to the experience levels built up in training, which in turn is directly related to the effort expended. The need for a fighter pilot to possess the quality of alertness and SA which denies the enemy any chance of surprising him can not be over emphasised.

The Pilot. In the new generation fighter aircraft, the only limitation in performance is the pilot's endurance. It is a universal character of fighter pilots that, as a group, they tend to be combative overachievers who are both intelligent and supremely overconfident. However, historical, cultural and political factors have a definitive impact on the operational thinking of a fighter pilot. It, therefore, becomes necessary to ensure that the psychological profile of the pilot is in keeping with the national ethos of warfighting. In the case of a fighter pilot, this has to be tempered with the need to nurture aggressiveness, which is essential to achieve that slight edge in combat that makes the difference between victory and being shot down in flames.

In the air-to-air arena, only the spirit of attack born of a brave heart will bring success to any fighter aircraft; no matter how highly developed it may be.

Adolf Galland

It has also got to be remembered that aggression is a double-edged sword and has to be used in a cool and calculated manner. In modern warfare, the pilots are 'Aerospace Athletes' and their physical training is also as important as the mental adaptation to rapidly changing combat scenarios. 'G' tolerance training forms an important part of this aspect since the current generation fighter aircraft have the capacity to sustain forces that are not normally compatible with the human body.

Team Work. The major difference between air combat over the trenches of World War I and now is that it has developed into a complex network wherein team effort takes priority over all other aspects. The present-day fighter pilot has got to be an effective member of a complex team carrying out multifarious activities to achieve the same end result. It is also necessary that the pilot be trained in the discipline of being a team member, rather than an accomplished individual. This team spirit also depends on the status of training that has been received by the individual and the team as a whole.

Exercises. The geopolitical situation that is prevailing around the world does not permit combat deployments for most of the air arms. The only way to maintain the edge in air combat, therefore, would be to conduct exercises at regular intervals wherein all the elements that would take part in actual operations are involved. These exercises must be debriefed with the aim of incorporating the lessons learned into the standard tactical development of the force.

CONCLUSION

More than ever before, air combat has now become a complimentary combination of man and machine. A jet fighter, without the agility to grapple with a daring foe or the ability to elude an attack, is all but useless in an air superiority role. The combat agility required of these high performance aircraft is primarily derived from two sources: power and aerodynamic design. Aerial warfare theoreticians and visionaries foresee a day when an aircraft filled with computers and their attendant sensors will obviate the need for an on-board pilot. But that is—if at all—in the far distant future. In the next generation, victory in aerial combat will still depend entirely on a highly skilled aviator, whose skills have been honed to perfection by strenuous and combative training, and the job of technology will continue to be one of support: to provide the edge over the opponent. The picture that emerges of a competent fighter pilot is that of a young individual with good physical coordination and quick reflexes who is naturally determined and aggressive, but also self-disciplined. The gulf between the average fighter pilot and the successful one is very wide, transcendable only by training to win under all conditions!

There can be no doubt that, for the foreseeable future, the key to success in air combat is the pilot, his training, ability and aggressiveness.

PAPER 3

The Role of Situational Awareness in Air Combat

Nine-tenths of tactics were certain enough to be teachable in schools; but the irrational tenth was like the kingfisher flashing across the pool, and in it lay the test of generals.

Colonel T. E. Lawrence *(Seven Pillars of Wisdom, Book III)*

...and fighter pilots!

INTRODUCTION

From the beginning of aerial warfare during World War I, when fighting in the air was thought to be clean, exciting and glamorous with the pilots being equated to the knights of old, the wheel has turned full circle. War in the air has become more impersonal than it could ever have been in those early days. Now, over seventy years later, the fighter pilot has become a highly trained technician rather than a knight, able to launch homing missiles at a target which is only seen as a tiny flicker on a radar screen. On the other hand this is not always the case and he must be prepared to oppose the enemy face to face and at close quarters when the need arises. But what is truly surprising is that in every air war fought to date, a small minority of pilots account for a disproportionately large number of aerial victories. The question that needs to be asked is: what was that one particular quality that set these pilots apart from their peers and made them the 'aces' they were proclaimed to be?

A large number of factors contributed to the success of these pilots in varying degrees. The quality of the aeroplane, superior marksmanship, better leadership and training, greater level of flying skill and even an element of luck could be listed among these. However, it is not possible to quantify the individual traits and, therefore, place them in any order of importance. The only common thread that is visible amongst these 'aces' is that they were men with great determination with the quality of 'wanting to win' in fuller measure than in the average pilot.

CONTRIBUTING QUALITIES

Aircraft and Marksmanship. Although an aircraft with better performance than the adversary is an advantage, there are any number of instances down the years where a seemingly outclassed aeroplane has emerged victorious over an apparently very superior opponent. Thus superior aircraft performance should be viewed only as a transitory advantage. Nor is numerical superiority a guarantee for success, although even that helps. Marksmanship on the other hand is of great help and often means the difference between a confirmed victory and damaging the enemy aircraft. In the current missile age marksmanship has lost much of its importance, although it can be argued that shooting ability of a different kind is now required.

Training and Leadership. High quality training helps to a great degree as it enables the pilot to optimise his manoeuvres in tune with the aircraft and weapon system capabilities. However, leadership seems to have a far greater effect, and it is particularly noticeable that some units, throughout history, have produced more than their even share of victories. Good leadership also provides the initial grounding for novices and keeps them out of disadvantageous situations till they have gained sufficient experience.

Flying Skills. Superior flying skills are also an added advantage, although extremely skilled aerobatic pilots do not automatically become good fighter pilots. In fact many successful fighter pilots have been described as only average aircraft handlers. They may not have been above average pilots at the outset, but improved with practice.

Luck. The most indefinable quality of all is luck or chance or whatever else this phenomenon is known as. Very few of the top-scoring fighter pilots of any era avoided being shot down, at times more than once. Often bullets missed their bodies by inches, still more frequently their aircraft were extensively damaged, but they survived. They were not immortal—quite a high percentage of them were killed in the long run—but without an element of luck at some point they would not have survived as long as they did, and their successes would have been correspondingly less. Luck is essentially a defensive quality linked with survival, and much less a factor in the attack.

Determination. Determination is an essential part of the make-up of a successful fighter pilot, without which it would be impossible to function effectively. It is not true that a fighter pilot is fearless, but they learn to control their fear which requires a very high degree of determination and self-discipline. It is also important to recognise the thin line that separates determination and aggression. Aggression, unless tempered with a cool and calculating mind, can prove lethal to the user, whereas determination will almost always be the precursor of success in the long run.

THE NATURE OF AIR COMBAT

> *A superior pilot is one who uses his superior judgement to avoid situations which would otherwise need his superior flying skills to get out of!*

Air combat appears at first sight to be an open-ended, manoeuvre-counter-manoeuvre process with limitless possibilities, but this is not the case. In any given situation, the manoeuvre options available to a fighter pilot depend entirely on the energy state of his aircraft and are not unlimited. Aerial combat is far more fluid and fast moving than any other form of warfare and in this sense, is more complex. The fact that it also operates in three dimensions, rather than two, only serves to increase its complexity. Carl von Clausewitz, in his monumental work *On War,* described what he termed as the 'fog of war'. Passages of the book dealing with 'frictions in war' are very relevant to the fast, three-dimensional air battles. Although in theory, war is a precise art where outcomes can be predicted after careful analysis it is not so in actual fact.

> *While everything about the conduct of war appears very simple in theory, in actual practice . . difficulties accumulate and end by producing a kind of friction that is inconceivable unless one has experienced war.*
>
> Carl von Clausewitz, *On War*

Clausewitzian 'Frictions' Translated to Air Combat Scenarios

Clausewitz lists four main types of 'frictions':

- Less than perfect intelligence upon which critical combat decisions must be based; i.e. 'fog of war'.
- Psychological pressures on the participants, aggravated by the possibility of imminent personal danger.
- Physical stress of combat that tends to lower efficiency progressively and cumulatively.
- Demoralising effect of the unexpected.

Fog of War. In the specific scenario of the air battle, the first 'friction' reflects lack of Situational Awareness (SA) to some degree. In a multi-aircraft combat situation, the confusion factor is such that it is impossible for any one individual to keep track of everything that is going on around him. Even in smaller engagements, like two aircraft engaging another two, it is impossible to be certain that more aircraft will not join in, literally out of the blue. Some other factors also increase this 'fog of war.' Enemy aircraft capabilities vis-à-vis one's own, relative energy states, enemy pilot training state and even relative fuel states are some of the more obvious factors.

Instinct for Survival. The human being's built-in instinct for survival is extremely strong and can be counterproductive at times. Early and inappropriate disengagement as well as an overcautious approach to a tactical situation which actually demands daring and aggression is caused by the second 'friction' of psychological stress. This could detract from an advantageous situation being fully exploited and converted to victory.

Combat Fatigue. Stress and strain of combat leading to what is termed 'combat fatigue' or pure physical tiredness because of the physiological effects of lack of rest, high 'G' etc. tend to lower efficiency and reduce performance levels in an individual. This is the third 'friction' and is far more serious when formation leaders are affected by it as it adversely affects the fighting efficiency of the entire unit and may also have an indirect effect on morale.

Effect of the Unexpected. The fourth 'friction' is perhaps the most important; the demoralising effect of the unexpected. At a time when the combatant thinks that he is fully in control of a situation, the realisation that all is not as it seems can be devastating. Shock action is effective in all forms of warfare, and in extreme cases it has been known to paralyse the thought process to an extent that the victim becomes incapable of further resistance. Shock action or surprise is the dominant factor in air combat and its effect cannot possibly be overrated.

Summary. The overall effect of the four 'frictions' mentioned above is to lower the theoretical performance of the fighter pilot by an unquantifiable amount: which in turn interrupts the efficient conduct of the air campaign. Victory in aerial warfare does not hinge on any one overriding factor, but is a combination of many contributory ones. The major factors are:

- Aircraft performance, which at best gives a marginal advantage.

• Tactics – defined as the art or science of manoeuvring formations in battle according to established principles to achieve maximum effect/results with minimum risk and effort. This would be the major factor in protracted campaigns and can also be decisive in isolated engagements. Tactical theory is based on twin foundations, which are:

– technical means available—leading back to numerical superiority and aircraft performance comparison; and
– the kind of war the air force is called upon to fight.

• Teamwork which enhances the effectiveness of a formation in combat, making it far greater than the sum of its constituent parts. Fighting in the air is a matter of teamwork and just one member of the team performing below par can jeopardise the entire formation.

• The most decisive factor, which contributes to all victories, is pilot quality.

Situational Awareness is the factor which minimises ‘frictions’, dissipates the ‘fog of war’ and helps the pilot instinctively to do the right thing under extreme stress, at least partially offsetting the effects of fatigue and anticipating and avoiding the unexpected. A formation leader with a highly developed SA can spread it across the group, thereby enhancing their effectiveness and efficiency by a considerable margin. Air battles are lost rather than won. Well-trained pilots very rarely make mistakes. This being so, only ill fortune can cause their downfall. The key to success in air combat therefore, lies in pilot quality and teamwork—directly linked to SA. This is the lesson of history!

SITUATIONAL AWARENESS

Air combat is a very complex subject and apart from the few gifted and instinctive fliers, the average pilot finds it difficult to grasp. For the fighter pilot, air combat problems fall into three categories:

• what he can see,
• what he can do with his aircraft, and
• what he can hit with his armament.

Of the above, what he can 'see' becomes the operative word for studying the effect of SA, or the lack of it, in the conduct and outcome of air combat. The antithesis to SA is vulnerability to surprise. The axiom 'expect the unexpected' is most applicable in air combat. It is a proven fact that four out of every five victims in air combat never saw their attacker.

Vulnerability to Surprise

Why does one force become more vulnerable to surprise than another? There are number of factors that determine a force's vulnerability to surprise:

- Emphasis on ultra low level work which makes adequate look around, especially astern, very difficult.
- Adoption and refinement of tactics to neutralise the effectiveness of enemy radar network.
- Availability and adequacy of ECM assets.
- SA state of the pilots, particularly the leaders.

SA in Modern Combat

In today's scenario, awareness of how the overall air combat picture as an engagement is progressing is aided by sensors, both-ground based and airborne. In fact the individual SA of the pilot comes into focus only when the fight has progressed to the dogfight stage. Until then SA is dependent on onboard sensors and other inputs that form the complex machinery of aerial warfare. In very generic terms this could be termed as the SA of the force as a whole. Situational awareness of a small air force with large areas to cover will be considerably less than that of a force with proportionately lesser areas of interest. In the case of a thinly spread force, combat is likely to be almost always at low levels as the concentration will be on low-level work in order to avoid radar coverage and exploit the gaps in the air defence network. This situation would have an adverse effect on the SA of individual formations as they would not be able to 'see' effectively at all times.

The degradation of SA as mentioned above is further compounded by the technological leap that aerial weaponry has taken in the past two decades. With BVR missiles now the norm rather than the exception, the necessity to bolster the pilot's SA with information of the air war scenario, at least within the theatre of operation, has never been greater. However, this is directly dependent on resource availability within the force.

National SA. Situational Awareness, as related purely to air combat, is also conditioned by another aspect of a larger SA to a certain degree. This would stem from the SA developed as a result of the nation's political, strategic and economic leanings which in turn would have a direct bearing on the force's combined awareness. SA amongst the senior combat leaders would always be tempered with this knowledge and may have an inhibiting effect on manoeuvre and offensive employment of the force to its optimum. However, in the context of SA relating to air combat, it will only be a peripheral concern.

Training in SA

Development of SA in a pilot is a complex training activity. The primary need is to train the individual to recognise one's own and the aircraft's limitations. Combined with this awareness, the pilot must be indoctrinated to recognise and keep out of situations with which he cannot adequately cope at all times. It is comparatively easy to maintain SA in engagements involving limited number of aircraft. But as the number of protagonists in the combat scenario increases, maintaining SA becomes more and more difficult, till it drops to nil at some stage. This steady decline in the SA state varies from individual to individual, with the pilot who can maintain SA till the end always emerging the victor.

Examining and analysing the victories of 'aces' of the past wars and studying their individual characteristics to arrive at some definable quality that is common to all, does not really throw up any one discernible trait. However, it does emerge that all successful air fighters were aware that whatever the odds in their favour, they could never be completely certain of the outcome of an engagement, as even the slightest lapse in SA could make them the prey rather than the hunter. Almost all these pilots were above the average in their flying abilities but had highly developed SA combined with a thoughtful and extremely analytical mind.

Fundamentals for Victory

The study of air combat engagements brings out certain fundamental principles to be maintained to assure ultimate victory.

- Victory can only be achieved by a display of true offensive spirit.
- Every attack must be driven home with implacable determination to destroy the opponent.
- Surprise must be maintained at all times possible.

Maintaining surprise, in other words, would be degrading the SA of the opponent to such a stage that it is nonexistent. Considering this, it can be stated that the most important attribute of a modern fighter is its ability to achieve surprise and the next most important one would be to avoid being surprised. Surprise is critical in the context of SA.

Help for the Overburdened Pilot

In modern-day combat, the pilot is given a large amount of data in different forms from a variety of sensors. In order to derive the maximum benefit from this plethora of information, the pilot needs to be assisted in its collation and determination of priorities. Otherwise this 'overload' of information will flood the pilot to such a stage that instead of increasing SA, it would effectively degrade SA. Coupled with the physical stress of flying a high-performance aircraft, information overload could actually have a debilitating effect on the pilot.

Many technological innovations are now being translated into useful aids in the fighter cockpit. Designers and engineers are working on ways that the aircraft itself could shoulder some of the work load of the pilot—'watch the back' while the pilot's attention is directed towards the target in front. These new technologies are expected to lead to the so-called 'super cockpit', wherein much of the pilot's burden would be shifted to a computerised 'intelligent autopilot' or 'pilot's associate' that will serve as a combined co pilot and backseater. The computer is also likely to have voice- activated functions. With the developments in the helmet-mounted HUD, it would become literally unnecessary for the pilot to look inside the cockpit. The computer 'pilot's associate' will also be able to advise the appropriate offensive weapon or evasive action. All these developments are oriented towards enhancing the pilot's SA in critical situations. In a combat arena heavy with threats, a fighter pilot is hard-pressed to assimilate the streams of data from his senses and aircraft sensors. The computer 'companion' is optimised to ease the load on the pilot and enhance his SA.

A keen SA is necessary for a pilot, and more so a formation leader, to ensure that the combat he enters is one of his choosing and as far as possible avoids the more difficult manoeuvring combat. The endeavour must at all times be to resort to a swift and deadly strike, against a foe taken unaware. The fighter pilot of today is a highly trained technician who controls and manages a sophisticated weapons system rather than an aeroplane. Historical analysis shows that if the pilots have adequate SA, even an outnumbered force inflicts a much higher loss ratio on its larger opponent.

Pilot Quality. Another lesson from history is that the dominant and critical factor in air campaigns, as in small engagements, is almost entirely pilot quality. Pilot quality is determined in the initial stages of a pilot's development by training and thereafter almost entirely by all the facets that combine to provide the necessary SA. Superior numbers alone does not necessarily guarantee success or victory. It is also not correct to link attrition rates and numerical superiority to predict the outcome of a campaign or even a battle. While superior numbers is a contributory factor in determining the outcome of an engagement, it is the SA state of the combatants that is the critical factor.

DICTA BOELCKE

The most renowned name in all of air combat is that of Manfred von Richthofen, Germany's legendary 'Red Baron', who in World War I shot down eighty enemy planes before himself perishing in battle. Yet a little-known fact is that Richthofen's acknowledged superior was his friend and mentor, Oswald Boelcke. Until his death in 1916, Boelcke, with forty victories, reigned supreme as the German Air Service's foremost ace, its premier air strategist, teacher and combat leader. It was the great Boelcke who handed down eight commandments of air combat tactics—the so-called *Dicta Boelcke*—maxims that remain pertinent even in the supersonic, radar-and-missile environment of aerial warfare of today. The fascinating thing about these rules is that almost all of them revolve around absolute SA.

- **Try to secure advantage before attacking. If possible keep the sun behind you.** The upper hand lies with the pilot who engages from a position of strength deriving from greater numbers, higher speed and above all the element of surprise.

- **Always carry through an attack when you have started it**. A flier who loses his nerve and breaks off before the battle is won provides his enemy with an opportunity to turn the tables.

- **Fire only at close range and only when your opponent is properly in your sights.** For Boelcke, the ideal machine gun range was twenty yards, where it was hard to miss. Even with today's radar gunsights and powerful cannon that can reach more than a mile, it remains true that the shorter the range the better.

- **Always keep your eye on your opponent.** Modern radar can detect an adversary long before he can be seen, but once a pilot sights a target, he must keep it in view at all times. As the saying goes, 'Lose sight, lose the fight.'

- **In any form of attack, it is important to assail your opponent from behind.** The long-range, radar-controlled, head-to-head joust with all-aspect missiles may be the preferred opening move in today's combat. But after the first pass, there is nothing like being firmly on an enemy's tail, which gives the attacker time to make the next missile attack and resort to guns if the missile fails.

- **If your opponent dives on you, do not try to evade his onslaught but fly to meet it.** Again the best policy, even against an opponent armed with all-aspect missiles. It is easier to defeat a missile that is coming head-on than to dodge one racing for your tailpipe. It is also easier to take the offensive.

- **When over the enemy's lines, never forget your own line of retreat**. Aside from keeping track of his position, a pilot should think ahead about fuel supply and enemy SAMs and aircraft formations that might block escape routes—classic SA.

- **Attack on principle in groups of four or six. When the fight breaks up into a series of single combats, take care that several do not go for one opponent.** Boelcke originated the idea of section tactics, two planes acting in concert against an adversary and guarding each other against surprise attack. And if two was good, four or six offered still greater fire power and an increased defensive outlook.

The rules themselves are simplistic and obviously intended for the guidance of a novice. In modern times, Rule 1 'advantage before attacking' could be written as 'reduce the enemy's SA !' all the Rules are concerned with some aspect of aerial combat which revolves round SA, be it determination, attack options, countering deception, or ensuring adequate escape routes. The essence of the whole document could, perhaps, be summed up as 'win' and 'survive'. The whole teaching and training ethos was oriented towards what was put down as, 'To see first, to be aware of all circumstances, targets and hazards and potentialities ... this was the key to success!' There could not be a better definition of SA even today.

CONCLUSION

The only reason for the existence of fighter aircraft is to deny the enemy the benefits that accrue with optimal use of air power. Air combat is a means to an end, it is not an end in itself. The aim of every war is 'the destruction of the enemy' and air combat alone would be a very expensive and inefficient way of achieving this. However, the aeroplane as a weapon of war is by far the most versatile and lethal machine yet produced and for effective use of these machines, knowledge of their inherent potential and their optimum tactical employment is a necessity.

Air combat tactics, as they developed through the years, concentrated more and more on increasing one's own SA while at the same time trying to degrade the enemy's SA. To achieve this, technological innovations were also brought into play, till at the present moment, 'stealth' characteristics would degrade the SA of the opponent to an extent wherein he is unable to react to an expanding situation. How does one cope with combat against an unseen enemy far beyond visual range, armed with almost infallible missiles? While radar is a valuable aid and can expand a pilot's SA bubble to a considerable distance, its 'look' is fairly restricted leaving a lot of blind areas. Although technological breakthroughs have made the task of the pilot more difficult and also given him more information, the life of a fighter pilot now is more difficult than ever before.

Success in air combat is entirely dependent on SA, a fact that has been true from the first aerial combat over the trenches in France during World War I to the latest skirmishes that have taken place over the desert during the Gulf war.

> *The key is what you can see, retain, anticipate, estimate in a three-dimensional movement of many aircraft. Can you look at an enemy aircraft and know the odds—to get him at the earliest—if he can get behind you first, and so on? It is a three-dimensional impression; you must get it in seconds. This is essential in aerial combat. The guy you don't see will kill you. You must act instantly, anticipate the other fellow's motives, know that when you do this, he must do one of several things.*
>
> Colonel Robin Olds, Commander 8th TFW, USAF

PAPER 4

Impact of 'Stealth' on Air Combat

INTRODUCTION

Stealth is a highly classified area of military development. However, stealth technologies in general and combat aircraft based on these technologies in particular, are attracting increasing attention. Much speculation is still taking place regarding the operational implications of their use in the ground attack and strategic roles, but their significance in the air-to-air combat scenario has not yet been fully studied. It is certain that air-to-air combat doctrines and tactics will be revolutionised as soon as stealth air superiority fighters enter service.

What is achieved by stealth? The purpose of stealth is to improve the ability of a weapon system to carry out its mission, by making it more difficult to detect. The ultimate goal would be to achieve such a high level of stealth that the system will probably perform its mission without being detected at all. This hypothetical situation wherein the aircraft is invisible cannot exist. Therefore, if the probability of detection is reduced, the chances that the aircraft will survive and complete its mission are accordingly increased. Since the Battle of Britain, the integration of sophisticated radar had essentially removed the element of surprise and freedom of action from conventional aerial warfare. With stealth, it is now becoming possible to regain the element of surprise in attack tactics, as radar detection ranges are being drastically reduced.[1]

BACKGROUND

A decade ago, stealth was mostly conceived in terms of reduction of the optical signature to the human eye. This took the form of camouflage paint schemes, which had limited effect. The electromagnetic and infra-red signatures presented by the aircraft were traditionally solved by the use of countermeasures, such as chaff and flare ejection or electronic countermeasures (ECMs) to degrade enemy

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[1] Gen. John Michael Loh, USAF, *Air Combat*, Vol. 19, No 10, October 1991, P. 9.

sensors or weapon seekers. Although a great deal of research was being done from the end of World War II in the area of radar absorbent paints/materials and the reduction of radar cross-section (RCS), it was the Rockwell B-1A bomber prototype that offered a marked improvement in RCS, mainly because of excellent airframe shaping. However, the real breakthrough in radar and, for the first time, in IR signature reduction was made by the Lockheed Martin F-117A 'Night Hawk'.

The F-117A was designed as a guided weapons-armed attack aircraft which, by design choice, renounced the traditional search for balanced qualities to the benefit of very low observability features. This was specifically in the extreme reduction of the RCS-equivalent figure and IR emission from the engine exhaust area in the critical rear quadrant.[2] The subsequent specifically designed stealth aircraft is the Northrop B-2A 'Spirit' which has entered service. Although regarded as an improved third generation stealth design, the B-2 sacrifices top flight performance to 'stealthiness.' As a result, the B-2 is significantly slower than the previous B-1B, which retains high speed, particularly at low level, as a critical survivability asset, even when engaged by supersonic fighters.[3]

The latest generation of stealth combat aircraft, planned to enter service early in the next century, is represented by the Lockheed F-22A and its Russian counterpart, the Sukhoi S-37. These are described as the very first air superiority fighters designed to satisfy fully the stealth requirement with an uncompromising approach to stealth. However, the achievement of maximum stealth characteristics has its own penalties. These fighters are larger, heavier and more expensive than the contemporary non-stealthy or moderately stealthy aircraft. Furthermore, it is still necessary to sacrifice some characteristics and performance parameters.

