BOYD LOOPS, ACE FACTORS

Some Concepts Re-Examined

By Simon Anglim

AND FIGHTER COMBAT

Many factors contribute to the success or failure of air operations. Perhaps the most critical of these is the fragility of aircraft and their vulnerability to a range of weapons systems. One of the most crucial, yet most under-studied aspects of air power practice is the need to protect attacking aircraft, this being best achieved by seizing, or at least contesting, control of the airspace over the area where the decisive blow is to be struck, a mission type referred to by the Messiah of airpower, *Generale* Giulio Douhet, as 'Command of the Air' but now known generally as *air superiority*.[1] The other side of the coin is the *air defence* mission, the denial of the free use of friendly airspace, which usually combines fighter aircraft – often types purpose designed for this role – into integrated air defence systems with ground-based anti aircraft artillery (AAA) and surface to air missiles (SAMs). These missions have shaped airpower up to the strategic level and, indeed, it was failure to appreciate their importance which led to the predictions of Douhet and his apostles coming unstuck so devastatingly in the Second World War and afterwards. Contrary to predictions that the bomber would always 'get through', air forces often had to win bitter attritionary air battles before their strategic mission could be fulfilled. The best known example of this was in the Battle of Britain in summer 1940 when, attempting to gain air superiority over southern England, the *Luftwaffe* found itself engaged in just such a battle with Royal Air Force (RAF) Fighter Command, which saw it beaten psychologically if not physically, having suffered 823 fighter aircraft shot down to the RAF's 915.[2] Later in the Second World War the United States' Eighth Air Force, attacking industrial targets in Germany with large formations of unescorted bombers, took such losses – sixty B-17s out of 220 in the Schweinfurt raid of 14 October 1943, for instance – that operations were suspended from October 1943 to January 1944;[3] the introduction of long ranged fighters, most notably the P-51 Mustang, the only fighter type to be mentioned regularly in academic textbooks, enabled Eighth Air Force to defeat the *Luftwaffe* in a series of large air battles fought over Germany in 1943-44, after which it could fulfil its mandate.[4] Following operations over North Vietnam in 1967-72, wherein the USAF suffered kill-loss ratios as bad as 2:1 at the hands of the North Vietnamese Air Force – one of several factors affecting American attempts to break Communist efforts with bombing – the USAF revised its entire operational doctrine and procurement policy, moving away from a Douhetian faith in massive first strikes towards an acceptance of the need to control airspace and ordering a new generation of very high quality air superiority fighters – the F-15 Eagle and F-16 Fighting Falcon, and the Navy's F-14 Tomcat for good measure – in order to fulfil this role.[5] Some of these new types were supplied to the Israeli Air Force which, supporting the Israeli invasion of Lebanon in 1982, inflicted a kill-loss ration of 85:0 on the Syrian Air Force, provoking the Syrian Soviet sponsors into a similar programme of doctrinal revision and adding impetus to the development of the MiG-29 and Su-27, types at least as good as their American counterparts.[6] Reviewing such evidence, we might conclude that combat between fighters, defined for the purposes of this paper as *military aircraft designed for the primary mission of destroying enemy aircraft in flight*, is an essential facet of modern warfare and is worthy of considerably greater academic study than it has perhaps received hitherto.

What contributed to the outcome of specific air battles is outside the scope of our discussion. The aviation journalist and prolific author on fighter combat, Mike Spick, has carried out a detailed survey of fighter operations on thirteen campaigns in World War Two and Korea, and concluded that while numerical ratios do count somewhat in the long term, there is little consistency in factors affecting individual combats.[7] One consistent characteristic, indeed, the very essence of air warfare, is the application of technology to the most hostile environment man has yet fought in. Fighter combat entails locating enemy aircraft, closing by stealth, firing upon him and then escaping; at each stage, both the skill of the pilot and the quality of the technology at his disposal play their part. Of the two, technology is demonstrably the greatest historical variable, having undergone radical and rapid change in a very short time indeed; the leap from rotary engined, canvas monoplanes travelling at less than a hundred miles an hour, at no more than a few tens of thousands of feet up, their pilots shooting at each other with pistols if they bothered at all, to jets capable of flying through the stratosphere at two thousand miles an hour, built of man-made ceramics and packed with electronics based systems capable of knocking down targets a hundred miles away took but a single lifetime – that of Sir Tommy Sopwith. However, the pace of change, which is dependent upon the need to meet shifting threats and so will increase in time of war, has been far from uniform. In World War One, a fighter type could serve for an average of eleven months before obsolescence; by World War Two, a fighter had a useful lifetime of around five years – the Bf-109 was Germany's principal fighter type throughout the war years, for instance – but these were subject to constant incremental improvement and individual sub-models might only be useful for around eighteen months to two years – the Bf-109E was supplanted by the faster

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Bf-109F in 1941, that by the faster still and more heavily armed Bf-109G in 1942, and each mark was up-engined or up-gunned several times. By the 1950s, expense was beginning to slow down the development of new threats, and jet types might have a front-line career of around ten years and, since 1970, increasingly sophisticated technology and longer development times has enabled current types to retain relative superiority for decades, the F-15 Eagle, for example, first seeing combat in Israeli hands in 1975 and still being used by the USAF over Bosnia in 1994.[8]

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Any changes made in the same period to the demands that combat flying makes of the pilot are harder to trace and certainly impossible to quantify. This paper attempts an assessment of the shifting balance between human and technological factors in combat involving fighters, and of how that balance has been affected by technological change. It will focus upon the core relationship between pilot and aeroplane, the so-called 'pilot-cockpit interface', the ability of the pilot to convert the information that he receives from his own senses and the aircraft's instruments into decisive, successful actions; we must, therefore, focus on those elements in pilotry and aerial combat affecting pilot comfort and survival and his mental and physical efficiency.