LIMITS OF STEALTH TECHNOLOGY

The main areas where low observability must be achieved to produce a reasonably well-balanced stealth combat aircraft are:

- radar return;
- IR emission;
- visual detectability—both direct and indirect; and
- low-emission or totally passive avionics, sensors and fire control systems.

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[2] Sergio Coniglio, *Military Technology* 4/95, Washington D.C: P 52.
[3] ibid.

Radar Return Reduction. This requires careful shaping of external surfaces and does not match the aerodynamic configuration best suited for at least adequate flight performance and characteristics. Further the RCS value changes significantly with the angle under which the target is being illuminated and, therefore, a priority quadrant where radar detectability should be minimum needs to be selected. Manipulation of external shaping works by reducing the amount of reflected radar energy should be complimented by the use of Radar Absorbent Material (RAM), which will contribute to the overall stealth characteristics. Although the RCS is the main factor in radar detection, the range of detection is also affected by many other factors. The size of the antenna, the transmitted power, the width of the beam and the amount of noise generated by the radar itself are all part of the radar-range equation.[4] The biggest contributions to RCS come from retro-reflectors—plane surfaces at ninety degrees to one another. These can be eliminated from the basic shape of the aircraft by canting the fins and the body sides and reducing the number of major components in the external shape. Cavities such as engine inlets and the cockpit are also great contributors to RCS. Long, curved, baffled ducts and flush inlets can considerably reduce the engine RCS.

Suppressing the IR Signature. The problem of IR emissions reduction involves three main sources:

- the heat of the engine components,
- the propulsion exhaust plume, and
- heat emanated by the skin.

Apart from radar, the IR spectrum is the only one in which targets can be reliably detected beyond visual range. It is also the spectrum outside the radar bands in which air-to-air weapons and autonomous anti-aircraft weapons normally operate. While it is impossible to eliminate IR radiation, it is possible to minimise the chances of its detection. Closed-loop cooling systems, special coatings and low IR emission exhaust nozzles can be used to reduce the amount of heat that is emitted. However, the tailored nozzles involve some penalties in terms of propulsive efficiency, which by necessity impacts on other performances. Thrust-vectoring, variable geometry nozzles, which are being incorporated in most of the future fighters to improve controllability, manoeuvrability and reduce trim drag, increases the penalties in terms of IR emissions.

Visual Detectability. In visual signature, external dimensions are the first significant parameter. Although the size of the aircraft has only a moderate effect on its RCS, the visual signature is obviously a direct function of its size.

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[4] Bill Sweetman, *Stealth Aircraft,* Airlife Publishing Ltd, England, p 37.

Visual detection is also enhanced by other elements, such as contrails, cockpit transparencies glint, missile firing etc. Altitude is critical to visual signature and the higher an aircraft flies, the more light is scattered on to its underside. Optical and electro-optical devices are now common place in ground-based search and tracking anti-aircraft systems and will gain increased acceptance to engage aircraft featuring low radar signature. Even with the technological innovations in control systems, highly manoeuvrable stealth aircraft still require large control surfaces as seen on the current generation of twin-fin fighters. This would make the aircraft more evident in the air-to-air role and detectability can not be completely eliminated.

Avionics and Fire Control Systems. Emissions from the aircraft's own systems provide identification and signature that even exceeds the range of radar.[5] Non-emitting avionics, sensors and fire control systems are at best double-edged swords. A totally 'silent' fighter would experience severe limitations in independent target search, detection and engagement, particularly if the target is also enforcing strictly controlled emission procedures. In this case, both the contenders would have to rely heavily on external support for engagement. Air combat between aircraft having similar stealthiness would require the definition and improvisation of complex tactical procedures and integration of the use of multiple platforms working in close cooperation.

Summary. The final picture that emerges can be summarised as follows.

- Fully 'stealth' aircraft are very difficult to build and so their production is a very long and expensive process.

- To maintain the desired low RCS value in an air superiority fighter capable of manoeuvring at 9G will require an exceptional logistic and maintenance effort.

- Considering these technological/industrial factors, it can be safely assumed that no nation will be able to afford deploying a really significant number of fully stealth aircraft.[6]

- Consequently, it follows that these high value assets will only be used selectively in high reward missions to minimise the risk of loss/damage.

- The deployment limitation is further compounded by the economical and psychological impact of the combat loss of even one aircraft.

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[5] Bill Sweetman, *World Air Power Journal*, Vol. 31, Winter 1997, P 67.

[6] Benjamin F. Schemmer, *Armed Forces Journal*, January 1991, P 44.

THE CURRENT AIR COMBAT SCENARIO

The evolution of air-to-air combat doctrines over the past few decades has witnessed the radar progressively emerging as the basic sensor for all the phases and modes of an encounter between opposing aircraft, including close combat well within visual range.[7] The radar serves as a range finder and deflection shooting computer system in close combat and beyond visual range (BVR) engagements are totally dependent on the radar's capabilities of detection, tracking and guidance.

All modern air superiority fighters feature a radar-based fire control/weapon system, optimised for BVR combat. To supplement this capability and also widen the engagement envelope of fighter units, both in the defence of friendly skies and in offensive air superiority missions over enemy airspace, AWACS-type aircraft are being procured by an increasing number of air forces. These sophisticated airborne systems complement the traditional ground-based radar 'belts', which remain the basis for an effective national air defence network.

Given the fundamental importance of the radar in all forms of air warfare, the induction of a low RCS aircraft will have a traumatic impact on the effectiveness of aerial combat and air defence procedures. The most apparent and practical effect on radar-based air defences will be a marked reduction in their useful detection and engagement ranges. This means that there will be a significant shrinkage in the controllable/defendable airspace for a given system, giving rise to gaps in an otherwise total air defence cover which can be exploited by the enemy. Offensive air operations over enemy territory against 'stealthy' air defence fighters will also become difficult to sustain, because the enemy will be able to engage the attacking aircraft with little or no prior warning.[8]

AIR WARFARE IN THE 'STEALTH' ERA

Based on the above considerations, the overall technical and operational problems posed by 'stealth' aircraft can be analysed in two different scenarios, depending on whether only one or both contenders deploy 'stealth' fighters and attack aircraft for offensive and/or defensive missions.

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[7] Sergio Coniglio, *Military Technology*, 4/95, p. 55.

[8] Bill Sweetman, *International Defence Review*, Vol. 27, March 1994, p. 32.

‘STEALTH’ VS CONVENTIONAL AIRCRAFT

An air campaign carried out by a stealth capable air force against a conventionally equipped adversary would be conducted in two phases.

- **Phase I**. This phase will utilise the entire stealth fleet to attack high-value targets. The enemy air defence network, including ground and airborne surveillance radar, SAM batteries and even AD fighter units, would be sufficiently degraded in this phase. The attack aircraft would be supported by offensive air superiority fighter sweeps.

- **Phase II**. The second phase of the air war would be carried out mainly by the more conventional aircraft, which would now have the freedom to operate with little or no interference from the already diminished enemy air defence. The stealth aircraft, particularly the air superiority fighters, would however be available to neutralise any new threats that come up and also to ensure that recuperation of the network does not take place.

Countering ‘Stealth’

Theoretically, the scenario detailed above should describe the plight of a conventional force when facing an adversary with adequate stealthy assets. However, this is not indicative of the ground realities. A determined conventional force can oppose and even overcome its stealth equipped adversary, provided it has numerical superiority and follows a well-planned multi-option approach to the conduct of the air war.

Multi-option Approach. To counter a stealth dominated attacking force the conventional force must undertake the following tasks.

- Air defence network that is in place needs to be studied with particular reference to its efficacy in the defence of one’s own high value targets which should be prioritised.

- Analysis of the enemy attack patterns, operational habits and the characteristics of the stealth aircraft, which in turn will lead to the possible identification of attack routes.

Based on the above, the air defence can be optimised to protect vital targets/areas and to institute adequate countermeasures at the beginning of the air war.

Anti-stealth Detection System. A specific weakness of the stealth aircraft which can be exploited is the difficulty in making such aircraft equally low observable in all electromagnetic and IR spectra, especially if illumination is from more than one quadrant. Based on this surmise, a reliable anti-stealth detection system can be put in place which would consist of a network of sensors working on different principles and/or wavelengths. However, such a network would undoubtedly be complex and would have to overcome the following difficulties.

- The process and speed of gathering, processing, correlating and presenting the incoming data would be critical to the success of the network.

- The location of the sensors, which would also have to be deep within the national airspace, is critical in achieving the necessary high detection probability needed for successful interception.

Fighter 'Wolf Packs'. The current tactics of fighter aircraft operating in sections of two or four aircraft would have to undergo a drastic change. A new airborne search discipline involving an entire squadron needs to be adopted and practised extensively. It would be possible to divide the airspace volume into subsections and exploit the highly directional radar beam of individual aircraft to search a given area. The individual fighters would operate in an integrated way with a common signal processing point in a fighter unit command aircraft. This command post would then relay by data link the collated and analysed data, back to all the fighters within its ambit of operations. This concept of a large fighter unit acting as a single yet flexible search and attack network would be greatly enhanced by individual fighters being fitted with radar operating in different wavelengths. A group of aircraft could also be used to form a moving by-static radar chain. Although this concept would require continuous and intricate training as a whole unit, the impact on the conduct of the air campaign of even a single 'kill' of a stealthy aircraft would justify the effort. The concept also has a bearing on the current cost spiral in the fighter production area.

- Since the fighters would be operating as 'wolf packs' it would be possible to equip them with less sophisticated onboard sensors resulting in a significant reduction in the acquisition cost of these fighters.

- It may be possible to revitalise the concept of fielding less sophisticated lightweight fighters in large numbers, which would once again lead to cost savings.

High-Low Mix. In general, the concept of a high-low mix would become the cornerstone for both offensive and defensive air superiority missions against a stealth-capable enemy.[9] The few 'high' element assets in the mix, with sophisticated multi-sensor data processing capability, would act as the controlling brain for complete fighter units by coordinating the 'low' component consisting of a large number of smaller fighters, equipped with sensors and weapons of different types and having different operational characteristics.

STEALTH VS STEALTH

The scenario wherein two adversaries would both deploy stealth aircraft of similar capabilities is intriguing. It would be simplistic to deduce that since they are of equal capability nothing would change. However, it is most likely that aerial warfare would end up in close combat dominated by visual detection. In such a scenario, the outcome would depend on traditional factors like:

- training levels, especially in fighter manoeuvres;
- numerical superiority;
- performance characteristics of fire control systems (e.g. helmet mounted sight); and
- availability of state of the art AAMs.

Buttressing these traditional combat winning traits would also be the use or otherwise of passive countermeasures (chaff/flare, towed decoys etc.) and the use of innovative active defence systems (rear firing AAMs) with which a fighter is equipped.

Effect of Technology. As the aircraft move into the regime of complex technological innovations, the countermeasures are also to be found in technology.

- It is conceivable that the initial attack phase would find the use of powered decoys as a measure to instigate the enemy into action, thereby unmasking the position of at least some of the defending force.

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[9] Staff, *World Air Power Journal*, Vol. 6, Summer 1991, p. 34.

- IRST devices could also be tailored to detect AAMs, launched in total electromagnetic silence, with sufficient margins to effect countermeasures and provide a reasonably accurate bearing and distance of the launch aircraft.

- Scientists are also studying ways and means to use passive sensors to detect low RCS aircraft after detonating long-range ballistic missiles at high altitude. The burst is expected to produce wide spectrum electromagnetic illumination of enemy aircraft in the area.

- The proliferation of low RCS aircraft will also reduce the usefulness of active radar homing fire-and-forget-long and medium-range AAMs. Because of the unavoidably limited capabilities of their miniaturised radar heads and guidance systems, these weapons will be greatly degraded by stealth technology.

CONCLUSION

Successful offensive and defensive 'stealth' aerial warfare will require long and painstaking effort, starting from the formulation of new strategic and tactical operational doctrines centred on the conduct of the air campaign as a whole. The usage of an entire unit together will yield results, if the numbers are optimised and fully exploited to obtain data gathered with differing sensors and effectively integrated.

At least a part of the Air Force should be reorganised and supplemented by a complex network of ground-based and airborne surveillance and tracking sensors (radar, IRST, laser and enhanced electro-optical systems), widely spread over the area to be defended and capable of correlating and processing even single target data. Although this network would be expensive to build, any efforts at neutralisation would prove to be too costly to the attackers.

A possible encounter between 'stealth' aircraft will degenerate into short-range visual dogfights. However, it is felt that the proliferation of 'stealth' or even moderately 'stealthy' aircraft in medium level air forces would bring in a period of uncertainty which in turn will open the doors to a complete revision of the tenets of air combat!

SECTION II

AIR WAFARE CONCEPTS

PAPER 5

Air Superiority: Intangible Imperatives

Any one who has to fight, even with the most modern weapons, against an enemy in complete command of the air fights like a savage against modern European troops, under the same handicaps and with the same chances of success.

Field Marshal Erwin Rommel

INTRODUCTION

From the time air power was recognised as an important component in warfare, all military strategists have debated its priority in the overall context of waging war and winning it. The opinions have varied from the fallacy of air power independently winning a war to the other end of the spectrum, wherein its contribution to the final outcome is completely negated as inconsequential. It is now recognised by all modern armed forces that dominance in the air is a prerequisite to victory. However achieving air dominance is useful only if a nation has the competence and the national resolution to exploit it to the fullest.

In today's world, the degree of air dominance that can be achieved by any air force would depend largely on the capability of the opposing force. Conceivably, the scenario that was obtained during the 1991 Gulf War will not be available in any future conflict. Therefore, an air force with an autonomous mandate would have to examine realistically the degree of air dominance that it would be capable of achieving vis-à-vis the projected requirements and only then lay down its objectives. This may even lead to force structure modifications as the threat perceptions at the political level change perceptibly.

DEGREES OF DOMINANCE

Air supremacy, defined as that degree of dominance wherein the opposing air force is made incapable of any interference in any form, would obviously be the ultimate aim of any air force. Practically, this level of dominance is extremely difficult to achieve and maintain for any length of time, even in the face of mediocre opposition. A more realistic objective would be to obtain **Air Superiority.** A generic definition of air superiority would be, 'That degree of dominance in the air battle, of one force over the other, which permits the conduct of operations by the former and its land, sea and air forces at any given time and place without prohibitive interference by the opposing force.' The operative word here is 'prohibitive', which implies that enemy air activity at a greatly degraded level is accepted.

Further dilution of air superiority would lead to the quest for a **Favourable Air Situation (FAS),** limited and defined in terms of area and time. This situation is likely to arise when the opposing forces are almost evenly matched and the land campaign demands only limited air superiority. A further degradation would be the acceptance of even a 'tolerable air situation', before the land and sea campaigns are launched. However such a situation can only support short and swift campaigns with extremely narrow and focused aims. Even then, the attrition to own forces would be radically high and may even be unacceptable.

FACTORS TO CONSIDER

At the outset of the air superiority campaign, two major factors must be carefully considered and satisfactorily resolved. These factors themselves would not affect operations after the commencement of hostilities, but would have an overriding influence on pre-conflict decision making. Detailed planning should be taken up only with the complete knowledge of these two factors:

- **Degree of dominance required**. The first factor is to determine whether it is necessary to obtain theatre air superiority or localised dominance defined by space and time. This would in turn depend on the following factors:

  – objectives of the military action,
  – expected duration,

- capabilities and nature of the enemy, and
- geography and extent of the area of operations.

- **Distribution of air effort**. The second factor is the balance between Offensive Counter Air (OCA) and Defensive Counter Air (DCA) operations. Not considering the political imperatives, which may dictate a shift towards DCA, the better option would be to concentrate on OCA, thereby exploiting the inherently offensive characteristics of air power to attack and take the initiative. However, the actual distribution would initially depend on the long-term and ultimate objective of the military action and would subsequently be dictated by the progress of the overall campaign.

COUNTER AIR MISSIONS

Offensive Counter Air encompasses all air operations conducted to seek out and neutralise or destroy enemy air forces in the air or on the ground at a time and place of own choosing. There are several types of OCA missions. The primary ones being:

- suppression of enemy air defences (SEAD),
- escort,
- airfield attack, and
- fighter sweep.

Defensive Counter Air is the detection, interception and destruction of enemy forces that intrude into own airspace or interfere with own operations. This can also be termed 'Defensive Air Superiority.' An effective DCA network would have the additional advantage of having much shorter lines of communication and logistic support, which in turn would generate higher sortie rates and conserve scarce resources.

Although both OCA and DCA are complimentary in achieving air superiority, DCA alone will not be able to obtain it except for extremely short durations over very specific areas. The predominant role in obtaining air superiority would have to be played by OCA and its full range of missions.

CURRENT TRENDS IN CONFLICTS

Since the end of World War II, there has been no single war that has affected the majority of the world. All conflicts have been regional in nature and this trend is not likely to change in the near future. Even if some of the regional conflicts have global repercussions, in purely military terms, the conduct of the war would remain a regional issue. In terms of the air war this implies that, within the basic principles of employment of air power, each air force would have to develop and employ its own operational concepts based on ground realities and determined by military doctrines that evolve from national priorities. The political will and the collective psyche of a nation would have the ultimate influence on the broad use of force in any given situation. In this context, more often than not, DCA would seem the more attractive option and may be given more importance. However, this would be a myopic employment of air power and will not achieve the desired results.

It would also be pertinent here to question the effectiveness of air superiority against an enemy who does not possess an air force or even a large standing army. In such cases the standard application of air power will have no relevance, because command of the air by itself may have little or no significance to the outcome of the conflict. It was demonstrated clearly in the Gulf War that even a modern and well-equipped army has no chance of success against a well-put-together Western coalition enjoying overriding air supremacy. However, the most important lesson that emerged from the one-sided air war was the overwhelming technological and numerical superiority that was needed to obtain and maintain such a state of air superiority even after the opposing air force was rendered incapable of any coherent action. Within the current global distribution of power, such a situation can only be obtained by Western coalitions. This leads to the all important consideration of the availability of such spontaneous coalitions in any and all conflicts, the world over. Even if this was the case, it is almost certain that such help would only be forthcoming if it suits the larger interests of the Western world. Therefore, a self-contained doctrine on the optimum employment of available air power, encompassing the local scenario, must be developed by all nations possessing any kind of air force and wanting to safe guard their territorial integrity.

The major air forces of the world are concentrated in the Western world and so the concepts of air warfare and application of air power stem from the threat perceptions of the United States and its allies. (The doctrines that were propagated by the erstwhile Soviet Air Force are not being considered here as the international political situation has changed drastically since their break up.) From the end of World War II onwards, the Western forces have always fought wars in conditions of air superiority and so now consider the obtaining and maintaining of complete air supremacy a norm rather than an exception. However, this would only hold true in the case of an air force that can bring overwhelming numerical and technological superiority to bear on an inferior adversary. It is doubtful whether the same concepts of operations were the basis for planning at the height of the Cold War, especially in the European theatre.

In the case of emerging nations, the opposing air forces would almost always be evenly matched and so the concept of air superiority would have to be studied in that light. The basic tenets of the employment of air power would of necessity have to be adapted suitably to cater to the local requirements in such a way that scarce resources are optimally utilised. This paper will examine the options available to a smaller air force forced to fight a 'stand-alone' war with an opponent(s) who has technological if not numerical parity. It is assumed that such a force would not be given the chance to have the first strike because of political compulsions and would only be permitted to react to emerging situations in the early stages of the conflict.

AVAILABLE OPTIONS

There would basically be three options available to the air commander:

- offensive quest for air superiority,
- emphatic DCA, and
- an optimum mix of the above two.

Air Superiority. In a purely academic analysis, the best utilisation of the air force would be to employ its offensive capability optimally in an effort to obtain air superiority at the earliest. This, in effect, would be an offensive quest for dominance of the air, commencing with pre-emptive strikes and thereafter continuing OCA missions till complete air superiority is achieved. This would automatically ensure that the initiative is retained through out the campaign. *Per force,* the commitment to such an option would have to consider and reconcile the following factors:

- political will to assume the offensive,
- sortie generating capability,

- assured greater attrition,
- risk of inadequate support to the land campaign, and
- reliable intelligence regarding enemy intentions and capabilities.

Defensive Counter Air. The pursuance of a DCA doctrine, which essentially means waiting for the enemy to initiate offensive action and then reacting to the situation, would need an extremely well-prepared and coordinated passive as well as active air defence system. The force must have the capacity to absorb a possible first strike and respond immediately to the multiple requirements that would emerge at the commencement of hostilities. A DCA-oriented air force must be able to swing the trend of the conflict in its favour at the earliest, failing which it would become increasingly difficult even to obtain favourable air situations. While exercising this option the following factors must be kept in mind:

- the capacity to absorb first strike,
- capability to inflict unacceptable losses on the enemy which requires a very high degree of numerical superiority
- adequacy of support to the land campaign, and
- capability to switch from DCA to OCA when necessary.

Combination of OCA and DCA. This would also involve reacting to the enemy offensive and then aiming to achieve the desired degree of air dominance. However, in short duration campaigns the desired degree of dominance may vary from day to day and the requirement would only be to ensure favourable air situations at strategic areas/points for stipulated periods. Complete air superiority should be aimed at only in case the land campaign goes beyond the predicted time frame or becomes inconclusive. In such a situation the air force would probably be tasked to gain as much advantage as possible in preparation for negotiations at the appropriate time.

THE BEST OPTION

Political considerations would have the air force in a purely DCA role, wherein the emphasis on the defence of the home land would be visible to the general public. However, even for the most docile of air forces, this role would not be acceptable as it would only lead to gradual frittering away of resources. Therefore, the best option for any air force that would be forced to fight a 'stand-alone war' would be a judicious combination of OCA and DCA. This would need to be orchestrated carefully and would generally follow a set pattern.

First, it would be necessary to absorb and blunt the first strike. Thereafter, concerted action would have to be initiated to obtain and continuously maintain a Favourable Air Situation (FAS) at the earliest, so that the land campaign could be conducted without hindrance. A further step would be to combine overall FAS with obtaining localised air superiority, clearly defined in time and space, in support of major and crucial land battles. A comprehensive doctrine, extensive knowledge of capabilities and meticulous joint planning are the cornerstones to the success of such an approach to employment of air power. In all cases, if the land campaign fails to be conclusive within the estimated time frame, it would become necessary for the air force to achieve air superiority at the earliest. Therefore, while striving for FAS in the initial phases of the war, the ultimate aim should always be the obtaining of air superiority.

In the post-Cold War scenario, wars have been fought in almost all parts of the world. Most of them have involved the use of air power at a lower level of technology and intensity, basically because the opposing forces have not possessed large air assets. In the case of Western intervention, air power becomes employed in a more elaborate manner and that too in a completely one-sided way. In any future conventional war, where both the protagonists have air operations capabilities, unless external assistance is given, the chances of any one side dominating the air war with undisputed air superiority are non-existent. The selection of the best option, for emerging nations with limited air power assets, will be guided by the political, economic and security concerns of these nations.

The salient points of the 'Best Option' discussed above are listed:

- Capacity to absorb a pre-emptive first strike.
- Immediate response to emerging situations.
- Capability to obtain FAS at the earliest.
- Maintaining FAS and assuring limited regional air superiority.
- Adequate support to the land campaign.
- Ability to switch effectively to OCA as the campaign progresses.

CONCLUSION

It is an undisputed fact that air power is a dominant factor in the conduct of any conventional war. The necessity to obtain and maintain air superiority for the success of other operations has been demonstrated time and again without ambiguity. In the case of air forces with only limited tactical capabilities, the degree of air dominance desired may have to be adapted suitably to cater to a variety of local factors. In all cases it is important to define the governing doctrine for the air force and work towards optimising the employment of limited and costly resources long before the commencement of hostilities.

To summarise:

- Air superiority is essential for the success of all military operations.
- Once achieved, air superiority must be fully exploited.
- To obtain air superiority OCA is more effective than DCA.
- Pure DCA alone will not bring even FAS.
- There is a decided shift towards unconventional warfare the world over, in which case the traditional employment of air power may not achieve the desired results.
- Emerging nations may not be able to obtain or retain air superiority and so should employ an optimum combination of OCA and DCA to achieve FAS at the earliest.
- The air force doctrine should take into account the national political ideology and threat perception.

> *The one who figures on victory before even doing battle is the one who has the most strategic factors on his side, and the one with many strategic factors in his favour, wins.*
>
> Sun Tzu, *The Art of War*

PAPER 6

The Role of Air Power in Offensive Military Doctrine

The whole art of war consists of a well reasoned and extremely circumspect defence, followed by a rapid and audacious attack.

Napoleon Bonaparte

INTRODUCTION

Military doctrine is a major factor that determines the force's organisation and the acquisition and development of its means of combat. An offensive doctrine calls for the conduct of war on enemy territory or, at a minimum, for rapid and resolute transfer of the war into enemy territory at the earliest opportunity after it has broken out as well as for pre-emption if and when possible. However, a country's military doctrine would depend on its security perception, grand strategy and political, military, technological, economic and social developments, and needs to be finely balanced in terms of offensive and defensive elements. It is in the balancing of the two and traversing from one to the other that air power plays a decisive role.

This paper briefly examines the importance of military doctrine *per se,* considers the factors that lead a nation to choose an offensive doctrine in terms of geo-strategic considerations, threat perception and security policy and military organisational preference, and then deals in some detail with basic air power doctrine. The principal focus of this study is on the relationship between offensive military doctrine and the role of air power in determining the basic tenets of such a doctrine when put into practice. The paper will confine itself to a brief discussion of the general features of military doctrine that can assist in the analysis of the role of air power in the overall doctrinal approach. Further, the nature and importance of military doctrine will be defined followed by the reason for the special appeal that an offensive doctrine has for the proponents of air power and the limitations of such a doctrine, as well as the stagnation that it would cause if applied in its entirety.

THE IMPORTANCE OF MILITARY DOCTRINE

> *At the very heart of warfare lies doctrine. It represents the central beliefs for waging war in order to achieve victory. Doctrine is of the mind, a network of faith and knowledge reinforced by experience which lays the pattern for the utilisation of men, equipment and tactics. It is the building material for strategy. It is fundamental to sound judgement.*
>
> General Curtis E. Lemay, 1968

Military doctrine is defined as, 'fundamental principles by which military forces, or elements thereof, guide their actions in support of objectives. It is authoritative but requires judgement in its application.'[1] At the operational and tactical levels, military doctrine establishes the principles that guide the design of military force structure and operations. Its crucial importance lies in its role as the connecting link between defence policy, seen as part of national strategy on the one hand, and the actual operational plans of the armed forces on the other. Ultimately the main focus of military doctrine is to ensure optimum attainment of national goals by the armed forces, consistent with military realities. Sound military doctrine, applied to combat operations, is a fundamental prerequisite for victory in warfare.

In order to achieve its primary goal, military doctrine has to transcend and reconcile the inevitable gulf that exists between political objectives and constraints on the one hand and conventional military thinking on the other. This can be done either by convincing the political leadership to modify its guidelines, or by totally abandoning purely military logic—or by a judicious mix of both. However, in the final analysis, any flexibility necessary to marry military realities and political goals would have to come from adapting and deviating from sheer military logic because, 'military and war are subservient to and must always serve political goals.'[2]

Changes and developments that take place in the security as well as military situations (postures, balance, policy etc. in both areas) require constant appraisal and may point towards the need for doctrinal changes. Therefore, of necessity, a viable military doctrine which caters for and is tailored to a country's political and military conditions would have to be dynamic. The need to change is inherent in successful military doctrine.

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[1] George Thibault (ed.), *The Art and Practice of Military Strategy,* National Defence University, Washington DC, 1984.

[2] Barry Posen, *The Sources of Military Doctrine*, Cornell University Press, Ithaca NY, 1984.

THE CHOICE OF OFFENSIVE MILITARY DOCTRINE

A country can adopt a deterrent, defensive or offensive military doctrine. The reasons to choose and pursue any one of them could be numerous and disparate. There are a large number of factors that have emerged that seem to be associated with the choice of offensive military doctrine by a nation state. These factors are merely the incentives, which operate independently or in some sort of a combination, and can emanate from a country's geo-strategic considerations, perceived threat situation, security policy and to a lesser extent from the preferences of the military establishment.

Geo-strategic Considerations

This may be the root cause to adopt an offensive doctrine and could stem from any or a combination of all or any of the factors listed below:

- **Offensive Goals.** Expansionism and territorial occupation (as a demonstration of power and prestige) are strong incentives to lay down offensive strategic goals, which in turn need the adoption of offensive military doctrine in order to be successful.

- **Geo-strategic Vulnerability.** The known existence of threats—overt or covert—to a country's territorial integrity strongly suggests the adoption of an offensive posture. The first manifestation of this vulnerability is the perceived lack of 'strategic depth.' Strategic depth is defined as 'the space between the furthermost line at which a country may maintain military forces for its defence without impinging upon the sovereignty of another country and its own vital areas'.[3] The danger inherent in the lack of strategic depth can be further compounded by the country's geographical setting, which may make it relatively easy for the enemy to reach the country's heartland. In such cases the only viable option left to a nation may be to initiate a war and wage it beyond its borders.

- **Damage Limitation.** All states aspire to limit and minimise wartime damage to their population and infrastructure. The initiation, conduct and/or transfer of war on or onto enemy territory will be given importance according to the priority given to damage limitation in a country. A nation that cannot conceptually accept even minimal civilian damage would *per force* have to adopt an offensive doctrine.

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[3] Stephen J. Cimbala (ed.), *National Security Strategy: Choices and Limits,* Praeger Publishers, New York, 1988.

Threat Perception and Security Policy

A nation may adopt an offensive posture because of environmental, organisational and operational reasons which may also be the underlying factors for changes in military doctrine. Threat perception and the security policy that stems from it would take into account the following factors, while adopting an offensive military doctrine as the cornerstone of national security perceptions.

- **Multiple Threats**. A country that is confronted by grave military threats posed by several adversaries has a clear incentive to adopt an offensive doctrine in order to deal with them successfully. An offensive doctrine makes it possible for the beleaguered nation to engage its adversaries in a timing and order of priority of its own choosing rather than face a coalition of adversaries simultaneously.

- **Unfavourable Balance of Forces.** A balance of forces which is either very fluid or convincingly in favour of the adversary would greatly increase the chances of a nation initiating a preventive war or at least a pre-emptive strike in the event of a crisis.

- **Existential Threats.** States that are isolated in the international scenario and which do not have any reliable allies would tend to use an offensive doctrine as an extension of a deterrent posture to lend validity and credibility to their threats to resort to war if their interests are threatened.

Military Organisational Preference

All over the world it is seen that the military establishment has a pronounced, deep-rooted and consistent bias in favour of offensive doctrine. Any defensive or deterrent posture adopted by the military organisation of any nation can be traced to have been imposed on it by the political authorities because, left to themselves, the military will always tend to be offensive. The principal reasons for such a bias are summarised below.

- **Fighting Spirit**. An offensive doctrine is seen as the means to advance and instil a strong fighting spirit in the forces, which is a prerequisite to achieve decisive victory in any war.

- **Victory and Decision.** An offensive operation is the best proven method to bring about a decisive and victorious outcome in the battlefield. It is an effective means of terminating the fighting at the earliest without ambiguity.

- **Uncertainty.** The benefit of initiative and confidence that is derived from planning ahead of any operation is inherent in adopting an offensive doctrine. As a corollary, it not only minimises one's own uncertainty but proportionately maximises the adversary's uncertainty. An offensive operation permits the concentration of resources at one's own time and place of choosing to execute a well-formulated and familiar plan while the opponent is bound to dissipate his efforts in a haphazard manner.

- **Resource Allocation.** Offensive doctrine has a twofold impact on resource allocation. First is the impact of one's offensive posturing on the resource allocation of a potential enemy who would be forced to allocate a disproportionate amount towards the defence of his own territory. Considering the finite allocation of national resources to the military in almost all nations, this defensive preparation will, at least partly, be at the cost of offensive capability. The second impact is on the resource allocation to own forces. Since a successful pursuit of an offensive doctrine requires a high degree of preparedness, sophistication and complexity, it would also need a greater allocation of resources than other doctrines.

- **Organisational Autonomy.** Irrespective of the nature of the adopted policy of a military organisation, it strives to achieve as much operational autonomy as possible. This is best served by an offensive doctrine which postulates a short and swift war in enemy territory as opposed to a long drawn out struggle within one's own borders which a defensive doctrine seems to promise. While this would be unacceptable to the political leadership, it fuels the demand by the military for absolute autonomy in the conduct of the war.

AIR POWER DOCTRINE

Air power doctrine is a statement of beliefs and warfighting principles which describe and guide proper use of air forces in military action. The air force promulgates and teaches this doctrine as a reference point on the best way to prepare (organising, training, equipping and sustaining) and employ air power. Since it was the last military force to enter the arena of warfare, air power doctrine has grown from the need to establish common guidelines for military action. This doctrine is perceptive in nature but provides only a suggested course of action in any given situation.[4] The postulated doctrine is 'authoritative, but requires judgement in application.' Air power doctrine can be described at different levels and details starting from the basic and going on to operational and tactical levels.

- **Basic Doctrine.** Basic doctrine is the foundation of all air power doctrine and states the most fundamental beliefs that guide the proper use of air forces in military action. This also provides the framework around which an air force develops operational doctrine.

- **Operational Doctrine.** The principles of the basic doctrine are applied to military actions by the operational doctrine which describes the correct employment of air power towards achieving distinct objectives as well as the organisation of air forces. Operational doctrine also takes into account anticipated changes and influences that may affect military actions.

- **Tactical Doctrine.** Tactical doctrine considers tactical objectives and conditions (threats, weather, terrain etc.) and applies basic and operational doctrines to military actions by ensuring the proper use of specific weapon systems to attain laid down objectives.

The above three levels are only a broad outline, not limited by rigid boundaries and are not mutually exclusive. In the development of an air power doctrine, it is necessary to consider the military doctrine of unified or combined action from the very beginning. Air power doctrine should provide a fundamental reference for the air force contribution to joint and combined doctrine. The joint doctrine relating to air forces, applies the prevalent air power doctrine to all joint operations and stipulates the optimum way to integrate and employ air power along with land and naval forces in military action. In order to remain relevant to current operations and viable for the future, air power doctrine has to be refined continuously by a process of learning from experience from the field level upwards.

The basic objective of an air force is to win the air battle—to gain and/or maintain control of the airspace and to take decisive actions immediately and directly against an enemy's warfighting capacity. These actions include destroying the enemy's forces, neutralising his command and control infrastructure, and eliminating all areas which would sustain his warfighting capacity. As a critical element in the interdependent army-navy-air force team, air power can be the decisive force in warfare. The success of the land and naval battle depends on the capability of own air force to render the enemy air force ineffective and exercise

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[4] Joint Chiefs of Staff, Joint Publication 1-02—*Department of Defense Dictionary of Military and Associated Terms*, US Department of Defense, 12 Apr 01(as amended through 1 Mar 07).

adequate control of airspace. The role of the air force in war was summarised by General John D. Ryan, USAF in 1972 as, 'Considering the nature of modern war, air power can dominate not only the air but the land and sea as well. The Air Force must be able to deny control of the air to enemy air forces and to provide ground and naval forces the assistance necessary for them to control their environment.'

OFFENSIVE EMPLOYMENT OF AIR POWER

> *The speed and flexibility of air operations puts a premium on gaining and keeping the initiative. Of air warfare, if anything, is the old adage true—that offence is the best defence*.
>
> Marshal of the Air Force, Lord Tedder, 1947

A fundamental understanding of air power doctrine is necessary for all proponents of air power to employ air assets in the most effective fashion. Basic to this is the need to study the air-space environment, the characteristics of air forces and the principles of war, which would provide a foundation for the broad plan of employment. It is also essential to recognise the three essential factors in warfare: man, machine and environment, which interact in a complex manner during warfighting.

Waging war is an extremely complex activity. But the principles of war lay down the major truths which have been proved beyond a reasonable doubt to ensure success in the art and science of conducting war. All the principles of war are interrelated and are not separate entities. They are important to the conduct of a successful campaign and their understanding requires an in-depth knowledge far beyond the mere principles. It is only natural that air power doctrine also flows from these principles and provides broad guidelines for their application. Although no one principle has a 'stand-alone' status, the cardinal principle of offensive action is the most important in the realm of air power employment.

Offence. Unless offensive action is initiated, military victory is not possible. The essential principle of offence is to act rather than to react. It also gives the commander the option to select priorities of attack as well as the time, place and modality to achieve objectives. Air power possesses the capability to seize the offensive and can be employed rapidly and directly against enemy targets. It also has the capability to penetrate and carry the fight to the heart of the enemy territory without actually defeating the defending forces. In order to take full advantage of the capabilities of air power and optimise its use, it is imperative to seize the offensive at the very outset of hostilities.

Strategic and Tactical Actions

Air Forces have to be employed in both strategic and tactical actions against the will and capabilities of the enemy. Strategic actions produce effects and influences which serve the needs of the overall war effort, while tactical actions produce direct effects on the battlefield. Air power is the only element that is capable of attacking the enemy's capacity and potential to wage war throughout the duration of the conflict. Strategic and tactical actions are not restricted by geographical areas or operating environments and air power can be employed to produce integrated effects in support of the overall objectives. These actions are offensive and not mutually exclusive. In fact, to ensure their optimum contribution to the synergistic conduct of warfare, it is necessary to treat them as part of the same entity.

Control of the Air—Air Supremacy

The first consideration in employing air power is gaining and maintaining the freedom of action to conduct operations against the enemy. This freedom can only be attained by purely offensive actions taken to gain and retain control of airspace which in turn leads to the neutralisation or destruction of the enemy's warfighting potential.

> *Air superiority .... merely a means towards the end; it is the state in which the exercise of air power becomes possible.*
>
> Marshal of the Air Force, Lord Tedder, 1947

The campaign for control of the air and the achievement of air supremacy is inherently offensive in nature. Once having obtained the necessary level of control, the ongoing efforts to maintain it are also essentially offensive. Therefore, the core of any air campaign is offensive from beginning to end to ensure success and it is universally accepted that victory in any other sphere can stem only from a complete mastery of the air.

Freedom of Action. The gaining of air superiority spans both strategic and tactical actions and is the first priority of the air force. Air superiority can be said to be achieved when own forces have the freedom to effect planned degrees of destruction while completely denying that opportunity to the enemy. It is a continuous campaign to gain and maintain the capability to use the enemy's airspace to perform one's own combat missions and to deny the enemy the use of all airspace. The freedom of action that accompanies the establishment of air superiority gives the forces the option to carry out attacks that are necessary for victory while restricting attrition to the minimum.

Tactical Flexibility. The most important contribution of the air forces towards the overall objectives is the control of airspace, since it provides the army and navy the freedom to carry out their operations without any interference from enemy air forces. Without this control, tactical flexibility is almost non-existent. Since the attainment of air superiority is a prerequisite for the satisfactory conduct of any other operation, it is necessary for the air force to concentrate all its efforts in the destruction and neutralisation of opposing air forces at the earliest. Support to the land or sea forces by way of offensive strikes should only be undertaken after air superiority has been achieved to a reasonable degree.

Air Offensive Against an Enemy's Warfighting Potential

All actions directed towards denying the enemy time and space to employ his forces effectively can be included in the wider context of offensive action. All air actions must be clearly oriented to denying the enemy freedom to operate while basing all strategic and tactical actions in the context of the overall objectives.

Attack in Depth. Integrated strategic and tactical actions produce a cumulative effect on the enemy's ability to wage war. The devastating fire power that is available to the air force must be completely exploited to disrupt the enemy forces' manoeuvre options and expose them to unacceptably great attrition. This is best achieved by concerted attacks on the rear echelons of the forces as well as the ones in direct contact. In-depth attacks should be mounted against the enemy's lines of communications and other logistic support network as well as command and control structures which would guide enemy actions.

Persistence in Attack. All offensive actions should be carried out to the fullest extent and persisted relentlessly till such times that it becomes impossible for the enemy to be effective in the battlefield. Attacks must be directed at the enemy capability to sustain warfighting capabilities so that his resources are depleted and his mobility completely restricted.

Coordination and Assessment. The effect of air power is most apparent when attacks are carried out against an enemy who is intent on resorting to a highly mobile manoeuvre style of warfare, which is dependent largely on timely availability of resources and replacements. These attacks have to be coordinated with the ground forces in order to advance the overall objectives at the fastest pace possible. The plan of attack should be such that all friendly forces can take advantage of the predictable reaction of the enemy. A coordinated plan must also have built-in flexibility to respond to the most unexpected and urgent operational requirements. This in turn would require the availability of resources for information gathering and assessment. Accurate assessments are vital to anticipate, initiate and re-focus the direction of attack.

Reduction of Enemy's Offensive Capabilities. Effective tactical attacks reduce the time available to the enemy to implement their war plans, while on the other hand increasing the chances for own forces to seize the initiative. Successful strategic attacks force the enemy to deploy their air forces in ever-increasing defensive roles which continuously hampers their capability to sustain offensive operations. The essence is to curtail all offensive action that the enemy is capable of undertaking while enhancing own capability to initiate the offensive at a time and place of our own choosing.

Initiative. Adequate defences are required in air operations, but a preponderance of reactive thinking would nullify the essence of air power employment. An attacking air force can grasp the initiative quickly by forcing the enemy to be reactive and give friendly forces the needed flexibility and the opportunity to control the tempo of war.[5] Offensive is the cardinal principle and central to gaining the initiative and maintaining it. It is a function of flexibility, manoeuvre, timing and tempo, with the defensive becoming a function of the actions necessary to preserve the initiative.

Projection of Power

Air forces are inherently offensive—even when defending, they attack—and aggressive defeat of the enemy's air forces is the first priority in warfare as it makes all other operations possible. The speed with which air forces can be manoeuvred makes massing them much easier than any other force and its three-dimensional employment gives it the capability to employ both mass and manoeuvre simultaneously. This advantage gives air power the unique capability of being able to project power instantaneously and independent of all other forces.

In today's context, projection of power at the precise moment that it is required, is of cardinal importance in establishing superiority, even in isolated and regional

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[5] Air Force Manual 1-1, Volume 1, *Basic Aerospace Doctrine of the United States Air Force,* March 1992.

conflicts. Air power comes into the forefront when such a situation arises. The history of air power in the past two decades gives enough examples of the efficacy of air power in projecting power in such a way as to leave no doubts about its utility as the cutting edge of military power projection capabilities of a nation.

LIMITATIONS OF THE OFFENSIVE DOCTRINE AND THEIR EFFECT ON AIR POWER

There are a number of reasons why a predominantly offensive doctrine, which advocates pre-emption and rapid and immediate transfer of the war to enemy territory may not satisfy a nation's security requirements.

- It is universally recognised that offensive and defensive forms of warfare are both complementary and mutually supportive at the tactical, operational and at times even the strategic levels.

Offence and defence are two sides of the same coin
Mao Zedong[6]

- A school of thought even propagates the theory that it is best to extract full benefit from the defensive posture by inflicting maximum losses on an enemy on the offensive before attacking under conditions convenient to one's own forces.

- It has never been proven without doubt that offensive warfare alone is the way to achieve ultimate victory. The utility of the offensive is neither fixed nor uniform and it has no superiority over other forms of warfare and doctrinal innovations. The value of different doctrines varies from case to case and with circumstances and objectives.

- Although offensive action allows the initiative to be seized and thereby dictates the time, place and pace of the battle, defensive doctrine is widely believed to enjoy the relative advantage of being a stronger and more economical form of battle, enabling a qualitatively inferior force to persevere against a far larger and superior enemy.[7]

It is apparent that a nation cannot rely on one doctrine entirely to attain and secure its objectives. Both the basic doctrines should be studied and the military should choose between them on an as required basis in the light of their relative

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[6] Quoted by Israel Ber, *Elements of Defence*, Ma'arachot, October 1953.

[7] Carl von Clausewitz, *On War*, Princeton University Press, Princeton NJ, 1974.

advantages, its own objectives and the theatre conditions prevailing at any given time. There is also some validity in the feeling that defensive operations by themselves lack sufficient decisiveness to produce a clear-cut victory. Towards this end they must be complemented by offensive operations. Air power provides the necessary impetus and offensive capabilities for even a purely defensive doctrine to become viable. However, the limitations that are placed on the military when a nation adopts a defensive doctrine also percolate to the employment of air power. Its inherent offensive nature gets somewhat diluted and it may even be used in the purely defensive mode. Invariably such an approach would whittle away the greatest strengths of air power—that of rapid concentration of mass and fire power, flexibility and the essential control of airspace. It would therefore be of the utmost importance in the utilisation of air power that, even on the defensive, it be used audaciously in an offensive manner.

CONCLUSION

It is seen that a country can adopt a deterrent, defensive or offensive military doctrine. However, regardless of the stance adopted, air power remains an offensive weapon of warfare. It is best utilised in support of an offensive military doctrine when all its inherent and devastating qualities can be brought to bear on the enemy, with maximum effect. The planners at the apex forum have to be completely aware of this fundamental characteristic of the air force in order to make sure that adequate attention is paid to the establishment and continued maintenance of a viable force which can employ air power at ease.

Irrespective of the national security doctrine and threat perceptions, several fundamental beliefs are imbedded in air power doctrine. Air power can exploit speed, range, flexibility and manoeuvre better than land and sea forces, and therefore needs to be allowed complete freedom of action independent of any other force. It is also essential to control air power assets centrally to exploit it to the fullest with execution being decentralised. Priorities of classic air power missions have changed constantly with variations in the national policy, but the beliefs about proper employment of this war-winning force have remained fundamentally constant, despite profound changes in technology, strategy and international relations.

In the *'New World Vista'* study undertaken by the USAF Scientific Advisory Board, the concept of 'Attack' has been dealt with separately.

> Shaping the Air Force to meet the needs of the future is a daunting undertaking. The team chose a fundamental and operationally oriented approach for revealing and defining the types of operational capabilities most relevant for the future. The role of military power is to control (dictate and enforce) the operations of all types of enemy forces.

The most crucial operational tasks required to control enemy operations are

- Project power globally
- Provide dynamic planning and execution
- Counter weapons of mass destruction: possession, delivery vehicles and effects
- Achieve information dominance
- Counter invading armies
- Counter mobile, time critical targets

The main end-to-end operational concept to accomplish these tasks is 'Absolute Air Superiority.' In order to apply air power, the Air Force must have an assured ability to defeat hostile airborne and ground-based air defenses and to operate at will anywhere in the battlespace. This capability entails destruction or neutralization of enemy systems before they can act, along with the development of systems that combine signature control and countermeasures to defeat any surviving threat.[8]

[8] *New World Vistas Study*, Vol. 2, Attack, USAF Scientific Advisory Board.

PAPER 7

Lesson in Air Power from Limited Armed Conflicts

Military action is important to the nation—it is the ground of death and life, the path of survival and destruction, so it is imperative to examine it.

Sun Tzu

INTRODUCTION

The United States and its Western allies have used military force more than 200 times since the end of World War II and a majority of these have been involvement in low-level or limited conflicts. Although intervention has been done by both the US and the erstwhile USSR, the conflicts have by and large remained localised and have not been allowed to escalate. The Gulf War of 1991 is unique, in that, the coalition was able to put together a force of a magnitude not seen before. It is also debatable whether such a force would assemble again in the near future. Therefore, although the Gulf War would fit the description of a limited war, it cannot be studied from the point of view of arriving at lessons in the employment of air power. Air power has played an increasingly predominant role in the wars that have been fought from the mid-sixties and now enjoys a position of pre-eminence in the conduct of limited armed conflicts.

In most of the wars that have been fought in the past 30 years, the adversaries have had access to air power (a notable exception being the Afghan War) and so the battle for air supremacy has been keenly contested. It is from these encounters that lessons have been drawn and a number incorporated into the doctrine of most modern air forces.

IMPORTANCE OF THIRD WORLD CONFLICTS

Of all the wars that have been fought in the past three decades, around 15 have involved major task forces from the West in fairly intense, extended conflicts and geographically all of them have occurred in the Third World. The West has also started encountering increasingly radical Third World states while becoming steadily more dependent on imports of oil, minerals and raw material from the same states. This has prompted the forging of military alliances between the Western nations, particularly the USA, and a large number of Third World states irrespective of political ideology.

The importance of these nations is also apparent in the steadily changing character of the technology transfer from the West. The US is selling F-15, F-16, E-3A and E-2C aircraft as well as advanced transport aircraft and missile systems. In the same fashion, Britain, France and Russia are aggressively marketing 'top-of-the- line' systems, to any nation that can pay the bill. Further, Third World nations are themselves now manufacturing tanks, combat aircraft and missile systems. In fact, Third World states now account for a significant share of arms sales within themselves. Military technology transfers continue to proliferate and the technology gap between the armed forces around the world is sharply reducing. This is particularly true in the Middle East and Asia.

With such a preponderance of arms around the globe, and the fact that one out of every nine nations in the world is involved in some form of conflict (at the time of writing), a study of the utilisation of air power would shed some light on the possible character of future struggles and also provide an insight into current weapon systems and modern operational doctrine. They would also demonstrate the impact of such weapons and doctrine under actual battlefield conditions.

COMMON AREAS OF INTEREST

The conflicts involve several types of warfare which were carried out in a variety of ways and settings. The types of warfare range from primitive guerrilla combat to modern land, air and naval exchanges, and the settings include urban warfare, mountain warfare, marsh and amphibious warfare, desert warfare and arctic warfare. While the conflicts have varied widely in terms of their objectives, tactics, force structures, training, support, weapons employed and many other aspects, they all provide insights into several combat situations of interest. The areas of interest in the employment of air power would include:

- The overall value and impact of technology in low-level and Third World conflicts.
- The impact of weather, distance and other special conditions of combat.

- The increasingly important role of warning, threat evaluation, intelligence and tactical command, control, communications and intelligence (C3I) systems.
- The relative impact of force numbers and advanced technology on tactics, training, support systems and logistics.
- The capability of the Third World states to absorb technology transfer and operate advanced weapons and support systems.

CATEGORISING THE LESSONS OF RECENT CONFLICTS

It is not always easy to categorise the lessons learned from recent conflicts, but each conflict provides important insights regarding technology and tactics and significant lessons emerge in some or all the following areas:

- **Threat Assessment Technologies.** Almost all the major conflicts involved tactical and/or strategic surprise exposing the serious limitations in the ability of the current intelligence and surveillance technology to cope with the pace demanded by combined arms and operations.