THE DECISION CYCLE

We will begin by establishing the process by which fighter pilots make tactical decisions. It is the making of such decisions that is the single most vital role of the fighter pilot; we must remember that, in common with all modern technology based weapons platforms or military organisations, the fighter is a *system*, in which the whole is greater than the sum of its parts. In this case, the system consists of all the working parts of an aircraft mated to detection and weapons systems; the pilot is the 'adaptive' element of the system, his *raison d'etre* being to co-ordinate the other components of the system in order to fulfil the mission at hand.[9] The main intangible factor within the system is the way in which the pilot perceives sensory cues and the way in which he mentally processes those cues into information on which he can base decisions. In their study of human factors in aviation, Green, Muir, James, Gradwell and Green summarise piloting as:

...the fighter is a system, *in which the whole is greater than the sum of its parts...*

> Observing and reacting to events that take place within the cockpit and in the environment outside the aircraft. The pilot is required to use the information that he senses in order to make the decisions and take the actions which will ensure the safe path of the aircraft at all times.[10]

Such mental activities play a vital part in aviation; Federal Aviation Authority reports show that in the period 1973-77 errors in pilot judgement were responsible for over half of all pilot fatalities.[11] With combat aircraft, we might add to Green's description 'the successful completion of the mission' which, in the case of fighters, will almost certainly involve destroying enemy aircraft in aerial combat. This will pit the pilot against a living, reacting opponent and so will complicate the events he must observe and react to and increase both the amount and the importance of the information upon which he must base his decisions. However, there is a clear limit on the amount of information the human brain can process at any one time, and so a degree of selectivity is important; all stimuli must be sorted and those deemed unimportant, discarded. The ability to assess and prioritise stimuli we call 'judgement' and to focus upon a limited range of stimuli, 'attention'; both are tested constantly in aerial combat.[12] Aerial missions can cover thousands of square miles of sky, often containing many hostile aircraft: airmen must maintain constant vigilance of what is going on around them and, combined with the size of the combat arena and the need to pilot the aircraft, the acquisition of accurate knowledge of a fighter pilot's current situation can be problematical. For instance, overclaiming of air-to-air victories by pilots tends to increase in proportion to the number of aircraft involved in an action.[13] Air Vice Marshal 'Johnnie' Johnson recalls that during the Battle of Britain:

> ...RAF fighter pilots claimed about three aeroplanes for every two brought down, while the Germans claimed more than three victories for every one they brought down. A few pilots tended, like the man who can never find all the birds he has shot, to overclaim persistently...[14]

Such uncertainty is compounded by the nature of air combat:- decisive action often happens in a matter of seconds, at very high speeds, and is executed in three dimensions. Consequently, speed of judgement and reaction is at a premium, and it is generally unwise to be too circumspect or to take too much time referring to higher authority. According to Mark K. Wells, in aerial combat in the Second World War, 'after the initial engagement, actions were most often taken instinctively, because pilots did not have time for reflection or deliberate decision-making'.[15] American Second World War fighter ace, Colonel Don Gentile, was even more emphatic:

> The whole thing goes in a series of whooshes. There is no time to think. If you take time to think you will not have time to act. There are a number of things your mind is doing while you are fighting – seeing, measuring, guessing, remembering, adding up this and that and worrying about one thing and another and taking this into account and rejecting this notion and accepting that notion. But it doesn't feel like thinking.[16]

Impressions are of a situation of the utmost fluidity and, frequently, of high unpredictability. Fighter combat epitomises Clausewitz's concept of 'friction', the impact of human abilities and limitations, enemy action, the environment and other unforeseen and unquantifiable factors on military activity.[17]

There are, however, ways and means by which the fighter pilot can survive the rush and confusion of air combat. Much of his training will be aimed, through over-learning and over-practice, at achieving instinctive reactions and skill sequences and rhythms and he can perform almost without thinking and will be resistant to the wrong moves; the emergency drills which all pilots must practise exemplify this.[18] However, as noted, air combat pits living, thinking opponents against each other and so there will be many decisions a fighter pilot must make which are not automatic. Consequently, judgement, mental agility, combined with tactical intuition and the ability to 'read' a situation as it develops is vital in order to anticipate an opponent's actions when both combatants are moving simultaneously at several hundred miles an hour, and to recognise and seize opportunities for aggressive action, which may be fleeting indeed. At the very least, without these attributes, the potential for the intervention of the two factors most feared by the fighting man, surprise and confusion, is high: one should bear in mind the most commonly quoted statistic in fighter combat, that 75-80% of all air combat victims never saw the one that got them until it was too late, in the light of which it comes as no surprise that two recent books by fast-jet fighter pilots contain the candid admission that, given the choice, most contemporary fighter pilots would kill the enemy at long range with radar homing missiles, so as to avoid a close ranged *melee*.[19]