- **Secure, Effective and Integrated C3I / AC&W / IFF.** All conflicts demonstrated the need for effective and secure command and battlefield C3 technology and systems, as well as reliable IFF capabilities.

- **Anti-Aircraft Artillery.** Recent wars suggest AA guns are still an important element of air defence.

- **Surface-to-Air Missiles.** SAMs have played roles of varying importance and short-range air defence systems (SHORADS) were found to have more impact on combat than medium or long-range SAMs.

- **Suppression of Enemy Air Defences (SEAD).** All conflicts have involved a major struggle between air forces and ground or sea-based air defences, although the results have varied widely.

- **Air-to-Air-Combat.** Barring a few exceptions all the conflicts have involved air-to-air combat, revealing the importance of advanced technology missiles, avionics, IFF, tactics and training.

- **Close Air Support.** Although extensive close air support activity has been involved, its overall impact on the ground war is debatable.

- **Interdiction.** Each conflict reveals a slightly different facet of interdiction and long-range attacks, but all indicate significant targeting, munitions lethality, damage assessment, tactical and coordination problems.

- **Helicopters.** In every conflict, extensive use has been made of combat and support helicopters.

- **Combined Operations.** For a variety of reasons no power has been able to unite land and air operations effectively. The inability of the land and air arms to function in unison and the unravelling of combined operations once they are initiated are seen in almost all cases.

ANALYSIS

Threat Assessment Technologies

One of the most dramatic lessons to emerge from recent limited wars is that advanced threat assessment technologies have a number of shortcomings when used against unsophisticated opponents. The limited effectiveness of signals, communications and electronic intelligence (SIGINT, COMINT, ELINT) against an enemy with very few such assets was classically brought out in the Soviet invasion of Afghanistan. The value of these types of intelligence in threat analysis is of considerable value in 'higher level' conflicts but its collection is becoming steadily more difficult because of the proliferation of countermeasures.

Platforms that can 'loiter' in the area and use stand-off assets like SAR, SLAR, FLIR and electro-optics to maintain surveillance over an extended period can be of great value. Although fighter aircraft and RPVs are useful tools, heavier aircraft with more endurance and range, a wider mix of sensors and sufficient onboard analysis are more capable of providing the field commander with near-real-time information. It was also seen that threat assessment is more effective when dedicated theatre assets are made available to the commander. Suitable sensors and communication satellites, all-weather electro-optical capabilities, computerised correlation capability and adequate ESSM and COMINT capability would improve the commander's decision-making ability considerably. The inadequacies in airborne targeting systems and the lack of tactical threat assessment technology, in a rapidly deployable form with near-real-time readout and analysis capability, tend to validate the conceptual proposals for advanced theatre collection platforms tailored to low-level wars. However, this platform would also become a high-value target during the course of the war.

Secure, Effective and Integrated C3I / AC&W / IFF

It has been established beyond doubt that a strong and effective command system backed by secure, effective and integrated communications at all levels is an imperative to victory. In order to achieve this, it is necessary to create a structure with suitable flexibility and initiative at every major level. There is no doubt that many failures and tactical problems in the recent wars occurred mainly because of the following three reasons:

- The failure to create suitable fusion centres for dissemination of gathered intelligence and compartmentalisation of command and control activities.
- Inadequacy of the communication and control system to link together small combat units.
- Targeting, C3/battle management and execution at the near-real-time speeds required being unavailable.

Landline communications are not subject to interception by ECM equipment but can be easily exploited by air attacks. Added to this, insufficient redundancy and protection of C3 systems can lead to army and air units being isolated from the main battle, precipitating incoherent action. It is seen that a mix of highly advanced reconnaissance, C3I, AC&W and IFF technology is well worth its high cost. In the Falklands War, the lack of a British capability to have continuous early warning was nearly decisive in determining the outcome of the war. They had no effective means to detect low-level attacks and had to rely heavily on 'close-in' air defence. Only luck limited ship losses.

In contrast, the 1982 Lebanon War is a classic example of the successful use of sophisticated systems and also demonstrated that it can be critical to employ the newest technical developments in each area. It was also seen that a second or third level power is capable of developing very sophisticated, world-class technology, provided some help was available from developed nations.

Anti-Aircraft Artillery

A wide variety of short-range air defence systems (SHORADS), including anti-aircraft guns and shoulder-fired missiles, have performed well in the conflicts. It is estimated that about half the ground kills of aircraft and helicopters in limited wars have been attributed to unsophisticated anti-aircraft machine guns or other unguided weapons used in 'curtain fire' or area fire modes. Proliferation and deployment of large numbers of low cost unguided AA guns in combination with SA-7 type systems greatly degrade the effectiveness of low-level attack missions.

Another development of interest is the use of the rapid fire AA guns in dual purpose and their effectiveness in ground combat. This emphasises the importance of guns in SHORADS, particularly with the increasing and decisive role being played by helicopters in the battlefield.

Surface-to-Air Missiles (SAMs)

SAMs have three basic types of impact on aerial combat:

- Shooting down hostile aircraft.
- Damaging hostile aircraft to the point that they could not perform assigned missions.
- Interrupting an aircraft's attack pattern by causing it to take evasive action.

The importance of the latter two is often overlooked because of the tendency to focus on kills rather than overall combat effects.

Light and relatively low performance systems like SA-7 and Rapier were found to be fairly effective against modern aircraft flown by well-trained pilots. Although manoeuvre countermeasures and active suppression would provide operational immunity, it is seen that these measures are difficult to practice. In contrast, the heavier SAMs were far less effective than predicted. This seems to have been as much a human factors problem as a problem in technology. Lack of training in C3I assets and non-availability of the most modern systems were contributory factors in the poor showing by these SAMs.

Line of sight and infra-red guided weapons were the most important assets in the battlefield mainly because of their fast reaction time and the relative ease of operation combined with simple maintenance. Although precision guided AA weapons (both close-in and long range) performed well in conflicts, it was seen that under actual battlefield conditions, none came even close to their theoretical kill probability.

Suppression of Enemy Air Defences

Every conflict has involved a major struggle between air forces and ground/sea-based air defences with varying results. They illustrate the delicate balance between the dominance of air power and that of the ground or sea-based defences, as well as the critical impact of different levels of tactics, C3I, technology and training.

Two important lessons emerge from the SAM suppression efforts:

- Improvements in air defence technology have shifted the priorities attached to SEAD missions. This is more so against Third World countries that have acquired sophisticated air defence missile systems.

- Anti-radar missiles and electronic countermeasures will probably not be enough against an even moderately well-trained opponent. It is seen that a high technology combined arms approach may be the most cost effective and reliable way to tackle this mission.

Air-to-Air Combat

Of all the conflicts in the recent past, the Soviet invasion of Afghanistan is the only one that did not involve air-to-air combat. Every other one showed that the outcome of aerial combat is increasingly a function of advanced, sophisticated technology incorporated in radar, guidance, computer interface, C3 and EW assets. This suggests that air combat mission effectiveness will increasingly move away from the traditional visual dogfight and that the effectiveness of fighters will steadily become a function of the proper use of:

- advanced air-to-air missiles,
- the associated avionics for on-board and weapon tracking and guidance, and
- the supporting BM/C3I/EW system.

The intensive technical training of pilots who are required to fly, command, control and communicate with sophisticated aircraft in a hostile, multiple threat environment will assume added importance.

There has been a steady shift towards technology-dominated air combat which suggests that close air combat will play a steadily diminishing role in future aerial conflict. The latest developments in missile technology clearly show the trend favouring the air-to-air missile over the cannon.

Close Air Support

All major conflicts have involved extensive close air support (CAS) activity. However, CAS has had far lesser impact on the ground battle than either the participants or the outside observers anticipated. This was partly due to inadequacies in target acquisition, C3I, training and munitions lethality. But more importantly, it was the result of the failure to insist on ruthlessly realistic operations research and combined arms exercise, testing and evaluation before combat. Somehow, all air forces seem almost congenitally incapable of honestly assessing and improving their capabilities in these areas.

Training exercises designed to meet specific battle needs, like detailed attributes of the target environment, special timing requirements and coordination between C3 assets and using dedicated technologies, will have to be carried out realistically if CAS missions are to be successful. A mix of emerging technologies, which combine advanced real-time targeting with smart area munitions, combined with dedicated C3I systems and adequate planning, training and organisation may be the answer.

Interdiction

Both battlefield and long-range interdiction revealed certain common targeting, munitions lethality, damage assessment and tactical problems. Long-range bombing attacks rarely had anything approaching the anticipated effectiveness. It is clear that accurate and effective targeting systems and weapons need to be developed and deployed for 'low-level wars' if interdiction missions are to have the needed effect on the outcome of the conflict.

The most effective use of interdiction attacks has been seen against naval targets. Large surface ships are extremely vulnerable to attacks by anti-ship tactical missiles. A further dimension of these missions involves the need for improved planning, targeting, C3I/BM and realistic training exercises for improved air crew training. The defensive lesson is that targets need as much active air defence and passive protection as possible to ward off determined attacks.

Helicopters

Every conflict has made extensive use of combat and support helicopters and it is indicated that their impact is highly dependent on tactics, the availability of advanced helicopter technology and munitions, and the availability of modern air defence weapons to the opposing side. The race between helicopter effectiveness and countermeasures is, and always has been, a close one. The effectiveness is affected by two major factors:

- The need for air superiority on the part of the force utilising the helicopter.
- The density of SHORADS within the enemy order of battle.

The helicopter usually proved superior to fixed-wing aircraft in providing close air support in most cases mainly because of the availability of a more responsive chain of command as the helicopter assets are normally organic to the land forces. Their loiter capability, slower speeds and ability to fly nap-of-the-earth tactics give the helicopter a natural advantage. The helicopter also offers a cost-effective solution to highly expensive and complex C3I/BM systems as against the fighter aircraft, which still operate under unresolved C3I/BM, munitions lethality, target designation and other associated problems.

Further, the helicopter offers an effective means of bypassing built-up areas and barriers, countering terrain and manoeuvring where armour is forced into positional warfare. At the same time it is clear from experience that survivability and numbers are more important than firepower and night and poor weather warfare capability.

On the negative side, helicopters in some of the conflicts demonstrated another general lesson: light helicopters are extremely vulnerable to enemy fighters and SAMs. This reputation of vulnerability has kept some of the most combat effective forces in the Second and Third World from investing in serious attack helicopters. There is no doubt, however, that the trend of future weapons development will be in the direction of tougher attack helicopters in the vein of the Mi-24 Hind and the AH-64 Apache.

Combined Operations

None of the forces that were involved in conflicts made full use of the synergy of combined or land-air-naval operations. The reasons for this serious drawback in tactical doctrinal thinking are numerous and varied greatly from conflict to conflict and at times from encounter to encounter. The most critical single problem in modern combined operations has been the inability to create an effective interface between offensive air attacks and manoeuvre units, in support of the air-land battle. This situation, wherein the capability necessary to implement ambitious tactics and plans is completely undermined, could stem from any, or all, the following reasons:

- Lack of effective command cohesion.
- Inability to target close air support properly.
- Not being able to ensure the correct aircraft-munitions mix and inadequate precision in strikes.
- Serious coordination and delay problems.
- Shortfalls dictated by terrain, logistics and range problems.

The recent experiences with combined operations give mixed lessons to be assimilated. The warning is that even highly professional and sophisticated forces continue to be unable to master combined operations and the air-artillery-manoeuvre unit interface completely. However, it has shown the edge military professionalism and adequate training gives to combined operations and has validated the need for sophisticated air and MRL area munitions as well as more effective C3I/BM systems. The only alternative would be to proliferate dedicated MRL, helicopter and fighter assets in direct support of brigade-sized manoeuvre units; a solution no nation will be able to afford.

Most of the air arms that have been involved in limited conflicts have suffered from certain common failures.

- An exaggerated view of the lethality of current air delivered weapons.
- Not fully realising the degradation that can take place in the C3I/BM system during hostilities.
- Exaggerated operational accuracy of weapons in the absence of terminal homing and target designator systems.
- Not considering the changes in target conditions in relation to the terrain while assigning missions.
- Failure to realise the criticality of immediate delivery following target acquisition, to mission effectiveness.

The critical importance of massive initial area lethality over single precision strikes was demonstrated and this validates the emphasis on C3I/BM and smart area weapons. The experience of these conflicts points to the fact that air arms tend to exaggerate the effectiveness of their weapon systems in peacetime and underestimate the need for constant and realistic training and practice.

CONCLUSION

From the lessons of recent conflicts, as categorised earlier, the following inferences may have to be studied in greater depth for integration into operational doctrine:

- Ensure availability of suitable sensors and communication satellites, all-weather electro-optical capabilities, computerised correlation capabilities and adequate ESSM and COMINT, to enhance the commander's decision- making capability.
- Surface-based air defence system should be made an optimum mix of SAMs and SHORADS, which are upgraded with regularity to keep pace with the rapid technological developments taking place.
- Impart intensive technical training to aircrew to fly, command, control and communicate in hostile, multiple threat environment.
- Carry out combined arms training, in as realistic a scenario as possible, to prepare the forces for SEAD, CAS and interdiction missions.
- Examine the need to induct attack helicopters into the inventory and operational ethos of the force, if not already done.
- Ensure the availability of a dedicated and state-of-the-art C3I/BM system with sufficient redundancy to ensure complete coherence of all units (air, land and naval) even in the heat of battle.
- Lay great emphasis on training of all personnel under as near battle conditions as possible.
- Planning should be done keeping in view the degradation of weapon systems in battlefield conditions.

PAPER 8

Russian Combat Aircraft: Concept of Operation, Future Employment and Implications

INTRODUCTION

Until the time the MiG-29 Fulcrum and Su-27 Flanker were revealed to the Western media, it was normal to assume that Soviet designed and built fighter aircraft were crude and inferior copies of older Western models and to write them off derisively as having little or no impact when operationally employed. Even the unique flying displays that were performed by the pilots of these aircraft were, more often than not, commented on as being carried out with minimal load and fuel with no tactical utility in actual combat situations and being far too complicated for an average pilot to perform. However, it is a matter of considerable interest that till now no Western designed aircraft has been able to duplicate the manoeuvres that the Fulcrum and the Flanker have been routinely performing in air shows around the world!

The disdain with which fighter aircraft of Soviet origin have been consigned to the dust heap of history, frankly belies the capabilities of these aircraft and their exemplary performance in more than twenty different air forces around the world. In international comparison they have always suffered under the constant criticism of myopic and at times ill-informed analysis. But in some ways, they are more advanced and better constructed than fighter aircraft from the West. For example the Su-27 includes systems (such as the infra-red search and track system) and fabrication techniques (the extensive use of titanium) that are highly innovative and offer clear advantages not available in any Western fighter. This is not to suggest that the MiG, Sukhoi, Yakalov and other design bureau have always produced flawless, classic, winning designs. They had their drawbacks like every other bureau and some designs were even blatant copies of Western aircraft. But they all had one common trait, in that all of them were built to measure up to very exacting criteria laid down by the defence forces and at times produced within very short lead time.

CONCEPT OF OPERATIONS

While discussing and analysing Soviet military equipment, and particularly fighter aircraft, one must bear in mind the fact they were all designed with the primary aim of defeating the NATO alliance in Europe. It is a historically proven fact that the West has continuously been taken by surprise by the capabilities of fighter aircraft that the Soviet Union was able to field against them. In the Korean conflict, the MiG-15 exposed the vulnerabilities of the Thunderjets, Meteors and other combat aircraft flying for the United Nations. This came as a rude shock to the West. Only the F-86 proved to be a match for the MiG-15. The 1960s and 70s saw the resurgence of Soviet air power and the appearance of the MiG-25 triggered a panic in the West.

'Quantity has a quality all its own,' Joseph Stalin is purported to have said, and NATO pilots facing Warsaw Pact forces were grimly aware of it. Though the argument of quality versus quantity remains debatable, for many years NATO pilots enjoyed at least a slight qualitative advantage over Warsaw Pact aircraft, that at times outnumbered them by as much as 5 to 1. The Soviets relied entirely on numbers to be able to saturate the defences of the West. In the late 1980s, however, the appearance of a new generation of Soviet fighters gave Western pilots and defence analysts an unpleasant surprise. The MiG-29 and Su-27 embodied heretofore unseen capabilities, with avionics, weaponry and performance that was equal or even superior to contemporary Western fighters. If these aircraft had been fielded in the same large numbers as previous types, the basic quality over quantity equation that has always been crucial to NATO superiority, would have been irrevocably overturned. Luckily for the West, the collapse of the Soviet Union negated the prospect of sustained large manufacturing programmes.

Even after the end of the Cold War, the basic thrust of development in Russia remains essentially focused on countering the equipment of the NATO forces. Currently Russia considers regional and local conflicts as the biggest threat to national security, which combined with severe economic constraints that currently prevail, have almost completely halted any futuristic technological innovations.

Traditional Russian military doctrine has always considered the Army as the basic arm of defence with the a Air Force being an essential but subservient component. Therefore, the overriding factor has been the availability of adequate air support to the ground forces. Air superiority *per se* never merited a separate campaign other than to ensure that the ground campaign moved forward inexorably. It was also assumed in the strategic planning stage that the ground forces would capture enemy airfields from which the supporting aircraft could then operate. The Army concept of overwhelming the opposition by sheer numerical superiority was translated to the arena of air warfare as well. In the context of the air superiority campaign, this led to the development of ground-controlled 'spot-interceptions' tactics, wherein the fighter was utilised as a tethered asset, which completely negated all the basic tenets that govern employment of air power. These doctrinal presumptions had a more than normal impact on the fighter design philosophy.

- All designs tended to be single-role oriented, with limited flexibility.
- Range, loiter time and the need for air-to-air refuelling to enhance both were not given adequate priority.
- Multiple weapon carriage capability was minimal.

For more than four decades after the end of World War II, the Soviet/Russian military culture did not credit the Air Force with an independent role or status. The impact of air power in the Gulf War brought on a concerted debate on its role in total campaigns and reluctantly convinced the strategists of the Air Force's critical contribution to winning a war. The tactical employment of fighter aircraft in the Russian context continues to be an enigma as open discussions on such matters are still not encouraged. There is also surprisingly little by way of written material that emerges from the Russian Armed Forces even now. Although in possession of some of the very best fighters in the world today, with performances that outclass all competition, the Russian Air Force still seems to be in tactical limbo as far as optimum employment of these assets are concerned. The situation stems from the failure of the command structure to re-evaluate and focus on potential threats from within and outside the country and their extreme reluctance to accept the loss of international stature resulting from the break-up of the Soviet entity and the division of military assets.

The Soviet Air Force has never been known for tactical innovation, as ideology was expected to complement and provide the necessary boost to inadequacies in training and low morale. The rigidity of training and doctrine, combined with the employment of fighters as essentially tied assets, never gave tactical aircrew the impetus and initiative to develop revolutionary tactics with which to improve and optimise the performance of their aircraft. Over a fifty-year period, the Air Force remained starved of independent thinking, leading to flawed tactical doctrine, ineffective intellectual development and strategic tunnel vision. The ill effects of this situation became starkly apparent when the designers started producing aircraft capable of extreme range and 10-hour loiter.

Even when the Mikoyan and Sukhoi OKBs produced their masterpieces, the Soviet Air Force was unable to optimise their employment which would have given them parity with NATO in offensive air power capabilities.

OPERATIONAL EMPLOYMENT OF RUSSIAN FIGHTERS

After World War II, almost all conflicts in which air forces were involved have pitted Western aircraft against Soviet fighters. For a number of disparate reasons, the side operating the Western equipment has generally held the advantage. Nowhere else is this more apparent than in the Middle East where time and again the Soviet equipment have been outclassed, the last time during the Gulf War. The air wars in the Arab-Israeli conflicts have produced such lopsided results leading to a worldwide feeling that all Soviet fighters are completely inferior to all Western aircraft.

A closer examination of these conflicts reveals a somewhat different picture. In nearly all cases, the inadequacies and failures were that of personnel and not equipment. Most of the air forces that operated Soviet fighters drew on Soviet doctrine for their employment, but were unable either to embrace it in its entirety or comprehensively adapt it to local conditions. Partial adherence to a doctrine will never win wars. Similarly, training procedures were also copied, without ensuring that at the combat squadron level, the pilot is able to access support systems in the same quantity and quality as practised in the Soviet Air Force. When the entire doctrine was adapted without dilution, as in the case of the air defence network of the Egyptians, it succeeded. Subsequent degradation of the system can be attributed to the inability of the Egyptians to capitalise on the initial advantage.

In cases where the training and operational doctrine are completely independent of any Soviet influence, the performance of Russian aircraft have been on par with any other contemporary fighter. The performance of the MiG-21 in the Indian Air Force, is a clear example of how training and innovative tactical employment can ensure optimisation of the capabilities of the aircraft as a weapons system. During the Vietnam War, the US Air Force and Navy considered the MiG-21 a potent adversary even though they were never employed in sufficient numbers to have long-term impact.

Soviet aircraft are designed for dedicated single-role utilisation, offering very little in-built flexibility for it to perform any other role. The Soviet Union could afford the luxury of role oriented training for pilots, as well as maintain the large fleet of aircraft necessary to support this doctrine. Most of the countries operating Soviet fighters have acquired them more for economic than political or ideological reasons. Therefore, they could never afford the number of aircraft needed to support single-role utilisation effectively. With the result, some of them have tried to adapt these aircraft, as best as possible, at times to unsuitable roles with obviously disastrous results vis-à-vis their performance.

Apart from being comparatively cheaper, the Soviet fighters are also easier to maintain in terms of technological sophistication. Since they are designed to operate from semi-prepared surfaces, they tend to be very hardy and are able to operate even from very primitive airstrips. This translates directly to a higher sortie generation rate. For example a MiG-21 squadron of 20 aircraft with a normal serviceability state of 75 per cent is expected to be able to mount 90 sorties a day; not in surge operations, but on a daily basis. The design philosophy, that supports the doctrinal concept of numerical superiority and saturation of enemy defences, in the employment of these fighters can be seen directly from the above example.

In a straightforward one-on-one comparison of role oriented performance, the Soviet fighters are as good as their Western counterparts. It is unfortunate that the Russian Air Force has utilised them with an almost complete disregard to accepted principles of the employment of air assets. Other air forces have deployed these assets with no clear understanding of their strengths and without concrete and tangible doctrinal thought to support the operation. This lacuna, and the less than optimum training of pilots and support personnel in these air forces, have combined to stigmatise and malign an entire era of Soviet fighter aircraft.

MIKOYAN MIG-29 'FULCRUM'

> *I had seen the performance of the MiG-29 during flying displays, but when I flew it I was amazed at how agile that fighter really was, and particularly at the ability to point the nose. It is a tremendous turn fighter. I am not allowed to make comparisons with any Western fighter, but what I can say is that its performance throughout the low speed end of the flight envelope is better than what has been accomplished by Western aircraft.*
>
> Major Bob Wade
> CF-18 Hornet display pilot
> (Over 6500 hours of fighter flying)

The MiG-29 is probably the best all-round fighter ever produced by the Russian aviation industry: versatile, with unsurpassed handling characteristics, superb performance and a wide range of highly effective weapons. The basic MiG-29 is an excellent close-in dogfighter, with a useful BVR capability and has won itself an enviable reputation, tarnished only by its somewhat limited range and shortfall in simultaneous engagement capability of its air intercept radar. These drawbacks have been remedied in the MiG-29M, making it the best Soviet lightweight tactical multi-role fighter.

Fire Control System

Although its weapons system allows it to function as a BVR interceptor, the aircraft is primarily meant as a highly manoeuvrable close combat fighter capable of flights at angles of attack (Alpha) more than 70 per cent higher than that permitted in any other aircraft. The most significant feature of the MiG-29 is its Fire Control System. This integrated system comprises the radar, a wide-angle helmet-mounted target designator system and an advanced electro-optical Infra-Red Search and Track (IRST) system, all of which are linked via the mission and fire control computers.

The electro-optical system comprises an IR tracker and a laser rangefinder, which gives the MiG-29 the capability, on a clear day, to make an emission free interception, detecting, acquiring, tracking and launching missiles without having to use the radar. This provides the Fulcrum with enormous tactical advantage and has obvious applications in a heavy jamming environment. The IRST and laser can also be used at close range, where they considerably improve the accuracy of the Gsh-301 30 mm cannon.

The helmet-mounted targeting device that a MiG-29 pilot uses is probably the first such operational system. Using head position sensors mounted on each side of the HUD, the computer can determine which way the pilot is looking (i.e. the head is pointing), allowing him to designate an off-boresight target. Missile seeker heads, the IRST and even the radar can be slaved to this system.

Cockpit – Visibility and Workload

Pilot visibility and cockpit workload are two areas in which the MiG-29 has been criticised in the West. Whereas the F-16 or F/A-18 pilot sits on top of the fuselage in a bubble canopy with unrestricted all-round view, the MiG-29 pilot sits deep within the fuselage, with the canopy frame at shoulder level. But the aircraft affords a much better all-round view to the pilot as compared to all previous Soviet designs, through 160 degrees on each side of the centreline.

For Western pilots, the cockpit of the MiG-29 might appear to be one of 'high workload', needing careful coordination of control input and complex aiming procedures. However, when regularly undertaken, these activities are controlled by the subconscious, which can handle many complex tasks simultaneously. Therefore, it does not overload the pilot's brain and leaves him as much cognitive capacity as the pilot of an aircraft with lesser need for fine control inputs and simpler weapon launch actions. Front-line MiG-29 pilots, with previous experience on Soviet fighters, are full of praise for the ergonomics of the MiG-29 cockpit as opposed to the Western pilots who find many aspects of it 'foreign' and are unable to adjust to it in the few sorties that they fly.

It is appropriate to examine and compare the HOTAS philosophy of Western fighter cockpits. The concept behind the HOTAS system of combat can be summed up as 'everything you need is on the throttle and stick'. It has been recorded that the average pilot can only use three functions simultaneously in an intelligent and coordinated manner and, therefore, these functions need to be kept simple to avoid confusion in the heat of battle.. The basic HOTAS did not strain the pilot, but with the addition of more and more functions to the system, the workload in a single cockpit situation has now gone beyond the capabilities of a majority of average people. In a study conducted by the US Air Force, it was determined that an F-15 pilot needs to be in constant and intensive flying practice (i.e. two sorties per day for at least three weeks continuously) for him to be able to utilise the aircraft as a weapons platform optimally, throughout its performance envelope. Most of the pilots also accepted the fact that becoming proficient on the F-15 was not easy and constant practice in simulators and on the ranges are viewed as a kind of graduate training scheme. It is also common for pilots to be undergoing additional training voluntarily after they felt that they were adequately qualified on type.

In comparison, the MiG-29 is simpler to master for a pilot who has been trained in Soviet fighter cockpits like that of the MiG-21, Su-22 etc. Of course, constant and concentrated practice is necessary to fly it to the limits. The MiG-29 cockpit's high workload criticism is only a perception and not a fact.

Combat Effectiveness

After the reunification of Germany, 24 MiG-29s were transferred to the Luftwaffe from the former East German Air Force. These aircraft were used in the aggressor role, in extensive trials that were carried out in conjunction with other NATO air forces, primarily the US Air Force. So the strengths and weaknesses of the Fulcrum and its relative performance spectrum are now fairly clearly understood.

Handling. The MiG-29 enjoys unrivalled high Alpha handling, with a service limit of 35 degrees, making the aircraft a particularly formidable opponent in a close-in, low-speed turning fight. An extremely sophisticated aileron-rudder interconnect in the flight control system progressively reduces aileron deflection at high Alpha while increasing the rudder deflection in response to the pilot's sideways deflection of the control column to command roll. Additionally the flight control system has no hard limits, so that it is possible, *in extremis,* to exceed maximum G and maximum Alpha simply by pulling through the synthetic 'stick-stop.' The behaviour of the aircraft, even at prohibitively high Alpha, is sufficiently benign and fully controllable, making it possible for the pilot to exploit even the farthest corner of the flight envelope, if the tactical situation demands it. Thus, the MiG-29 pilot can pull more G or go to higher Alpha in order to boresight an enemy fighter, evade a missile or avoid a hillside, while his Western counterpart simply cannot override his aircraft's hard limits.

Air Combat. It was once believed that the high workload cockpit and lack of onboard processing capability would be a severe constraint in the MiG-29's effectiveness in BVR combat. But trials have disproved this fallacy. Although the aircraft's primary BVR weapon, the R-27 (AA-10 'Alamo') is not as capable as the AMRAAM, the aircraft and weapon combination has proved to be as capable as the F-15 Eagle/AIM-7 Sparrow combination in simulated engagements. These engagements have also shown that in the WVR scenario the aircraft is virtually unbeatable. With superior agility and acceleration to any Western fighter, the MiG-29 pilot also has a decisive edge because of the helmet-mounted missile–cueing system. This endows a formidable off-boresight capability, allowing the pilot to engage aircraft far off the aircraft's nose. The effectiveness of this superb helmet sight is further enhanced by the MiG-29's primary close-range armament, the Vympel R-73 (AA-11 'Archer') missile, which is generally acknowledged to be superior to the AIM-9 Sidewinder. The R-73 is probably the most effective close combat missile in service today.

In the final analysis, it is certain that the MiG-29 is a match, if not superior to all contemporary aircraft including the F-15. Visual engagements with the Fulcrum should be limited to situations wherein definitive advantage and a quick solution are guaranteed by virtue of initial positioning and/or numerical superiority. Once engaged in combat with a MiG-29 it would be almost impossible to effect a getaway. It is inevitable that all close combat encounters with this aircraft will culminate in a solution rather than a stalemate.

SUKHOI SU-27 'FLANKER'

While the MiG-29 was creating a stir in the Western military aviation circles with its unparalleled aerodynamic envelope, the design bureau of Pavel Sukhoi was already test flying their latest fighter aircraft, the Sukhoi Su-27. Although lesser known in the West as compared to the Mikoyan bureau, the Sukhoi bureau has produced an impressive array of combat aircraft from its inception in 1939.

Russian warfighting doctrine advocates defeating any airborne invasion much before it reaches Russian airspace. Neutralisation of AWACS and tankers are a prerequisite for the success of such a campaign. The Sukhoi-27 was conceived to execute the basic mission to travel deep, past the swarms of fighters, and kill the 'brains' of an invading air force. The aircraft was given tremendous range and great payload potential, as well as the capability to operate from very austere facilities. The aircraft, support units, command and control system and also the unit tactics incorporate a mandate for independent operations, unknown till now in the Russian Air Force, that has been poorly appreciated in the West.

The Flanker Family

The enormous versatility of the design was exploited to produce a large number of multipurpose variants. In order to garner as much of scarce government funding as possible, these variants were designated with different numbers.

Su-27UB. The obvious initial linear projection was an operational trainer, Su-27UB, inducted into service in 1986.

Su-30. Closely based on the trainer, the Su-30 is a two-seat interceptor optimised for long duration (more than 10 hours) air superiority missions. It achieved Initial Operational Capability with the Russian Air Force in 1993 and was further developed into the multi-role Su-30M (export Su-30MK) with 12 hardpoints to carry 8000 kg (17,635 lb) of stores.

Su-33. A navalised Su-27 with limited multi-role capability, the, Su-33, was the first variant to incorporate the 'unstable-integrated-three-plane' configuration. The Russian Navy is now expected to field only one aircraft carrier as against the initial proposal of four. Therefore, it is not likely that the Su-33 would be produced in great numbers.

Su-34. Structural refurbishment produced a dedicated shipboard side-by-side trainer, that quickly demonstrated great potential to be a deep-interdiction maritime strike aircraft. It entered production as the Su-34 and Su-32FN to replace theSu-24 Fencer. The dramatic reduction in the demand for carrier-borne fighters has put further production of this variant in jeopardy.

Su-35. A progressive development of the Su-27 possessing genuine dual-role capability was initiated in 1988. The definitive fighter, designated Su-35, had an all-moving foreplane, digital flight control system, four multi-function cockpit displays, 30 degrees inclined ejection seat and retractable in-flight refuelling probe. The fighter is expected to be procured in large numbers for the Russian Air Force and for export.

Su-37. Variant with Thrust Vector Control (TVC) that is being advertised by the Sukhoi bureau as a 'fifth-generation super manoeuvrability fighter'. Currently the aircraft is only a technology demonstrator, but the conversion to operational combat capability is expected to be simple and swift.

Despite a killing stranglehold of economic travails and a pragmatic reorganisation of the aerospace industry in Russia, the obvious insertion of capital from sales to the Peoples Republic of China and India have put Sukhoi back on the rails. It is estimated that the production facilities can deliver any variant within a lead time of 18 months. A shrinking market for new fighters is expected to result in the production of only about 2500 combat fighter airframes in the next decade. Sukhoi is slotted number four, behind Boeing, Lockheed Martin, and Dassault, with 6.42 per cent of the market share amounting to over US$7.56 billion. Together with the MiG-29, the Su-35 offers the best suite of sensors and offensive and defensive avionics in service anywhere, together with guns and missiles which, with the exception of the AMRAAM, again has no rival. Currently the Su-35 is also the only air defence fighter certified to fly ten-hour missions.

Basic Configuration

A modern fighter is built around its radar. The size and shape of the antenna, which is a direct function of its primary mission, determines the rest of the specifications of the fighter. The Su-27 has a one-metre diameter forward fuselage bulkhead, from where the rest of the fuselage flows as a semi-monocoque structure, using the maximum amount of titanium alloys so far seen in any fighter. Titanium alloys have the best strength-to-weight ratio but is about 80 times more costly and requires special fabrication techniques. Approximately 30 per cent of the Su-27 is made of titanium as compared to about 1.5 per cent in the F-16 and around 24 per cent in the F-15.

The Flanker is powered by two Saturn Lyulka AL-31F two-shaft afterburning turbofans weighing 1530 kg (3373 lb) each producing 122.6 kN (27,560 lb) of thrust. The Su-35 uses the improved AL-35 (2400 lb extra thrust) and the Su-37 uses the AL-37FU with TVC. The AL-31F has a subsonic cruise specific fuel consumption of 0.67 kg/hr/kg and the engine has a very respectable 8:1 thrust-to-weight ratio.

The Flanker's weapons load is formidable. In addition to the GSh-301 cannon (150 rounds) up to 10 AAMs can be carried in the air superiority role:

- 2 x semi-active radar homing R-27R (AA-10A 'Alamo-A') under fuselage
- 2 x IR homing R-27T (AA-10B 'Alamo-B') on centre wing pylon
- 2 x semi-active radar homing R-27ER (AA-10C 'Alamo-C') or IR homing R-27ET (AA-10D 'Alamo-D') beneath each wing
- 4 x R-73A (AA-11 'Archer') or R-60 (AA-8 'Aphid') close range AAMs on outer pylons

Cockpit and Avionics

The cockpit layout is virtually identical to that of the MiG-29 or any other Soviet combat aircraft, making pilot transition comparatively simple, which is one of the less appreciated advantages of the Russian design approach. However, even with the Fulcrum and the Flanker sharing a strong external resemblance, the view from inside is importantly different. The MiG-29's cockpit gives the pilot the sense of being inside the aircraft peering out with the canopy rails that come up to the pilot's shoulder. By contrast the Su-27 pilot seems to sit on top of the aircraft with the rails coming up to only the arm level, affording a far better view in all directions. Another important difference in the cockpits is that the Su-27 has a weapons stores indicator just below the HUD, a head-on representation of the aircraft with ten sets of lights representing the ten weapons stations.

Radar. The all-weather digital multi-mode radar operates in either air or ground surveillance modes or in both modes simultaneously. The Su-37 is also equipped with a rearward facing radar in the tail stinger area of the fuselage. The pilot can view forward and rear-facing radar data on one display or on two separate displays, depending on the selection made in the cockpit. The forward looking electronically phased array radar provides simultaneous tracking of up to 24 air targets and is capable of ripple fire engagement of eight targets at one time. It can detect airborne targets with RCS of $3m^2$ at 140–160 km (76–86 nm) and ground targets at 130–170 km (70–92 nm). The surveillance is ± 90 degrees in azimuth and ± 55 degrees in elevation. The surveillance area to the rear of the aircraft is ± 60 degrees in azimuth and elevation, with detection ranges of 30–50 km (16–27 nm) based on a similar $3m^2$ target size. The radar can be retrofitted in any Flanker variant.

The Flanker uses the same IRST system as the MiG-29 that can be slaved to the missile seekers, the gun, the laser rangefinder, the radar, as well as to the pilot's helmet sight.

Thrust Vector Control

The Su-35 and Su-37 are today the most attractive multi-role fighter products of the Russian aerospace industry. Sukhoi is continuing the development and testing of the Su-37 with thrust vector control and plan to export the fighter aggressively. This raises the prospect that India or a country in Asia may be the first to achieve operational capability of this type in the world. The engine used is the AL-37FU with a maximum thrust in afterburner of 14,500 kgf (31,970 lbf). In addition to TVC, the Su-37 has a variety of other innovative equipment such as a high-precision laser-inertial/satellite navigation system.

The TVC is integrated into the fly-by-wire controls and operates in both automatic and manual modes. The cockpit is equipped with a side-stick control to the right and a fixed throttle on the left, which measures the pressure exerted by the pilot's fingers to adjust thrust settings accordingly. The nozzles of the two AL-37FU engines can deflect together or differentially to a maximum of 15 degrees at a rate of 30 degrees/second and is used primarily in pitch. The engine can also be retrofitted to any Su-27 variant with minimal modifications.

The term 'super manoeuvrability' defines controllability up to 60–70 degrees of Alpha with transients exceeding 120 degrees. Although experiments have been going on and technology demonstrators have been flown in the West, the Russians have finetuned the TVC to achieve it. TVC permits post stall manoeuvring and weapons pointing which are impossible in conventional aircraft, giving the Su-37 the ability to engage an enemy advantageously irrespective of the initial relative positioning. The designers genuinely believe that the Su-37, with its extremely high thrust-to-weight ratio, thrust vector control operated by the integrated fly-by-wire control along with the wing-tail-canard aerodynamic configuration, is a truly fifth-generation super high manoeuvrability aircraft.

Handling. The essence of a combat aircraft is how it flies and fights. All pilots would know that aircraft have individual characteristics and traits unique to themselves and the Flanker has more than its share. The Su-27 was the first aircraft to demonstrate the now famous 'Pugachev Cobra' in 1989 at the Paris Airshow. The actual significance of this manoeuvre and also that of the 'Kulbit' is still debated. Although there seems to be a consensus that they do not fit into normal combat tactics, it is accepted as useful in extreme conditions. The real significance of these manoeuvres is that it comprehensively demonstrates the extreme agility of the aircraft, its slow-speed handling characteristics and its easy controllability at angles of attack that would have any other aircraft falling out of the sky! It also underscores the reliability and responsiveness of the engines that are able to transition from idle power to afterburner rapidly and smoothly.

FUTURE EMPLOYMENT CONCEPTS

> *In the development of air power, one has to look ahead and not backward and figure out what is going to happen, not too much what has happened.*
>
> Billy Mitchell

There have been suggestions that the Su-37 with TVC would be a difficult aircraft to master, and that training would be prohibitively expensive and time consuming. As a corollary, it is also pointed out that any dilution in training to effect time/cost saving would be detrimental to operational effectiveness and safety. Whatever the misgivings among the sceptics, it is now an undeniable fact that in the close combat environment, the reality of vectored thrust has come to stay. Dogma based on blind belief in superior technology and training patterns, needs to be put aside and both the Fulcrum and Flanker must be examined in detail if we are not to 'shoot ourselves in the foot' in any future engagement. The Flanker has convincingly closed the gap on the technological edge that has been the cornerstone of Western planning against Russian equipment.

It is also a matter of interest that the basic Su-27 has spawned variants to fit every role in which a fighter aircraft could be utilised for the foreseeable future. No other aircraft and its derivatives have so far effectively managed this complex requirement. It is only now that the JSF is being developed to undertake various roles. If reports are to be believed, the JSF designers are still trying to cope with the disparate requirements without having to sacrifice one or the other performance criteria. In this light, the achievement of the Sukhoi OKB could perhaps be termed revolutionary. The prevailing economic condition in Russia has had a particularly devastating effect on the military aviation industry. In the near future it is more than likely that only the Su-27 and its variants would be offered for export. A realistic analysis of future employment and its impact would, therefore, have to consider the implications of the proliferation of this aircraft because of possible licensed production and allied secondary export even to rogue states.

Mini-AWACS

The majority of the world's air forces do not have dedicated AWACS support. In most cases it is simply not affordable and the technology involved is beyond the scope of indigenous industry. The dual-seat Su-30, currently in service with the Russian and Indian Air Forces, is capable of utilising onboard sensors to pass on target information to other lesser capable aircraft via data link. The use of this aircraft as a mini-AWACS provides the time necessary to track and sort a large number of targets and also provides defence in depth. The aircraft is capable of monitoring the air situation and also controlling the air defence forces in the vicinity to optimise their effectiveness. The concept of an air defence/superiority force built around one or two Su-30 aircraft being operated in the command and control role is already being translated to reality. Such a force, that can effectively remain electronically silent till the very last minute of an attack, will be a force multiplier of great tactical importance.

As a take-off from this concept, it is not difficult to envisage a pair of Su-30s being the hub of a dedicated air superiority force made up largely of aircraft of the MiG-21 'Lancer' class. Not only will such a force be economically viable to nations with lesser resources, but also will be an effective equivalent of a potent high-tech air dominance force. The force also be able to cover a very large geographical area that will be appealing to the ground forces commanders.

Command and Control

The collapse of the Soviet Union and the reorganisation of the Russian Air Force brought home the fact that serious improvements were necessary in a number of areas, including command, control and intelligence systems. It was recognised that even NATO finds that war plans have never fully caught up with the need for efficient communications and, therefore, the Russian Air Force has established a cohesive command and control doctrine. Air links with command and control aircraft were strengthened, but the most important innovation was the optimisation of the Flanker's 'stand-alone' capability in C3I jamming situations. The Su-27 force is capable of independent tactical action in line with the major objective, even after loss of command and control links. This is the complete opposite of all doctrine so far associated with the Soviet Air Force (as well as other air forces operating Soviet aircraft). This rapid acceptance of tactical independence reinforces the recognised capability of this aircraft to control emergent tactical situations effectively. The aircraft's extraordinarily long loiter time, without in-flight refuelling, enhances its performance in both the AWACS and C3I roles.

Utilisation in Conjunction with UCAVs

It is an accepted fact that Unmanned Combat Aerial Vehicles will not replace manned fighter aircraft in the foreseeable future. But it is not difficult to appreciate the fact that UCAVs will have a niche role in future aerial warfare. Undoubtedly there are certain advantages that come with the employment of UCAVs. However, there are a number of issues that still needs to be addressed before they can be operationally inducted. While discussion on those factors is extraneous to this paper, the following as yet unresolved and vexing problems are of interest:

- Operation of manned and unmanned aircraft as part of an integrated force.
- Functional control of the UCAV.
- Overall situational awareness necessary for the authorisation of weapons release from UCAVs.

All the above issues can be comprehensively solved if an aircraft in the vicinity, with real-time situational awareness, exercises operational control over the UCAVs. The Flanker is again an ideal aircraft to be utilised as a 'mother ship' to control a number of UCAVs. The limitation of this concept would only be that of the capabilities of the UCAVs and their role orientation. It is certain that SEAD, which would have to precede any meaningful strike package, would be a definitive UCAV role very soon. The possible high attrition of SEAD assets and the UCAV's capability to loiter after the initial suppression to neutralise any further defences that might emerge makes them ideal for this role.

Although UCAV technology has so far not reached the stage of air combat, a situation in which UCAVs are flying as part of a larger force in the air-to-air role is also not difficult to imagine. As a student of air power I have absolutely no doubts regarding the primacy of manned aircraft in the efficient application of air assets. But I am also equally convinced that the day is not far when a combat formation, whether in the air superiority or strike role, will be a combination of manned and unmanned vehicles. It would appear that the Flanker was built to take advantage of precisely such a futuristic situation.

IMPLICATIONS OF THE INDUCTION OF THE FLANKER

The induction of any new weapons system into a region heralds a spate of reassessment of threat perceptions, followed by doctrinal and tactical review that may even lead to realignment of alliances. The impact and the degree of change will depend largely on the effectiveness and capabilities of the new system itself. The induction of any Flanker variant, even in small numbers, is an event that needs the undivided attention of all strategic planners for a number of reasons.

High-tech Arms Race. The open availability of the Su-27 to any nation with sufficient financial backing is a worrisome prospect. In a broad politico-military sense, it raises the spectre of a high-tech arms race in some of the more volatile areas around the globe. In a shrinking world market for costly combat aircraft, the Flanker today offers more for money spend than any other fighter and that too with no political strings attached. Already, the French have been forced to offer the Rafale instead of the Mirage-2000 to nations in South-East Asia as a counter. Although the Flanker is being aggressively marketed, the sales seem to be inhibited by the dubious after-sales and through-life support that the Russians offer.

Doctrinal Ethos. The Flanker is an inherently offensive weapon system and its acquisition by an air force, even one that subscribes to a non-offensive stance, would have to be viewed and analysed as such. Although it does not mean that any country that inducts the Flanker is going to invade its neighbour immediately, it does point to a change in perceptions and a subtle shift in doctrinal ethos towards a more belligerent and offensive attitude. This aspect needs careful consideration at the highest level of command while analysing the possible intentions of an adversary or even that of a neutral neighbour. It should be given more attention and importance in decision-making than it has so far been given.

Operational TVC. It is almost certain that the Indian Air Force would be the first to be operational on thrust vectored fighters. While accepting the advantage of TVC in combat situations, the enormous gain in tactical innovation that this situation gives to the IAF (or any other air force) could perhaps be termed as a quantum leap in air combat tactical development. The full impact of this controversial technological marvel on combat employment, especially in group combat situations, is still unclear. But even air forces that may not become TVC operational, need to study this new system in order to anticipate and develop counter tactics. Even if the advantages seem dubious in the current context, it is not prudent to let another air force assume a monopoly on its operational employment ethos.

Air Superiority. The flight demonstration of the Su-37 has been described as 'seeing a giant war-fighting beast translating in all directions and spitting fire like a dragon with many arms.' While this may be an overly poetic write-up, the fact that this aircraft has truly gone on to being the first genuine fifth-generation fighter without a comparable opponent in the sky at present, should be a constant worry factor for war planners. The counters to this aircraft by Western terms are only in the developmental stage and a near-term response does not seem possible.

Reliance on stealth and BVR solutions can achieve air superiority in conditions wherein the enemy defences have been degraded sufficiently. But when faced with an adversary, capable of and willing to absorb even high attrition in order to overwhelm a technologically superior force, the situation may well become untenable. In such a situation the Su-27 will form the war-winning force.

Technological Edge. Ever since World War II, air dominance has been a factor that Western forces have taken for granted. It is a mandatory prerequisite for the conduct of any other operation. In turn, the ability of the Western forces to achieve and maintain this dominance is heavily dependent on the unrivalled technological edge that their equipment have so far enjoyed. During the Cold War, the obvious numerical superiority enjoyed by the Soviet Union had, at least theoretically, always been countered by the presumed technological superiority of NATO aircraft. Air forces around the world that operate American or European aircraft have unquestioningly adopted this doctrine of total reliance on technological superiority. It has to be borne in mind that technological superiority ensures air dominance only when adequately supported by other equally superior technological assets like AWACS, EW etc. The absence of such support immediately neutralises the technological superiority of the force. The induction of the Flanker system into any region, especially one that has a deficiency of support elements, degrades the so-called technological superiority decisively, to an extent wherein it cannot be considered an edge anymore. Even a tactically favourable air situation, let alone air dominance, would remain a distant dream in such a situation.

CONCLUSION

Sun Tzu said, 'One should appraise a war first of all in terms of (five) fundamental factors and make comparisons of various conditions of the antagonistic sides in order to assess the outcome.' The fifth factor that he mentions is doctrine. From amongst all the warlike efforts of mankind, perhaps it is in the arena of air warfare that doctrinal ethos plays the most important role. The need to study, understand and then counter the adversary's doctrine, from the sublimely strategic to the basic tactical two aircraft level can never be overemphasised. The capability of a weapons system plays an important role in the formulation of doctrine and development of tactics in a force. Therefore, it is imperative for all serious practitioners of the employment of air power to understand the implications of the induction of futuristic weapon platforms into their areas of interest and influence.

Section III

Aircraft Design

PAPER 9

Performance Characterisitics of Fighter Aircraft

INTRODUCTION

Since their first employment in World War I fighter aircraft have been developed in a number of disparate ways, as technology has pushed performance frontiers out and concepts of air power employment have under gone sea changes. For example, technologically, the advent of turbojets and airborne radar and, conceptually, the change from high-level bombing to low-level terrain hugging attacks, have been turning points in the basic requirements of a fighter aircraft design.

The role of the fighter aircraft has been one that has changed considerably in a very short span of time. Its roles are still in the process of being defined. The multiple uses of the fighter, that have become apparent with the achievement of extreme technological sophistication combined with the dynamic development and application of doctrinal adaptation in the use of air power, have strongly impacted the design requirements in the development of the fighter aircraft.

DEVELOPMENT OF FIGHTER MISSIONS

Historical Evolution

In the initial stages of the advent of the aircraft in warfare, they were utilised for aerial reconnaissance only. However, as aircraft performance improved, the fighting capabilities of the machine became obvious and pilots began taking advantage of it. Tactics to engage or evade hostile aircraft began to emerge as a natural consequence. The first dedicated fighter was arguably the Fokker E1-a monoplane fitted with a synchronised machine gun firing through the propeller arc.

At the beginning of the World War II itself, the need for fighters to counter the threat from hostile bombers as well as protect friendly bombers was recognised. The Spitfires and Hurricanes achieved the former during the Battle of Britain and the North American P-51 Mustangs and Lockheed P-38 Lightnings, acting as escorts, gave a graphic account of the latter role. Ironically, the P-51 was designed as a dive-bomber but excelled in escort duties and the P-38, designed as a high-altitude interceptor, performed, best below 5000m.

The introduction of the turbojet brought along an increase in cruise altitude and speed. This presented new problems for the designers in terms of aircrew survival, necessities related to pressurisation, low temperature and high-speed escape, as well as the need for elaborate search and fire control equipment to accomplish the mission under conditions of reduced manoeuvrability but vastly expanded battlespace.

Superiority in speed was of utmost importance in the gun-armed dogfighting era, when the initiative always rested with the swiftest, whether it was for pursuit of the enemy to engage him or to evade him by flying out of range. The Korean War demonstrated the effectiveness of lightweight fighters and the USAF put in a request for one, which produced the Lockheed F-104 Starfighter. However, subsequent conflicts have shown that large fuel capacity to ensure sufficiently long range and endurance is more important than being agile at the cost of staying power. In more recent times air refuelling has added an important tactical element to range and endurance.

Speed, BVR and Agility

In fighter lore, ‘speed is life.’ By increasing an interceptor’s speed, the engagement point can be moved farther away from the target. In ‘visual-identified’ interception of intruding high-flying reconnaissance aircraft, speed can be traded for height in a constant energy zoom-climb, to achieve transient flight well above sustained flight ceiling. With the trend changing towards beyond visual range (BVR) combat, fighters will attempt to engage their targets with medium range air-to-air missiles, which in turn require long-range airborne radar and foolproof identification systems to be effective. In this case, the fighter must manoeuvre hard after launch to stay outside the enemy’s missile envelope in order to minimise the danger to itself. Survivability in this scenario would depend almost entirely on rapid acceleration and sustained supersonic manoeuvrability.

High supersonic speed has received renewed interest with the advent of BVR missiles, but in reality only the speed attained during acceleration from radar contact to missile launch (to impart maximum energy to the missile) is useful. Secondly, even in an aircraft equipped for BVR combat, only 0.1 per cent of the total service life is spent in the region above Mach 2. In contrast, the penalty in cost increase to ensure sustained manoeuvrability beyond Mach 2 is so high as to make it prohibitive. In any case, in all roles other than BVR, manoeuvrability and acceleration is far more important than pure maximum speed.

With modern, agile and off-boresight capable missiles, there is no escape from close combat by virtue of superior speed alone. Once engaged, only superior manoeuvrability and/or technology (countermeasures like chaff, flares or jamming) can win the day. In fact, in most air superiority engagements, speed is almost an embarrassment because rate of turn (a factor that determines agility) is governed and restricted by 'G' limits, both structural and physiological. Even a head-on pass at supersonic speeds, almost always necessitates reduction in speed while manoeuvring for a firing position in order to exploit qualities of turn rate and radius.

The Fighter as a Weapon system

As operational requirements became more complex, driving design to greater sophistication, it was realised that all factors affecting combat performance had to be integrated at the earliest stage in design to optimise performance. The outcome was the project management concept of the completely integrated weapon system in which not only the airframe and engine, but avionics, armament, test and support equipment, training devices, tools, trials etc. were all designed as part of the whole package. This approach, combined with an improved production cycle, permitted intensive flight testing with an increasing number of aircraft to uncover and rectify all major 'bugs' before embarking on full-scale production.

Operational Requirement

Establishment of clear-cut performance requirements, vis-à-vis the intended role of the aircraft, is extremely important as it drives the design and is also the yardstick by which the aircraft's success is measured. However, the design is not normally based on a completely defined specification but on what could be termed a 'cardinal point specification', which is a prioritised list of the customer's most important requirements. For example, low radar signature may be more important than the mean time between failures (MTBF). The process of defining the major design parameters to optimise the configuration and developing a workable specification for a complete weapon system are mutually influential. For modern aircraft, this period of definition is so long that at times profound changes take place, even in the basic concept of employment of the aircraft, at times even before the type's entry into operational service.

To be cost-effective, the operational lifetime of a modern combat aircraft type has to be at least 30 years or even more. The combination of such an extended operational life cycle and the lengthy project gestation period can mean that a requirement has to be defined 15 or more years before it can be put to the acid test of combat. The odds against accuracy in this kind of crystal-gazing are great. The accuracy is further degraded by the rapid developments taking place in the field of weapon and sensor technology which may be deployed by or against the aircraft.

PERFORMANCE REQUIREMENTS

Operational Versatility

The design of an aircraft is a complex undertaking, requiring teamwork from experts in a wide spectrum of fields, such as aerodynamics, propulsion, structures, flight controls, materials, electronics, performance and operational analysis, human engineering, manufacture, costing etc. The basic aim of the design team is to examine and determine the inadequacies of the existing combat aircraft in the light of the latest developments in the threat scenario and to pursue emergent ideas that are valid and relevant, rather than endeavour to conceive entirely new designs.

With limited defence budgets and the uncertainty of the threat, it is becoming increasingly important to ensure versatility and adaptability of the weapon system from the design stage itself. A summary of the main design features required for operational versatility is given below. The emphasis placed on each of the phases will depend on the intended role of the fighter.

Summary of Design Requirements for Operational Versatility

Operational Phase (Optimum Requirements)	Primary Design Requirement
Take-off (Minimum distance)	High afterburning (A/B) and thrust to weight ratio (T/W), high flap lift, low wing loading, thrust vectoring
Transit/loiter (Maximum economy)	Low throttled specific fuel consumption (SFC), high cruise lift to drag ratio (L/D)
Speed (High maximum & penetration)	High dry T/W, low store drag, good ride capability
Combat agility (Very high)	High dry T/W, high control power, good L/D at high 'g', high usable lift, thrust vectoring
Combat persistence (High)	Low combat SFC, good L/D at high 'G', versatility of weapon carriage
Combat mobility (High)	High (A/B) T/W, low drag at all Mach numbers
Survivability (High)	Stealth (to give 'first shot-first kill' capability), threat awareness and countermeasures, robustness, redundancy
Landing (Minimum distance)	High flap lift, low W/S, flareless, good retardation

The preliminary design period of an aircraft will only occupy the first two years and absorb around 1 per cent of the total life-cycle cost, but decisions taken during this period have a disproportionately high impact on its life-cycle cost.

Lethality

This is a function of the destructive power of the aircraft's weapons, which must be easy to use, reliable, non-counterable and effective. The lightest, cheapest, easiest to use, hardest to counter and most effective air-to-air weapon is still the gun.

The cannon, though adequate for dogfighting with other aircraft, should however be complemented with short-range IR guided missiles, which would effectively prevent disengagement. Interceptors are now using medium-range missiles in the BVR mode, mainly against less manoeuvrable and positively identified targets.

Manoeuvrability

Also known as agility, this is the ability of an aircraft to change position and velocity rapidly in order to gain advantage in air-to-air combat. An aircraft's performance is assessed by load factor (i.e. vertical acceleration in 'G'), turn rate and turn radius. Combat superiority is seen as depending on the product of specific excess power (SEP is a measure of the ability to regain energy by climbing or accelerating), sustained turn rate (maximum turn rate without loss of speed) and instantaneous turn rate (maximum achievable turn rate with transient loss of speed).

Handling Qualities

The aircraft should have handling qualities such that the pilot is able to operate throughout the performance envelope with ease and safety. Superior handling qualities are necessary to utilise the full potential of the aircraft optimally and have now become almost a prerequisite in fighter design.

Radius of Action

The ability of an aircraft to reach and attack its target and return depends on its radius of action, which is directly influenced by the nature of combat in which the aircraft is engaged. For example, the target for the air superiority fighter may be close at hand and combat manoeuvring would consist mainly of linear and turning accelerations. The best aircraft will be the one that can perform all combat relevant manoeuvres at a given radius of action or, as a corollary, achieve the longest radius of action for a specified combat requirement.

Persistence

This is the ability to stay in combat while retaining optimum performance. It is expressed in units of time for a specified fuel load and radius of action. The ability to manoeuvre without afterburner while ensuring adequate dry T/W ratio and the capability to carry a mix of armament are the guiding factors in determining persistence.

Visibility

This is the ability to detect the target first and keep it in continuous view or surveillance either electronically or visually and is more applicable to interceptors designed for operations well beyond visual range. For air superiority fighters, however, unobscured forward and rear cockpit visibility is vital, specially during close-in combat.

Stealth

Stealth can be defined as the ability of an aircraft to attack a target with the maximum amount of surprise by denying detection till as near the target as possible. This is achieved by reducing the aircraft's visual, radar and infra-red signatures. All the three are minimised by keeping the aircraft small, as well as by the following methods:

- **Visual**. Eliminating smoke trails with and without afterburner, camouflaging appropriate to mission environment, and reducing size, number and visibility of identification marks.

- **Radar.** Avoiding surfaces at right angles to each other (which will limit the number of corner reflections), lessening the number of spikes, shielding engine compressor face, using radar absorbent material and paint, carrying stores internally or conformally, minimising energy emissions from the aircraft's own sensors, and providing effective and comprehensive electronic countermeasures.

- **Infra-red**. Minimising use of afterburner, shielding and/or cooling engine exhaust,and using decoys.

Resilience

This is the ability of a force of aircraft to return repeatedly to the battle area after the first engagement and is directly affected by the number of aircraft available, maintainability, survivability and repairability. Other than for the numbers, which is an imponderable from the design point of view, reliability and maintainability would be the vital factors determining this trait. Survivability in battle would depend on how well its four most vulnerable components (i.e. crew, power plant, fuel and flight control systems) are protected. Threat awareness on the part of the crew is the first line of defence and this can be improved by all-aspect detectors and the use of head-up displays in the battle zone.

Costs

From being a fairly cheap instrument of war, the fighter aircraft has now become the most expensive military hardware. The escalation of cost began with the rapid increase in the performance of the aircraft soon after World War II, which necessitated incorporation of elaborate and expensive avionics to ensure an acceptable level of target detection and weapon lethality. The aircraft of today have become larger and more expensive because of the need for complex systems to be embedded, as well as the incumbent need for them to stay in service for much longer. For example, the cost of engines alone, excluding inflation, between 1950 and 1973 increased such that cost per pound of thrust doubled. This dire situation has made procurement agencies around the world insist that cost be given equal weightage as aircraft performance.

CONCLUSION

With increasing unit cost and reducing availability of resources to spend on new equipment, the numbers of aircraft in the world's armed forces have declined radically and service life of most aircraft types has been extended. At present there is more technology available than can be included in any single aircraft, if cost is to remain within bounds. This has meant that the philosophy of fighter design, which was 'doing what can be done' in the 1950s and 'doing what should be done' in the 1970s, has today been replaced by a more pragmatic 'doing what can be afforded'. There are various suggestions as a way out of this quandary, like making everything else subordinate to cost or increasing service life to ensure adequately long (both in terms of time and quantity) production lines, but the only certain thing about the coming generation of fighters is the fact that they will have to do everything of which the current generation is capable, but better and that too at a comparable overall program cost.

PAPER 10

Tailless Designs for Combat Aircraft

INTRODUCTION

Combat aircraft design teams across the world are showing strong interest in the new concept of tailless combat aircraft, both manned and unmanned. The anticipated benefits of cost, range and radar signature are considered high enough to warrant the development and installation of extremely complicated flying controls. Alternatives to ensure that adequate directional control is maintained are still in the conceptual stage and manufacturers are experimenting with a variety of methods. Thrust vectoring would contribute greatly to the eradication of the problem, but aerodynamic controls are also needed, particularly at high speeds. However, aerospace industry researchers believe that they are close enough to solving the problem of effective controls and are now seriously testing concepts for a tailless supersonic fighter and unmanned attack aircraft.

Lockheed Martin Tactical Air Systems (LMTAS) is deeply involved in research on both adaptive flight controls and tailless aircraft designs. They have conducted wind tunnel tests of a tailless supersonic fighter design and have proposed the modification of the experimental F-16XL (described later) into a tailless delta wing aircraft. Developments are simultaneously taking place in sophisticated computer algorithms to control the flight of tailless or damaged aircraft.

Pros and Cons

Advantages. Tailless designs have certain inherent advantages:

- The decrease in cost would be a direct benefit of reduction in overall weight, as compared to a conventional aircraft.

- Drag would reduce considerably and so a given amount of fuel would take the aircraft further.

- Stresses on the airframe would be reduced so that life-cycle maintenance costs would drop.

- The design would have lesser radar reflectivity, allowing it to get closer to a target without being detected.

Disadvantages. The main disadvantage is that the designers would have to find new ways to manoeuvre the aircraft, which means developing more complicated flight control systems, along with sophisticated computer algorithms to run them. Proposals to retrofit existing fighters are being rejected because it is felt that the benefits of a tailless design should be built into an aircraft from the start. It is also seen that no significant improvements in radar reflectivity can be achieved when modifying non-stealth designs.

INNOVATIONS IN FLIGHT CONTROL SYSTEMS

Adaptive Flight Controls

The futuristic work on tailless designs is benefiting from research into adaptive or self-repairing flight control systems that compensate for battle damage to high-performance aircraft. The adaptive system enables the flight control computer to make instantaneous adjustments if the effectiveness of an aircraft's control surfaces changes due to failure or losing part of the airframe. This advanced control system has been tested in a series of flights conducted on the NF-16D Variable Inflight Stability Test Aircraft (VISTA). These tests were successful enough to warrant more tests focused on applications to future aircraft. This follow-on work, a project called 'Restore' (Reconfigurable Systems for Tailless Fighter Aircraft), will be conducted on much more demanding tailless supersonic fighter configurations. The concept is exploring design flexibility for different configurations. The tailless technology is developing rather rapidly and could be in use on a variety of airframes by 2010 and LMTAS expects to incorporate adaptive controls in aircraft with or without tails much sooner than that.

Restore. The programme is slated to run for three years, culminating in a piloted, real-time simulation. The objective of Restore is to develop a system that continuously measures and adapts control gains to overcome battle damage and mechanical failures as well as normal changes in aircraft configuration. This adaptive control technology is also being applied to tailless fighter configurations, which inherently involve numerous coupled, non-linear control surfaces.

Other applications of adaptive flight controls envisioned by researchers include providing corrections for other unforeseen changes in aircraft behaviour due to icing, manoeuvre outside the aircraft's designed flight envelope and non-symmetrical carriage of weapons and external loads. This work is also complementary to other futuristic projects discussed in the US Scientific Advisory Board's *New World Vistas* publication, including smart structures. Smart or active structures use innovative technologies that could deform the shape of the airfoil's skin to control the flow of air around the aircraft. This would allow the designers to move away from the traditional hinged controls. It also would reduce radar reflections from the gaps between control surfaces. The adaptive control algorithms are expected to work just as well for these types of control surfaces.

Innovative Control Effectors

The second tailless aircraft programme is called ICE, for Innovative Control Effectors, which is beginning its second phase of refining the configuration through wind tunnel testing. The idea is to design innovative control surfaces, which would provide high manoeuvrability to aircraft without tails. Researchers are also looking at the impact of those controls on weight, drag, hydraulic power requirements, low observability and maintenance. The main aerodynamic challenge is creating enough yaw moment to control a tailless configuration through agile fighter manoeuvres. The Northrop B-2 bomber is the only known operational tailless aircraft and it uses split ailerons to create yaw, a technique dating back to 1940. But this has been rejected in the ICE programme because there is not enough room in a thin supersonic wing to fit the powerful actuators necessary for fighter manoeuvrability.

ICE started with six trade study concepts and evaluated their weight, radar signature, hydraulic power required and other parameters. Air Force configurations have 65-degree leading edge sweep, are single-engined and have a fighter or fighter/attack role. The Navy configuration has been defined using a canard and a diamond wing planform with less sweepback for lower aircraft carrier approach speeds. There were three critical flight conditions that sized the control surfaces for both the configurations:

- Roll performance at 30 degree angle of attack (AOA).
- Excellent Level One handling qualities during approach and landing.
- Roll performance at 300 kt while pulling Gs, where thrust vectoring has limited effectiveness.

All-Moving Wingtip. An all-moving wingtip is one of the controls chosen for the second phase of ICE. It is mainly used to create drag at the tip to yaw the aircraft, but it also creates non-linear roll and pitch forces. These forces can be difficult to master—for example, the rolling moment actually reverses direction as the AOA changes.

- **Low AOA.** The wingtips are only moved in the trailing edge-down sense. At low AOA below 5–10 degree, it produces rolling moment in the conventional sense, i.e. if the right tip deflects trailing edge-down, the aircraft will roll to the left. The control system will neutralise the roll by deflecting the left elevon down and the other trailing edge surface will deflect to stop the aircraft from pitching down. The net effect is that the aircraft will yaw right because the drag from the right wingtip is greater than the drag from the left elevon.

- **High AOA.** But at higher AOA above 10 degree, the same right wingtip deflection will make the aircraft roll right because the airflow separates rapidly and destroys lift. This produces a stronger yawing moment, but now the rest of the flight controls have to reverse themselves to check the roll. Sophisticated flight control software is required to handle these sign reversals.

Thrust Vectoring. Thrust vectoring is a clear choice for tailless control. With reasonable vectoring angles of 15–20 degree, thrust vectoring is very powerful below 200 kt and the aerodynamic surfaces are more efficient at generating control moments above 200–250 kt.

Spoiler Slot Deflector (SSD). The SSD control has a conventional spoiler on the upper wing, paired with an aft hinged deflector on the lower wing that opens to create a slot through the wing. The deflector wants to pop open and mechanically connecting it to the spoiler reduces the hinge moments for the overall device. The SSD has good aerodynamic effects and has been chosen for the ICE second phase. Opening the right SSD reduces lift and creates drag on the right wing, causing a powerful roll and yaw to the right, while pitch effects vary non-linearly. The SSD is a high pay-off surface and produces sufficient yaw and roll at even maximum lift. However, it has two limitations:

- It severely influences the downstream elevons and can even cause them to reverse and so requires sophisticated flight control software to control it.

- The SSD cuts an opening through the load-bearing structure.

Leading Edge Flaps (LEFs). LEFs work in an area that is dominated by vortex flow and are most effective at changing leading edge suction in the 20–30 degree pre-stall AOA range. Inboard LEFs are used to control pitch with the aircraft pitching down when they are deflected down. Outboard LEFs control roll and yaw. Deflecting the right one down will make the aircraft yaw left and roll right. This effect is variable and can also reverse.

The elevon works in a conventional sense but produces more adverse yaw than normal because of the side force from the aft-swept hinge line, located on a long moment arm from the centre of gravity. This adverse roll is countered by raising the associated spoiler. The inboard pitch flap is used for pitch only and can generate large moments. Tailless aircraft work well with inboard and outboard surfaces to split pitch and roll functions, which reduces the chance that activity on one axis will saturate the other. A spoiler on the wing lower surface acted like a flap and increased lift at lower AOA but produced a strong roll in the opposite direction at higher AOA, and so was abandoned. Similarly, a deployable rudder was also found to give marginal control moments and is not included in the second phase. At the conclusion of the first phase of tests, two aircraft configurations were selected for the second phase—one that includes the SSD and the other with all-moving wingtips. This phase of the ICE will refine the designs in greater detail. More wind tunnel and rotary balance tests to ascertain spin characteristics will also be carried out.

F-16XL AS THE TAILLESS TEST PLATFORM

LMTAS has studied converting the F-19XL research aircraft into a tailless demonstrator, but the modification has not been conducted due to lack of funds. The study examined removing the vertical tail and providing directional control with a thrust-vectoring engine and a new wing featuring all-moving wingtips and high-rate leading edge flaps. The new wing was based on the ICE studies and would have brought the ICE beyond wind tunnel models into flight tests. As a lower cost alternative, retention of the wing and modification of only the ailerons are also being considered. The benefits of a tailless F-16XL would be, a weight and drag reduction and a lower, stealthier radar cross-section, with agility that matched the standard F-16 fighter without angle of attack limitations.

Although the tailless drone X-36, which is a 28 per cent sub-scale model, has flown, the F-16XL would have been manned, full-scale and supersonic, and would complement rather than compete with the drone trials. The high speeds would also study how control power suffers due to structural elasticity. The F-16XL was to be powered by the thrust-vectoring version of the Pratt & Whitney F100-PW-229 engine, which is being used in NASA's F-15 Active Programme. However, the study also felt that an all-new wing would have made it easier to test the ICE concepts as it would have been a tailless design from the outset. The forebody of the F-16XL would have made it less directionally stable and also reduced agility, having to utilise portion of the control power for just stability. Simulation of the all-moving wingtip of the ICE was to be achieved by modification of the ailerons.

FLYING WINGS FOR UNMANNED COMBAT

Another Lockheed Martin project is exploring the use of highly manoeuvrable, tailless unmanned aircraft, that could be used for more dangerous wartime missions. Unmanned aerial vehicles have been conducting long endurance reconnaissance missions over hostile territory for years, but these aircraft are designed for stable flight at subsonic speeds. The military is interested in unmanned aircraft that are capable of manoeuvring more violently than manned fighters (which are limited to the pilot's tolerance of maximum 9G), fly at supersonic speeds and take over some of the tough missions like Suppression of Enemy Air Defences (SEAD) and low- altitude high-speed reconnaissance. Researchers feel that this new generation of unmanned aircraft, called Uninhabited Combat Aerial Vehicles (UCAVs), has the potential to be cheaper to produce and operate than manned fighters.

Cost Factor. Although the UCAV would cost more than a fighter to manufacture, it would still be substantially cheaper in the overall cost assessment. Over the life of manned fighter, support costs are 50–60 per cent of total life-cycle costs and it would also take around two million dollars a year to train a pilot. A UCAV operator can be trained purely with the use of a simulator and it is estimated that a 90 per cent reduction in operating costs can be achieved.

Tailless UCAVs have certain inherent benefits:

- Simple construction of a flying wing.
- Efficient low-drag aerodynamics.
- Ease of engine integration.
- Natural low observability of the design.

Utilisation. Although the UCAVs are still in the conceptual stage, their probable utilisation and operational employment are already being discussed. Their integration into the theatre of operation would have to be carefully planned, after the employment doctrine has been adequately established.

- **SEAD.** The first application is most likely to be for the destruction of air defences, particularly the most lethal modern surface-to-air missiles. Proliferation of these missiles, particularly in the Middle East, is being predicted by analysts. Notional concepts of operation have the UCAVs flying at the same speed as the manned strike aircraft, but preceding them into defended areas by several minutes. Their dual tasks would be to neutralise known air defence sites (pre-programmed coordinates) and to launch weapons at mobile SAMs that pop up unexpectedly.

- **Fixed Target Attack.** In conjunction with the high-visibility UCAV launching stand-off weapons, a high-speed version would be used to surprise the enemy at close ranges. These radar evading UCAVs would be able to get within a few miles of the target and attack with much greater lethality. They would fly at high speeds—Mach 0.8 to 0.9—and also manoeuvre at very high Gs, if necessary.

- **Theatre Defence.** Two other high profile roles for the UCAV would be theatre ballistic and cruise missile defence. Both these mission require aircraft that can fly very long endurance patrols while monitoring missile launches.

- **Surveillance.** The UCAV would be able to get close to the target and under weather for surveillance and reconnaissance purposes by virtue of its manoeuvrability and high speed.

CONCLUSION

Stealth requirements are driving vertical tails off future fighter designs and every manufacturer is seeking alternatives for powerful directional control. Tailless concepts also simplify construction and lower costs. Adaptive controls have been seen to be capable of handling the quirky nature of tailless designs as well as coping with battle damage. However, the tailless designs would take at least 5–10 years to reach operational capability and, therefore, the needed funding is not readily available for research and development. This may adversely affect the long term prospects of the tailless designs.

The following inferences can be drawn from the above discussion:

- Tailless designs, both for manned and unmanned aircraft, have great advantages in many areas and are also extremely cost-effective in the long term. Although development progress is comparatively slow at present, the concept is likely to take root in aerospace doctrine.

- Operational induction of UCAVs would have wide-ranging effects on air warfare. It can also be surmised that since human life would not be endangered, proliferation of these aircraft/vehicles would accentuate the use of air power in any conflict.

- The main stumbling block is the control of these designs, which is being addressed comprehensively by the aerospace industry and solutions are already being tested.

- The pronounced stealthy characteristics of this design will put a great deal of stress on the current air defence systems, which would be degraded considerably. Therefore, protection of VAs and VPs will pose much more difficulties in future conflicts. It may not be possible to ensure complete all-round protection for them on a continuous basis.

- The current resource crunch that is slowing the development process is seen as a temporary phase and tailless designs can be expected to be operational in the near future.

SECTION IV
WEAPON SYSTEMS

PAPER 11

UNINHABITED AERIAL VEHICLES: THE FUTURE AND IMPACT ON AIR WARFARE

A bird is an instrument working in accordance with mathematical law, which instrument it is within man's capacity to reproduce with all its movements.

Leonardo da Vinci

INTRODUCTION

To meet the challenges posed by greater and lesser conflicts in the era following the end of the Cold War, new tactics, methods and weapons are required. Democratic governments the world over have become more unwilling to incur casualties in overseas operations mounted to counter, what may be, an implausibly remote foreign threat. In addition, the rising cost of modern major weapon systems is leading to what has been called 'structural disarmament' in almost all armed forces. Taken together, the two factors militate towards the use of uninhabited and less expensive systems that will enable the community of nations to demonstrate that it can and will effectively meet armed conflicts. A vital component of such a combat element would be new aerial systems, which would find ready application in conflicts of a limited scale and even for high intensity operations like those of the 1990–91 Gulf War. This situation has changed the sporadic interest in Uninhabited Aerial Vehicles (UAVs) to one of sustained and continued interest in the past decade. However, even though the history of UAVs goes back by almost 90 years and also encompasses several wars, they have not received the attention they deserve in the study of air power.

Much confusion exists regarding the correct terminology to describe the different categories of UAVs that are now flooding the battlefield.[1] UAV still remains the more generic term to denote all uninhabited/unmanned aerial vehicles, but the

[1] Bill Sweetman, 'US Air Force Probes Technological Frontiers', *International Defence Review - Extra*, June 1996, p. 2.

term 'uninhabited' as opposed to 'unmanned' has, in recent times, become a more politically correct word.[2]

DEVELOPMENTAL HISTORY

The ability to steer a flying machine without the hands-on attention of an onboard pilot was demonstrated when the world's first automatic pilot was tested in a Curtiss biplane in 1913. During World War I, Briton, Germany and the United States undertook experimental development of the concept of uninhabited aerial vehicles, albeit with extremely limited success.

The first really successful UAV was a radio-controlled Remotely Piloted Vehicle (RPV), which was used by the Royal Navy as a target drone for shipborne anti-aircraft firing practice during the inter-war period. Simultaneously, the same developments were taking place in the United States and at the outbreak of World War II, large quantities of these targets had been manufactured on both sides of the Atlantic.

World War II. The concept of attack drones gained validity during World War II, the best remembered example being Germany's V-1 flying bomb and 'Misteln' pickaback composite aircraft. Less well known is the Interstate TDR-1, an expendable UAV with a 2000 lb (907 kg) warhead, which was used with some success in the Russell Islands campaign in 1944, guided by TBM Avenger aircraft.[3] Other UAV experiments involved the droning of aircraft as large as the B-17 and PB4Y four-engined bombers, primarily as explosive carrying expendable UAVs. They were, in effect, primitive guided weapons: there is even today only a very fine line of distinction between a guided missile and an expendable UAV.

Post War. After the end of World War II, all energy was channelled for the development of guided missiles, and the interest in the UAVs was restricted to their usefulness as target aircraft, with limited residual acknowledgement of their potential for reconnaissance. The loss of a U-2 and its pilot to a Cuban SAM

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[2] The term 'unmanned' would mean that there is no human in the loop, leading to a fully autonomous vehicle/system that is capable of making decisions on its own. Whereas 'uninhabited' would mean a system that does not carry human beings within itself, but is controlled by humans who make the decisions.

[3] Kenneth Munson, 'Pilotless Pimpernels', *Air International*, February 1992, p. 80.

provided the impetus to get the Teledyne Ryan 147 (AQM-34) subsonic aerial target modified to carry reconnaissance payloads.

Vietnam. The original AQM-34 was the prototype from which a huge family of multi-capable UAVs for high, low and medium altitude photographic and video reconnaissance, COMINT, ELINT, ECM, decoy, leaflet dropping and damage assessment missions eventually grew during the Vietnam War. These UAVs had a very successful record in Vietnam. From 3435 sorties flown between August 1964 and June 1975, more than 83 per cent of the drones returned safely and in the final four years of that period, the recovery rate was well over 90 per cent. By the end of the Vietnam War the Ryan drones had conclusively demonstrated that RPVs could deliver the goods, were highly survivable, put no human crew at risk and were far cheaper than fielding manned aircraft. Although their potential at least in the reconnaissance role was appreciated, surprisingly the interest in this potential of UAVs diminished to a point where no significant development was even considered.

Middle East. The focus on RPV/UAV activity has thereafter been in the Middle East. In 1972–73 Israel acquired the first of these vehicles for use as decoy drones and high altitude reconnaissance platforms. These proved their worth in the 1973 Yom Kippur War and Israel was convinced about the value of the tactical UAV to the point where they are now the world leaders in this field. Four generations of UAVs have already been produced by Israel. First-generation UAVs (Mastifs and Scouts), in the role of decoys and expendable attack drones, were able to expose and destroy Syrian gun and missile batteries in the Beka'a valley in 1982 to such effect that not a single pilot from the subsequent manned aircraft attack force was lost. The campaign was a perfect illustration of the UAV's value as a force multiplier, making the best combined use of both manned and unmanned aircraft.

Gulf War. Time and again the effectiveness of UAVs had been demonstrated, but their utility continued to be underplayed and over looked up to the beginning of the Gulf War. In the early stages of the predominantly air war, decoys such as Chukar and TALD were deployed to 'switch on' Iraqi radar, enabling them to be located and destroyed by anti-radar missiles from attack aircraft. Reconnaissance/surveillance types like Pioneer and MART supplied a superb degree of real-time and other battlefield intelligence, as well as designating targets and directing and correcting artillery fire. Overall system availability throughout the campaign exceeded 90 per cent and losses due to direct enemy action were very few.

UAVs have finally come of age. To exploit their capabilities further, the US has set up a series of demonstrations to assist in establishing the requirements and operational concepts of UAVs. These were called Tiers and their results have provided insight into the multifarious advantages that accrue with the deployment of UAVs.

DESIGN CHALLENGES

UAVs are now becoming universally accepted and adopted and the market has expanded sixfold in the five years between 1993 and 1998, The demand is for short range UAVs followed by high altitude and long endurance versions. A host of new applications are opening to the UAVs beyond the traditional reconnaissance or surveillance missions. UAVs have already shown their utility in electronic warfare as airborne jammers, decoys and emitter-locators. Future roles will include anti-radar hard kill, communications relay, pre-launch and boost-phase TBM (Tactical Ballistic Missile) targeting and kill, and both lethal and non-lethal submunition dispensing.

Despite tremendous progress, though, there still remains a gap between user expectations and actual system performance, indicative of the inherent physical constraints of small robotic aircraft as opposed to larger manned equipment. The design challenges in UAV development are numerous, and may be grouped under issues relating to airframes, propulsion, data links and payload.

Airframe

Small, lightweight UAVs are unstable in bad weather, strong crosswinds and gusts. This not only decreases the endurance but can also adversely affect the sensor payload and the air-vehicle electronics. Payload miniaturisation and solid-state navigation systems have decreased the pressures on airframe design to some extent. Conventional designs modified with side-force generators greatly decreases sensitivity to gusts and allows flat turns to be made. Flat turn flight manoeuvres can eliminate the need for sophisticated and expensive stabilised gimballed sensors. A stable flight profile also results in range and endurance benefits.

Other airframe aspects are more problematic. Drag to weight ratio increases as the mass of the aircraft reduces and unless it can be compensated with a big power to weight ratio, the UAV is likely to have a lower speed and range for a given fuel fraction as compared to a larger and heavier aircraft.

Propulsion

Most current UAVs use gasoline powered engines. Manufacturers are now looking for advances in their adaptation for heavy fuel usage. The desire to move to more non-volatile fuels further complicates the need to have as high a power to weight ratio as possible because the use of heavy fuels often incurs a performance penalty in internal combustion engines. The requirement therefore, is to modify the existing gasoline driven engines to run on heavy fuels with little or no power loss and with reasonable fuel economy. Research is being actively pursued in this field with the aim of increasing the cylinder pressure above that of the mechanical compression ratio by new electronic fuel ignition methods.

Data links

Secure and reliable data links between UAV and ground stations are still not a foolproof set up. Disruption in data link can easily occur, either intentionally or accidentally, and current transmission bandwidths can be limiting in the speed and quality of data received. IFF systems are also not without flaw and could become an issue as the use of UAVs progressively increases. Designing reliable, robust and capable data links still remains one of the greatest challenges and data links could be termed the 'Achilles heel' of the UAV. Of the 36 UAVs lost by the US during the Gulf War, only one was lost to enemy fire. However, 11 were lost and 10 more damaged due to hardware failure. A comprehensive UAV system failure study places data link a close third, behind gyros and Flight Control System (FCS) components, as having the highest probability of failure leading to catastrophic loss.

Advances in navigation systems and more robust rate sensors that can stand the rigours of UAV flight and have increased reliability, offer a vast increase in the capability of the UAV at an economical price. Most current UAV systems use broad-beam transmission with omnidirectional antennae, which while being simple to capture, is also extremely vulnerable to jamming. The use of super high frequencies necessitating the use of directional antennae, data encryption and spectrum spreading transmission techniques will further enhance reliability.

The general desire to receive information in real time means that the data rates must increase. It is also necessary to exploit different technologies other than datalinks (which are essentially line-of-sight operations) if UAVs are to have a true over the horizon capability. One method that is being tried out is the use of relays to get around the LOS constraints, but it complicates the control situation since two or more UAVs must be monitored and guided. Long-range reconnaissance drones use pre-programmed flight profiles with data being transmitted only on the return leg of the flight or recorded for later manual retrieval. However, this defeats the capability to have real-time information available to the commander. It is likely that more autonomous UAVs based on artificial intelligence techniques, such as neutral networks will soon emerge. In future, self-cueing, intelligent sensors will focus on targets of interest and direct the UAV to loiter over the area if necessary.

Payload

The miniaturisation of electro-optic, infra-red and radar sensors is a boon to UAV applications. Smaller, lighter but more powerful warheads also will allow greater arming of UAVs. However, it is also necessary to design the ground stations to be rugged, reliable and user friendly. Better man-machine interface would ease training requirements and speed dissemination of targeting and reconnaissance data. With the increase in the automation of the UAV, it is becoming necessary to have onboard systems that do not directly contribute to the mission requirements but add to the overall all up weight. This puts a constraint on the actual payload carrying capacity of the UAV. While integrating payloads into UAVs, a variety of factors like size, weight and power requirements also have to be carefully considered.

OPERATIONAL EMPLOYMENT

Although UAVs are being used by a large number of countries, only one or two nations can boast of a unified UAV effort with the aim of defining the basic doctrine for their optimum application under conditions of war. The major thrust of developments involves requirements for two major combat realms–range and endurance. The range could be termed close, short and medium.[4]

These are the two areas in the operational spheres within which further developments and refinements will take place. Close range would mean a radius of action of around 50 km, short range possibly 150 km and medium range 650 km. Endurance systems will have a much greater distance and time aloft. Differences in operating speeds are also great–varying from 90 kt to 0.9 Mach. The close range systems will not have to be in the air for more than three hours, while the Endurance system is set to last a minimum of 24 hours.

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[4] The US Armed Forces has combined all UAV programmes under a Joint Program Office (JPO) which has crafted ‘The UAV Master Plan.’ This is meant to remain as the baseline for future needs of UAV requirements..

Interoperability of Sub-systems. Even though the performance of the different types of UAVs is very varied, the commonality and interoperability of tactical subsystems, components and parts are great. The mission sensor package, fusing a large number of items (FLIR. SIGINT, ECM, etc.) along with near real-time data link, finds application on a range of UAV platforms suited to different range and endurance criteria.

Mission Packages. The UAV mission package and the range of possibilities make it look as if the battlefield commander could survive with little else. There are mission packages for: [5]

- Reconnaissance and Surveillance (R&S)
- Sigint, ECM and decoy
- Air-to-Ground weapon strikes
- NBC and mine hunting
- Meteorology, mapping and navigation
- Limited close-in anti-missile defence
- Information relay via data link
- Forward logistic deliveries, search and rescue
- Training target drone activities

UAVs in Low Intensity Conflicts

The dramatic political changes in the Soviet Union, combined with global peace efforts, have redefined the role of the military all over the world. Defence forces are being forced to accept large budgetary cuts while being prodded on to taking on a host of non-traditional missions. This has necessitated the refocusing of its resources and attention to address adequately these Low Intensity Conflict (LIC) missions. There is often a mistaken presumption that scaling down of the systems and technology that cater to major conflagrations would be sufficient to cope with LIC. While some of the equipment may be useful, real-life experiences have shown the need to have special resources to be involved effectively in LIC. UAVs are now being increasingly viewed as a cost-effective approach to accomplishing highly lethal or politically sensitive LIC missions.

Advantages. There are several reasons why UAVs may be more appropriate for certain LIC missions than manned aircraft.

- With the availability of sophisticated yet inexpensive weaponry, such as shoulder-launched SAMs, Third World nations and even small guerrilla bands pose a

[5] T Marvin Leibstone, 'US Unmanned Air Vehicles', *Military Technology,* September 1992, p. 29.

significant threat to major weapon systems. Therefore, employing mega-million dollar manned aircraft, which may even cost more than the entire operating budget of the organisation against which they are being used, is a no-win situation. Low cost UAVs provide a more cost-effective solution.

- The interrelated risks of loss of life, aircraft and political dignity may far outweigh any benefits derived from utilising a manned aircraft for certain LIC missions. The consequences would be less profound if only unmanned aircraft were lost. At the far end, UAVs have the additional advantage of enabling the operators to claim non-attribution, especially with the universality of marketing of UAVs prevalent today.

- Some of the UAVs are so small and compact that they are man portable and so are capable of furnishing over-the-hill type intelligence to even a small group of soldiers. In effect, they provide dedicated and indigenous air support to individuals or small groups performing special operations.

It is perceived that UAVs have a very large role to play in a brave new world. The global military budget crunch is being viewed as positive for the future development of UAVs, in that they are low cost and remove personnel from dangerous missions.

Maritime UAVs

> *Remotely piloted vehicles proved to be marvellous, versatile devices. They allowed the battleships to attack the enemy on their own, without the need for outside assistance in spotting. Spotting by the RPVs not only allowed for accurate naval gunfire support but also provided instant battle damage assessment.*
>
> Vice Admiral Stanley R. Arthur
> Commander US Naval Forces
> Operation *Desert Storm*

During Operation *Desert Storm*, UAVs operating from USS *Wisconsin* and USS *Missouri* flew 163 sorties over occupied Kuwait, totalling 553 hours. They contributed so much to the performance of the Navy that Vice Admiral Arthur calls it, 'the first occasion in the history of warfare for human beings to capitulate to a robot.'[6] It is anticipated that in the expanding role the Navy has started playing in the area of power projection, naval vessels will often sail into hostile waters

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[6] Steve Shaker, 'Saving Life, Limb - and Face - with Robotic Fighters', *Defence & Diplomacy*, October/November 1991, p. 56.

without the comforting backup of aircraft carriers and associated air support. Some naval strategists, therefore, recommend that all major vessels have their own indigenous air assets. The use of UAVs would be the best, most economical way to accomplish this.

The following missions are being considered for maritime UAVs:

- **Ocean/Land Reconnaissance and Surveillance.** UAVs could conduct real-time reconnaissance and surveillance missions, furnishing intelligence, threat warning and assessment information to the tactical commander.

- **NBC Warfare Surveillance.** UAVs could perform remote observation and atmospheric sampling to see if NBC contaminants are present, what their consistency is and what areas are contaminated.

- **Meteorological Reconnaissance.** UAVs could conduct remote weather observations and meteorologic/oceanographic measurements to support current or planned military operations. Remote observations and measurements include temperature, barometric pressure, humidity, visibility, wind velocity and direction, oceanographic conditions and sound velocity conditions.

- **Disruption and Deception.** UAVs can emit false signatures and disrupt enemy forces. False emissions can mislead enemy intelligence and can cause them to take action contrary to their best tactical interests. Decoy UAVs can also draw missiles away from high-value targets. Jamming UAVs can prevent the enemy's use of the electromagnetic spectrum and deny them the use of radar, communications and other C3 resources.

- **C3 Relay.** The real-time relay of voice, video, telemetry and other data can be performed by UAVs, furnishing the Battle Group/SAG commander with good communications and intelligence links with individual unit commanders. High altitude Long Endurance (HALE) UAVs can also fill the communications gaps if satellite communications are disrupted.

- **Target Acquisition/Spotting.** UAVs can give real-time target acquisition data to the BG/SAG commander for identification, evaluation and weapons designation. The UAVs can also pinpoint precise locations for the initial placement of naval gunfire and anti-ship and ground missile attack.

Advocates of large aircraft carriers with their complement of high performance conventional manned aircraft have often been pitted against the proponents of trading a few super carriers for numerous mini-carriers outfits with VTOL aircraft. Perhaps the best solution would be a navy with an optimal mix of super carriers and numerous mini-carriers with VTOL UAVs operating off frigates and cruisers.

Disadvantages

It is admitted that UAVs have unlimited uses, some of which have not yet crystallised completely. In theory, there is little reason to doubt the ability of the UAVs to perform all the functions described and discussed in detail above. In practice however, certain inherent difficulties are still to be eliminated.

- **Scenario Dependence.** UAVs are, by necessity, of light construction affording limited protection. Therefore, in dense combat environments they are extremely vulnerable to enemy weapons and electronic warfare systems. In other words UAVs are more scenario dependent than other airborne systems and so there are constraints to their utilisation. On the other hand, the alternative solution to a UAV–the manned aircraft–can operate effectively within a very wide spectrum of situations. The UAVs, at best, complement the manned aircraft mission, at least in their present state of development.

- **Survivability.** One area of debate within the UAV community is the need for self protection. Almost all UAV missions will take the vehicles into high threat environments for extended periods of time. A necessarily large RCS further aggravates the threat to the modern UAVs. While a higher rate of attrition as compared to the manned aircraft is acceptable for UAVs, they are not designed to be one-mission, throwaway resources. Therefore, cost-effectiveness and survivability are interlinked and form one of the major decisive factors in the doctrinal development of UAVs. The mission requirements of the UAVs are so varied that each of them has adopted its own approach to survivability, ranging from high altitude operations to reliance on stealth technology. However, survivability remains a major cause for concern in UAV operations. The risk of air vehicle loss goes against making the UAV itself more complex and sophisticated and yet unsophisticated UAVs often mean higher costs to obtain/achieve the same result. This paradox weakens the main argument–that of cost-effectiveness–for increased UAV operations.

- **IFF**. One of the obvious disadvantages that still remains a hurdle in the acceptance of UAVs for expanded roles by force planners is the issue of IFF and ‘friendly fire’ kills. More sophisticated UAVs, especially those that are weaponised, place a far greater onus on operational responsibility. If the issue of IFF has still not been completely resolved for the manned systems, it is doubly apparent in robotic vehicle operations.[7] Therefore, the introduction of smart, lethal UAVs into the operational scenario is likely to be cautious at best, despite the demonstrated potential.

- **Jamming.** In the C4I field, when UAVs are being used as communication relays, they are susceptible to jamming. This necessitates the use of modern cryptotechnology that is not only expensive, but needs heavy equipment and so compromises on the payload carrying capacity. Even in communications between two high-flying aircraft (for example, at 12 km and 20 km respectively) jamming via the side lobes is possible with a powerful enough transmitter. The answer to this problem would perhaps lie in the use of laser communication links (which may be possible because of the high operational altitude) which have much shorter wavelength and so are much harder to intercept.

FUTURE CONCEPT

The art of warfare is constantly being altered and refined to include both radical and conservative ideas that are spawned by the introduction of new challenges as well as changed geo-strategic perceptions and the forming of political alliances. What remains constant in this ever-changing scenario is the need to update continuously the available armament and optimise its use while keeping within budgetary constraints. A vital component of such an arsenal would be new aerial systems that would find ready and common application in both limited and high intensity conflicts.

The concept is to have aircraft that are ultralight, high-flying and unmanned, capable of loitering for several days in loop patterns over predetermined sectors at altitudes in excess of 20 km. At this height, only the most modern air defence missiles and high-performance aircraft would present a threat to the UAVs. The incorporation of stealth and defensive EW would greatly enhance their survivability.

The concept envisages two main types of long range/high endurance UAVs:

[7] Clifford Beal, 'UAV Development: The Art of Compromise', *International Defence Review,* May 1993, p. 383.

- a large platform able to carry a heavy multi-sensor package for reconnaissance and targeting; and
- a fleet of smaller UAVs carrying a variety of munitions that cover both air defence and air-to-ground roles.

The larger craft would continuously scan nominated large areas with a variety of sensor suites that would ensure all-weather day and night capabilities. It is expected that sensors designed for space-based applications would find useful utilisation in these UAVs. The smaller UAVs in the team would be equipped with higher resolution sensor suites designed to follow up on the cues handed over by the larger platform that would designate a target and track the munitions launched against it.

Possible Tasks

The major tasks these UAV packages could fulfil are enumerated below:

- **Reconnaissance**. With modern cameras and sensor suites, both optical and radar, and the ability to loiter over a designated area for days, they could provide continuous and real-time intelligence as opposed to the 'snapshot' coverage of the satellites and high-flying manned aircraft. A system that could provide onboard interpretation and analysis is also under development and testing, and would greatly improve the performance of the system.

- **Communications.** Although satellite communications are already widespread, these aircraft could function as retransmission hubs for coded voice traffic and other critical data, without requiring even the smallest of antennae that are necessary now. This would be a great advantage to forces operating behind enemy lines and on other clandestine operations. They platforms could also jam hostile communication links or confuse the enemy with erroneous information.

- **Counter force.** The UAVs can be equipped with air-to-ground and air-to-air armaments and used as attack platforms. Although the load would be smaller as compared to a high-performance fighter bomber, it would be far cheaper and cost-effective since an expensively trained pilot would not be part of the system. Almost any ordnance in use today could be deployed and the choice will only depend on the target and other considerations like proximity to populated areas etc. The element of surprise can also be maintained as the loiter capability of the system is immense and weapon release can be done at any time and at any target within the ambit of the platform. The great height at which they operate would mean that it can be thought of as a vertical attack system, less vulnerable than a cruise missile or manned aircraft, which attack horizontally.

- **C4I.** Although the UAVs cannot be used as a command and control asset, they can be used as relay posts. This would be indispensable in situations wherein manned systems can not be deployed in the stand-off mode because of prevalent local conditions. A large platform escorted by several smaller UAVs with adequate air defence weaponry and capabilities will be able to cover an entire theatre of operation. This would almost nullify the need to send manned reconnaissance flights for deep penetration flights and would also provide excellent post-strike damage monitoring capability.

CONCLUSION

It is becoming increasingly difficult for governments across the world to sustain any operation that results in own casualties. Under these circumstances the employment of UAVs in missions that are considered 'high risk' is an attractive proposition. UAVs have been developed for a number of years starting almost with the advent of heavier-than-air flight. However, its efficacy as a force multiplier was proved conclusively during the 1973 Arab-Israeli conflict.

Although UAVs are now being commonly used, they still face a number of design challenges, mainly in propulsion, data link reliability and carriage of adequate payload. However, the missions that they could undertake efficiently cover almost the entire gamut of air operations. Of particular interest is their potential to be highly effective in low intensity conflicts wherein the demarcation between adversary and neutral/friendly assets is not very clear. There is also a great deal of interest and development taking place in the use of UAVs in maritime missions.

This is not to suggest that UAVs are the panacea of all operational disadvantages of manned aircraft. There are still a number of issues which need to be solved comprehensively before UAVs can be said to have come of age.

PAPER 12

Uninhabited Combat Aerial Vehicles:

Leaving the Pilot on the Ground

INTRODUCTION

Almost all the major air forces of the world are now examining UAVs for a variety of roles including attack and reconnaissance. It is felt that this would give them a technical edge in future conflicts and even in peacekeeping operations. Active consideration of incorporating UAVs in a force, till now dedicated to manned combat aircraft, mirrors the research activity in the field and UAVs are now being seen as complementary–and in some cases, alternative–platforms to aircraft. The concepts and developments discussed subsequently have universal applicability in their impact on the future of air warfare and the employment of air power as a whole.

The concept of employment of UCAVs is mainly based on three vital goals:

- Cutting down the production and operating cost of combat aircraft.
- Eliminating the need to have long-range attack weapons.
- Minimising the risk to aircrew.

The cruise missile (used extensively in the 1991 Gulf War), offers only a partial solution to the need to strike targets without risking pilot loss, since a million dollar airframe is destroyed every time a cruise missile is launched. Manned fighters on the other hand can deliver bombs and missiles at a much lower cost per pound of payload. UCAVs have a cost-effectiveness 'niche' that falls between the cruise missiles and manned fighters, and in several areas actually outperforms the manned fighters.

New World Vistas–Air & Space Power for the 21st Century, a study prepared by the USAF's Scientific Advisory Board (SAB), outlines a 21st century force that can detect and track targets worldwide, communicate target information among all its platforms and weapons, deploy itself in full strength by air and use survivable, responsive systems to attack targets promptly and at high sortie rates. The study identifies three specific classes of air vehicles that are very different from anything flying today.[1]

- Uninhabited Combat Aerial Vehicles (UCAVs), where 'Uninhabited' denotes a new generation of vehicles that combine the advantages of piloted and pilotless systems and are more effective than either.

- An advanced strategic air lifter, capable of transporting at least 70 tons over a distance of 20,000 km—that is between any two points in the world—without refuelling.

- Hypersonic vehicles–mostly uninhabited–with speeds in the March 12—15 regime, but also capable of decelerating to lower speeds for weapon release.

> *The 'uninhabited' combat aircraft (UCAV) are new, high performance aircraft that are more effective for particular missions than are their inhabited counterparts. The UCAV is enabled by information technologies, but it enables the use of aircraft and weapon technologies that can not be used in an aircraft that contains a human. There will be missions during the next three decades that will benefit from having a human present, but for many missions the uninhabited aircraft will provide capabilities far superior to those of its inhabited cousins.*
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> New World Vistas–Air and Space Power for the 21st Century, Summary Volume, Chapter 1 Technologies for Arming the Air Force of the 21st Century, para 3.0 The Future Force.

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[1] Nick Cook, 'Leaving the Pilot on the *Ground', Jane's Defence Week,* 03 July 1996, p. 34.

ADVANTAGES

The decision to develop an aircraft that would leave the pilot outside the aircraft penetrating enemy airspace while still retaining control over it would bring about major cost-saving design changes to combat aircraft. There are three major advantages in employing UCAVs.

- **Cost Saving.** Great cost and weight savings come from the removal of the cockpit and associated environmental and safety equipment. In addition the aircrew is removed from the dangers of penetrating well-defended enemy air space. The removal of the pilot also facilitates positioning of the engine to adhere to the principles of stealth technology and this minimises RCS. Designed from the outset for a short flying life, with less system redundancy than a manned aircraft, the UCAV effectively combines low cost and high performance.

- **Sensor Packages.** The UCAV can be equipped with slimmed down onboard sensor packages that can relay partially analysed data through an 'electronic tether' to the controlling agency (airborne or on the ground), thereby avoiding large displays, computers and other pilot cueing devices.

- **Electronic Silence.** The combination of off-board sensing of enemy targets, low observability in design and the low probability of intercept of the UCAV's weapons allows them to operate in virtual electronic silence. The UCAV would rely on the inputs from outside sources to strike targets with little or no warning.

- **Flexibility.** The UCAV also offers flexibility. With lower budgets and smaller ordnance production rates, air forces will be less and less able to afford stockpiles of specialised stand-off weapons to attack different targets. The UCAV will be able to attack even heavily defended targets with short range, simple weapons, which can be stockpiled and delivered to the theatre in large quantities.

- **Strike Capability.** By virtue of its capability for long endurance at high altitudes, the UCAV permits low cost unpowered weapons to achieve the same stand-off range as much more sophisticated and costlier powered weapons. It is also possible to utilise the UCAV to attack with precision guided munitions from very high altitude.

- **Manoeuvrability.** The absence of a crew ensures that the limits of manoeuvring imposed are those of technology rather than human physiology. Even today's aircraft technology would permit a 20G design, whereas a pilot in a modern fighter is restricted to a maximum of 10G because of the effects of G-induced loss of consciousness. In conventional attacks, the UCAV, through aggressive manoeuvring, could out-turn defensive fighters and even their missile armament.

Prerequisites

Data Handling Capacity. Crucial to the UCAV design will be the ability to receive and transmit large amounts of data at extremely high rates. In fact it is the ability to deal with high data rates that distinguishes unmanned combat aircraft from the more sophisticated cruise missiles. It is therefore, necessary to integrate the aerial battlespace with an advanced C3I concept to ensure optimum utilisation of the UCAV.

Off-Board Sensing. Another unavoidable necessity for the use of technologically superior but less expensive UCAVs will be the ability to use off-board sensing. Even manned fighter and strike aircraft costs are being reduced by eliminating expensive onboard sensors and processors. In the case of the UCAV it will be crucial to have the target data collected by satellites, ground radars and airborne sensors, filtered and analysed by AWACS and then fed to the UCAV.

Target Identification. In order to exploit fully the UCAV, it should have the capability to identify targets autonomously. This requires an automatic or aided target recognition system with a very low false alarm rate. It is felt that the most effective location for this system would be the centralised analysis site within the theatre of operation and not with individual aircraft.

Data Transmission. The ability to move large amounts of data between platforms would be crucial for total battlefield awareness. Extensive movement of data could be accomplished by the development and use of phased array antennas that can handle large swaths of bandwidth.

IMPACT ON AIR WARFARE

> *An effective UCAV will be enabled in the next century as the result of the simultaneous optimisation of information flow, aircraft performance and mission effectiveness. The UCAV will not completely replace the inhabited aircraft for decades, if ever, but the presence, or absence, of a pilot is now a design trade that can be made in a logical way.*
>
> New World Vistas
> Air and Space Power for the 21st Century

Although still in the developmental stage, UCAVs will have a profound impact on air warfare and the employment of air power in any future conflict. Many strategic doctrines and tactical assessments will, *per force*, have to be drastically remoulded to encompass the advent of these unique aircraft. While the impact would be obvious almost immediately in the air forces that are already in the forefront of technology, it will percolate down to even the smallest of forces at a rapid rate because of the qualities of flexibility and innovation that are inherent in air power.

Cost-effectiveness. The cost of UCAVs, which could be stored almost like missiles, would be minimal compared to conventional aircraft. Cost-effectiveness accrues not only from removing the pilot from the aircraft but also as a combination of effects of production, storage, operations and training efforts. This reduction in the cost and non-exposure of the crew (which is increasingly becoming politically untenable) would mean that war planners will be more willing to expose the aircraft to risky combat situations. In the current battlefield environment, if the probability of survival is less than 0.98, manned aircraft do not fly. A further fallout of such cost savings would be that even small nations would eventually be able to possess sufficient assets to be able to project air power in a viable fashion, leading to 'small wars' becoming increasingly more devastating. The extremely low observability of the UCAV will result in the reduction of stand-off distance at the weapon release point, which will in turn reduce weapon sensor, guidance and propulsion costs.

Target Selection. Currently mobile targets of high value are considered almost safe from aerial interference because of the limited capability of attack aircraft and cruise missiles to keep pace with the rapidity of their movement and deployment. The target set envisioned for the UCAV would include the more difficult moving, mobile and unknown or unexpected targets. This ability to attack high-value targets (obviously involving high threat) without fear,while still maintaining the element of surprise,would increase the battlefield flexibility for tactical planners, which had over a period of time been degraded because of the long time of flight and stand-off weapons.

Ground Attack. The UCAV will now bring a new impetus to the most dangerous roles in air power, deep penetration strikes and suppressing enemy air defences. The control for these missions will be from AWACS at the beginning of the campaign and will subsequently shift to theatre-based ground facilities as the war progresses. This would avoid any delay in decision-making which would have to be based on real-time information. UCAVs would have the inherent flexibility to perform multiple missions using precision guided weapons in integrated attacks against high and medium threat targets. Typically these might be airfields, radar sites, SAM batteries and even second echelon armour formations. Attacks could be coordinated in such a way that the UCAVs would form the first and maybe even the second waves, leaving manned aircraft to press home attacks when the threat density diminishes sufficiently to ensure adequate and acceptable chances of crew survival.

Air Combat. The UCAV would be able to take full advantage of leading technologies and so the ‘aircraft will be designed for performance and not to suit the pilot’. Design techniques would be more akin to missiles than those normally associated with aircraft, making the UCAV supremely manoeuvrable and stealthier. It is conceived that a single manned aircraft could control at least three UCAVs armed for air supremacy missions, flying a sweep miles ahead. The ‘mother aircraft’ will remain electronically silent while receiving target information from the UCAVs/high altitude reconnaissance UAVs/satellites. With two brief signal pulses–one for the UCAVs to arm their weapons and a second to fire—the fighter could shoot down an equally high-performance aircraft without ever being exposed to danger. This sort of unit, which can operate autonomously even in extreme threat conditions, would fly support to provide air superiority for both manned and unmanned components of the strike package.

Integrated Attacks. Such small but highly interconnected aerial units will allow an air force to fight effectively without having to mass its forces in a given time and space. The combination of manned and unmanned aircraft penetrating enemy air space in an unpredictable manner and pattern will allow the air force to conduct seemingly random attacks that would produce highly integrated destruction of the enemy's war making potential. The element of surprise, flexibility and concentration of force that UCAVs permit in both the strategic and tactical scenarios, makes them a war-winning force multiplier, when optimally deployed and aggressively employed.

Training. Apart from the odd training deployment for realistic exercises, the bulk of UCAV flying training could be performed on simulators. To fly a UCAV to its target, an operator would first plan the attack on a PC-based mission support system and then load the strike profile on to the vehicle. During the mission, changes could be data linked and sitting at a control station an operator would be able to control and coordinate an entire 'package' of UCAVs. The number of support personnel in the theatre will be reduced and it will not be necessary to transport large number of shelters, workstations and environmental control units. This would also point towards cost-effectiveness in the overall operating scenario.

CONCLUSION

Uninhabited Aerial Vehicles have conclusively proved their intrinsic worth in the fields of reconnaissance and surveillance. Their capabilities will only improve with technological advances that are taking place and it is conceivable that over a period of time only UAVs would be used in the reconnaissance role—both tactical and strategic; 'snapshot' and continuous. Further, developments in their attack capabilities make these vehicles even more important in the overall picture of air superiority. It has been proven beyond reasonable doubt that a combination of manned and unmanned aircraft would be the optimum mix in any future war to obtain and maintain air superiority. This would also be the most cost-effective way of employing what is becoming the most expensive arm of modern combat forces—air power.

There are some unknowns about UCAVs that need to be explored before the entire concept can be suitably adopted. The weakest link is the durability of the electronic links and the desirability of the pilot's associate device to cut workload. A pilot's associate could conduct much of the aircraft's routine business and could also alert the pilot to danger or potential targets and free him to operate several UCAVs simultaneously. A break-in the electronic link, caused by jamming or equipment failure, would automatically return the aircraft to base without carrying out any further lethal missions.

Removing human vehicle operators from the risk of being in the vehicle is an old idea. Like so many good ideas, it has had to wait for technology to catch up. Operating a vehicle to its performance limits remotely is not a trivial problem. The controller has very few visual clues and no motion cues from which to deduce attitude and velocity. Therefore, of necessity, UCAVs usually need a certain degree of autonomy. UAVs can do jobs that are too dangerous for human presence, and the absence of a pilot means that the vehicle can be very small and light.

As is typical in the expanding area of technology, where there are large numbers of potential customers, many companies have seen the potential of UAVs and have entered the market with everything from production hardware to mere ideas. This has led to a proliferation of cheap and expendable UAVs, primarily used for reconnaissance of the most basic kind. The technologies required to field a truly capable UCAV is still beyond the grasp of most nations and is likely to remain so for some more time. But it is a foregone conclusion that this technology will slowly emerge and be accessible to all nations harbouring a vestige of air power. Then, the concepts of aerial warfare, as propounded now, will be revolutionised and the primacy that it enjoys today in the conduct of war will be reinforced as never before.

PAPER 13

Guns for Battlefield Air Defence

INTRODUCTION

Until the late 1950s the only aerial threats on the battlefield were high altitude area bombing and dive attacks at short ranges, and so the air defence available to counter this threat was equally simple, consisting of machine guns (small calibre rapid fire or large calibre with slow rates of fire) with simple fire control systems. The introduction of fast jet aircraft with sophisticated target acquisition and aiming systems and carrying potent weapon loads into the battle area prompted the development of more effective battlefield air defence systems. The new automatic guns had very high rates of fire with new sights, radar and computers incorporated into the fire control system.

However, the rapid improvements in missile technology which produced air defence missiles with enhanced kill probability and longer ranges made them the supreme air defence weapon. With the balance tilting towards the missiles in the research and development field the air defence guns were slowly pushed to a secondary role in the overall air defence set-up.

The change in the threat scenario with the end of the Cold War, as well as the evolution of varied aerial threats in the battlefield, have now made the importance of the air defence gun come full circle. Although not replacing the missile in primacy as an air defence weapon, the gun has now been acknowledged as an equal and integrated part of battlefield air defence systems.

AERIAL THREATS ON THE BATTLEFIELD

Since all air defence systems would vary dependent on the threat that would have to be countered, it would first be necessary to analyse the threats on the battlefield. The traditional concept of aerial threat on the battlefield was restricted to the fixed wing aircraft. Now however, threats evolve from a variety of aerial targets.

- **Fixed wing aircraft**. These are still regarded as the main threat. Aircraft are now capable of conducting operations at extremely low altitudes at very high speeds carrying 'smart' weapons with varied attack profiles. They are also capable of muti-directional saturation raids with the help of refined navigation and attack systems. The reduced radar and infra-red (IR) signatures of modern aircraft coupled with the use of electronic, IR and laser counter measures makes the aircraft less vulnerable to air defence than before.

- **Helicopters.** The helicopter has become an equally important threat in the battlefield in the past 20 years or so. From limited utilisation, the helicopter is now a multi-mission capable machine capable of flying at terrain following heights in poor visibility and at night. Their load and ordnance carrying capability makes them a major threat to ground troops, especially mechanised forces.

- **Guided Weapons.** Although of fairly recent origin, the threat from guided weapons is perhaps the most difficult for air defences to cope with, because of the wide variety of sub-systems in use and being developed. These include:

    - Laser, TV or IR guided bombs
    - Powered or gliding weapon dispensers
    - Missiles; stand-off, cruise or tactical ballistic

All the above weapons have very low radar and IR signatures and almost all the missiles travel at supersonic speeds and are fairly manoeuvrable. The capabilities of Uninhabited Aerial Vehicles (UAV) to transmit reconnaissance data in real time considerably shortens the time between collection of data and air-strike. This makes UAVs high-value assets and so prime targets for the air defence systems.

- **Electronic Warfare**. In the recent past, electronic warfare has become an important element in the battlefield. Flying jammers with radar and IR countermeasures and advanced systems that create decoy targets effectively degrade the air defence systems and so could be considered a passive threat.

Air defence systems are considered high priority targets in the battlefield and so would be targeted by ground-based weapon systems as well. However, it is the attacking tactics that must be taken into account while devising the air defence concept of the battlefield. Tactics create major challenges to the air defence, the latest being multi-directional saturation raids heavily supported by ECM and a multitude of accurate weapon systems.

No one system enumerated above can be identified as the main threat in today's environment for any length of time. The threat would vary from country to country and from battlefield to battlefield. This necessitates the development of different air defence systems to cater for varied and specific tasks in different theatres depending on the overall perspective of the nation/defence force in the theatre concerned.

REQUIREMENTS OF AN AIR DEFENCE SYSTEM

As a result of the technological advancements in the threat scenario, the requirements for effective battlefield air defence have also changed dramatically in recent years. The basic requirements for a battlefield air defence system are enumerated below.

- Mobility, in order to be able to keep pace with the fast moving battle area and baseline air transportability to be used for rapid deployment.
- Survivability to conventional attacks.
- Anti-jamming protection for the weapon system and allied communication equipment.
- Capability to detect targets with low IR emissions and small radar cross sections.
- Quick reaction and multiple target engagement capability.
- At least limited capability to operate autonomously in high threat environments with minimum degradation of performance.
- Cost-effective, so that a large number of systems can be deployed to achieve saturation effect.

GUNS VERSUS MISSILES

There can not be any definitive answer to whether the gun or the missile should be used as the air defence weapon of choice on the battlefield. Both have their own advantages and disadvantages. No armed force has till today discarded one for the other and almost all of them use both in a judicial, tactical mix for the air defence of the battlefield. The missile has the following advantages over the guns:

- greater range,
- lesser system weight giving it enhanced air mobility,
- better engagement envelope against manoeuvring targets, and
- greater single shot kill probability.

By contrast, the air defence guns have the following advantages:

- lesser reaction time,
- full engagement capability even at extreme short ranges as there is no inner dead zone,
- better resistance to electronic and IR counter measures,
- high rate of fire and multiple target engagement capability,
- comparatively lower system as well as operating cost, and
- built in self-defence capability and secondary use as a ground weapon.

Two factors stand out as very important considerations in favour of guns–the extremely short reaction time (3–5 sec as compared to 7–12 sec for missiles depending on type), and the fact that up to distances of 3–5 km, the bullet is faster than the missile. Given the very short exposure times of modern low flying aerial threats, air defence guns are virtually indispensable to counter them.

At present there are a great number of air defence gun systems in use all over the world. The calibre varies from 20 mm to 76 mm. The effective range of the gun in kilometres is roughly the same as the calibre in centimetres–thus a 20 mm gun has an effective range of approximately 2 km. This would mean that the heavier guns have an advantage in terms of range and the mass of the projectile, but the rate of fire, which is the most vital factor in hit probability, reduces with increase in calibre. The medium calibre guns (30 mm and 35 mm) are the most popular as they have an optimum combination of range, accuracy and rate of fire. However, the latest developments in ammunition, like course correction or terminal guidance which require electronics and propulsion systems, would need higher calibre guns in the region of over 76 mm.

DEVELOPMENTS IN AIR DEFENCE GUN SYSTEMS

Because of financial constraints under which all armed forces operate, almost all development taking place in recent years are aimed at being cost-effective, while being able to fit into the existing force structure. This has led to the upgrade of old systems instead of the development of replacement systems. The effectiveness (i.e. the kill probability of an air defence system) can be enhanced by any of the following methods:

- improved fire control,
- new types of ammunition,
- new gun systems, and
- battlefield mobility.

Fire Control Systems

The old optical sights were effective only with considerable practice and even then the hit probability was very low. New electro-optical sights combined with modern fire control systems increase the hit probability dramatically. This has a dual effect in that, it cuts down the consumption of ammunition, and so is cost- effective, and the guns have a limited autonomous combat capability. The latest sights (which may incorporate any or all of the facilities listed i.e. day-vision camera, LLLTV or thermal imager, laser range finder, inertial sensors, air data sensors, fire control computer, CRT display) are capable of receiving azimuth and elevation information on targets from separate sources, which reduces reaction time considerably. The detection sensors would have to be optimised taking into account the threat expectations as well as the opponent's countermeasure capabilities. The fire control sensors can be segregated from the firing unit thereby minimising the chances of neutralisation. The overall performance of the system can further be enhanced by tying the guns to a command and control network, which would make a coordinated and more effective air defence with a mix of guns and missiles possible.

New Types of Ammunition

The most widely used ammunition in air defence systems is still the High Explosive Incendiary (HEI). Its advantage of low cost is some what offset by the high consumption per target necessitated by low hit probabilities. These, as well as Semi-Armour Piercing HEI (SAPHEI), are relatively ineffective against most of the modern targets, which are either heavily armoured or very small in size. Since ammunition is the deciding factor in kill probability, it has now become necessary to have them specially optimised for special tasks. This would also be a cheaper option than replacement of existing gun assets. The different types of ammunition that are currently in use or are in the testing stage are discussed below.

Armour Piercing Discarding Sabot (APDS). This is a kinetic energy munition for use against armoured or hardened targets. Owing to the lower shell mass and the use of a propellant with higher energy it has a 20–35 per cent higher muzzle velocity as compared to conventional rounds. A lower drag value ensures a lower velocity fall-off thereby improving accuracy and range. A burst of 50–180 rounds (from twin/multi–barrel guns) ensures destruction of target and so the system is suited for use against stand-off missiles fired at high value targets.

Frangible APDS (FAPDS). Essentially the same as the APDS, this new munition is now ready for production. It has the same penetration capability and accuracy as APDS, but the penetrator disintegrates into a number of fragments, even at low impact angles. As a result, the interior of the targets are severely damaged or destroyed by the fragments or incendiary effects.

Armour Piercing Fin Stabilised Discarding Sabot (APFSDS). Although initially developed for anti-tank applications, since this type of ammunition has greater armour penetration capability because of the high energy and low impact area, it has now been adapted for use against stand-off missiles.

Proximity-Fused Ammunition. All the four types of ammunition discussed above need a direct hit on the target for its destruction. To improve kill probabilities, new munitions have been developed which ensure that a shell detonating close to a target will have enough impact to damage it. This is achieved by proximity-fused ammunition with a large number of fragments inside the shell. The ammunition needs a radar sensor in each shell and so a large calibre is required for this type of ammunition. The use of proximity-fused ammunition greatly increases the available target area (fixed wing aircraft beam attack 5–10 times and head-on 50–70 times; helicopter beam attack 20–30 times and head-on 80–100 times; missile head-on 300–400 times). The latest development in this category is the 'Bofors' 40 mm Programmable Prefragmented Proximityf-used round (3P). This shell weighs 975 g, contains 1100 tungsten pellets and is extremely ECM resistant. Each round is individually programmed with inputs from the fire control system and the range sensors and also incorporates safety against unintentional triggering while passing in close proximity to trees etc. The 3P fuse can be set for six different functional modes which covers all the possible applications for an air defence gun and so is an 'all-target' ammunition. Although the cost per shell is about four times that of a conventional HEI, the effectiveness rises by a factor of 15–20.

Advanced Hit Efficiency and Destruction (AHEAD). This is another new ammunition developed by Oerlikon-Contraves of Switzerland and contains 152 sub-projectiles released by each round just ahead of the target. This 35 mm shell requires a sophisticated fire control system to function optimally and the sub-projectiles form a 10 degree cone from the point of impact in the direction of flight. AHEAD is specifically designed to counter small, very low and fast flying targets like drones, dispensers and missiles and can be retrofitted to all 35 mm guns.

Future Trends

Course-corrected Ammunition. Many companies are trying to improve the accuracy of air defence guns by introducing course corrections to the ammunition in order to compensate for aiming errors and to cater for the manoeuvres of fast moving targets. The shell is fin-stabilised and the course changes can only be through few degrees. The efficacy of these munitions has not yet been proved fully in actual conditions. Another disadvantage is that the calibre has to be 76 mm or more to house all the electronic equipment as well as the course correction thrusters. Although the kill probability will increase dramatically with the use of this ammunition, because of high developmental and production costs, cost- effectiveness is debatable.

Guided Ammunition. These are 'gun-fired-missiles' with an IR or radar seeker, normally with propulsion in flight. Only large calibre rounds can be used in this type of munition and it also has the same limitations of the course-corrected ammunition. However, this is almost a single-shot air defence system with a very high kill probability and an enhanced range of up to 12 km. Guided munitions are being seen mainly as anti-helicopter rounds for use by tanks in the battlefield.

There are other developments taking place which would have no direct bearing on the kill probability. These are:

- cased telescopic ammunition,
- cylindrical ammunition, and
- caseless ammunition with fully combustible case.

These are all aimed at improving the overall performance of the existing guns at minimal cost.

Battlefield Mobility

Mobility has now become an unavoidable necessity for any air defence system to be effective in the battlefield. Firstly, to be able to keep pace with the fast moving armoured forces in the battle area itself, and equally important, for self protection as the air defence weapon systems are high-value targets in any battlefield. For this reason almost all air defence guns are being made mobile by being mounted on wheeled or tracked vehicles and if this is not possible, then by having enhanced transportability.

The air defence gun has an effective range from zero to four km and can be classified as a Close-in Weapon System (CIWS). It would therefore be beneficial to combine a fast reaction gun (with its inherent advantage of low cost ammunition and limited capability against ground threats) with an air defence missile (much larger engagement range) in one mobile air defence system so that they complement each other. However, the developments so far in these hybrid systems have produced fairly heavy vehicles which are not as mobile as they should be for optimum use in the battlefield.

CONCLUSION

Most of the current systems will remain in service for a further 10–15 years or even longer. There would be improvements in fire control systems and ammunition performance but the guns by themselves would not change very much. The only improvement that is conceivable on the gun is reduction in weight which would in turn give even light vehicles on the battlefield air defence capabilities. However, new and emerging technologies that are being used in the improvements of the guns are capable of producing giant leaps in the evolution of the gun as a weapon for battlefield defence. The future could see the use of laser guns, electro-thermal guns and electromagnetic rail and coil guns in the battlefield air defence system. This development would depend not only in mastering the technologies but also on financial and political factors which may prove to be more important.

Air defence of the battlefield is a subject of increasing importance, especially with the advent of stand-off and/or dispenser weapons of immense potency. This paper has only looked at the trends in the development of air defence guns and suggested an integrated hybrid mobile system as the best option in battlefield air defence. The potential of modern air defence guns is great in terms of fire rate, accuracy and kill probability. The system which has an integrated missile and gun defence with the capability to be tied into a higher level command structure will be able to maximise and realise the full potential offered by today's modern radar and associated fire control systems.

There are three basic types of battlefield air defence; organic air defence, point air defence and area air defence, the first two being purely tactical and the third both tactical and operational. Organic air defence is generally entrusted to self-propelled equipment for the protection of mobile formations and is essentially the same as point air defence, which covers the protection of fixed installations, in all aspects except mobility. Area air defence is meant to cover a complete locale and could be both static and mobile. No matter how up-to-date and effective modern non-conventional weapons become, gun systems will retain their primacy as a CIWS and continue to play a major role in countering the threat from the air.

This book contains papers on air power organised into four sections—Air Combat, Air Warfare Concepts, Aircraft Design and Weapon Systems. Although all the papers analyse air power issues, they are disparate in their content and cover a very large swath of air power topics.

The Air Combat section has four papers that cover intangibles like planning for air supremacy and training. When read together the four papers give a holistic view of air combat. The Air Warfare Concepts section contains a few papers on the air power lessons that could be derived from limited armed conflicts and also contains a detailed analysis of the Russian concept of air warfare.

The sections on Aircraft Design and Weapon Systems are inter-linked because both have papers on Uninhabited Aerial Vehicles, analysing their future employment and impact on warfare. The section also contains papers on fighter aircraft design-related issues as well as air defence weapon systems.

The papers in the book are thought-provoking and deal with fundamental doctrinal and philosophical issues that have been studied since the beginning of air power theory. They have contemporary relevance to the development of air power theories and strategy.

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