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However, in many cases, they must close with their antagonists. Major General Robin Olds, another American ace of the Second World War and commander of the highly successful Eighth Tactical Fighter Wing in Vietnam, encapsulated success in close range air combat as:

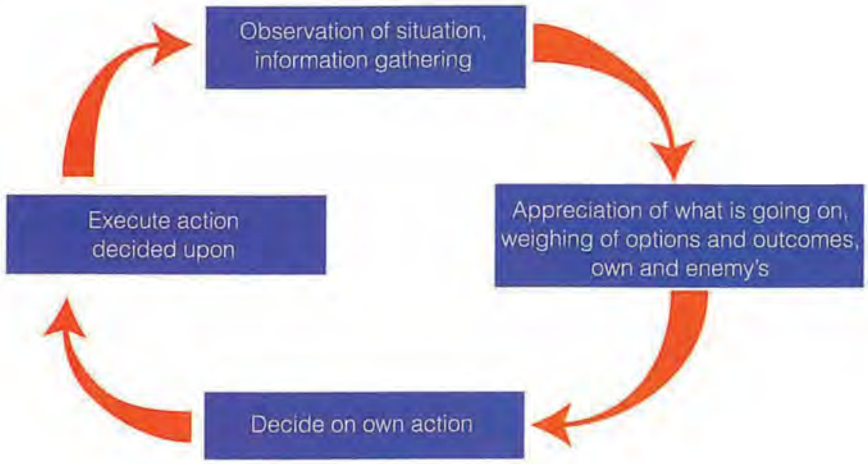
> What you can see, retain, anticipate, estimate in a three dimensional movement of many aircraft. Can you look at an enemy aircraft and know the odds...if he can get behind you first and so on? It's a three dimensional impression; you must get it in seconds...The guy you don't see will kill you. You must act instantly, anticipate the other fellow's motives, know that when you do this, he must do one of several things.[20]

Another fighter pilot of the Vietnam War, Lieutenant Randall Cunningham, USN – the first American pilot to achieve ace status, or five air-to-air victories, in that conflict – concurred:

> The pilot must have a three-dimensional sense of awareness and feel time, distance and relative motion as if they were part of his soul...Analysing multiple complex time and space oriented problems correctly is one significant key to aerial combat.'[21]

TURNING THE LOOP

Although fighter pilots of the First and Second World Wars recognised this as clearly as General Olds and Lieutenant Cunningham, it was not until the post-Korean War period that academic research was carried out into the patchwork of qualities they identify. Studies of modern manoeuvre-based warfare (on the ground as well as in the air) have identified combat as an ongoing, repetitive process of 'time-competitive observation-orientation-decision-action-cycles', known more commonly as the 'OODA cycle'.[23] Put into plain English, a combatant, in our case a fighter pilot, will observe his situation, make an appreciation of its likely outcome and decide upon a course of action, carry out the action, then set himself up to begin the process again by resuming the observation of his surroundings.



Different types of combatant move around the OODA loop at different rates; an infantry soldier engaged in a firefight will go through the loop several times per minute, whereas a corps or air command headquarters might take a day to complete the cycle; personal accounts suggest that fighter pilots live near the quicker end of the scale.[22] This process was first identified by a fighter pilot and trained scientist, Colonel John Boyd of the United States Air Force (USAF), who later became perhaps the best known of the 'Fighter Mafia' who rewrote USAF fighter doctrine in the late 1960s. Colonel Boyd identified success in warfare as being attained by 'turning inside the enemy's OODA loop' and completing one's observation-decision-action cycle more quickly and efficiently than he does. The benefits of this are summarised succinctly by Richard Holmes: 'each time the slower side acts, the faster one has already embarked upon a new course of action which renders the slower side's inappropriate. With each sequence the faster side's time advantage is magnified until the slower side can no longer act effectively.[23] The interaction between two pilots struggling through the 'OODA cycle' is apparent in Captain Robert Thresher's account of what must have been one of the very last engagements between piston-engined fighters, which began when his F-51 Mustang was attacked by a North Korean Yak-3 on 1 November, 1950:

> I snapped my head around and saw the yellow winking lights of a Yak's two 12.7-mm machine guns and 20-mm cannon. He had been sitting up there all this time in the sun and now he had the advantage over me. I went into a sharp turn...I knew the Yak could turn inside me but, in my panic, I held it in, hoping that the enemy pilot would not be able to follow through after his last pass. At 7,000 lb max gross weight, the Russian-built fighter had the turning and climbing edge over any Mustang...I rolled out to see that the enemy pilot had gone across the top of my Mustang and, taking advantage of his speed, he had pulled into a tight loop. That was all he needed. He was above me with an altitude advantage. If he could come out of the loop right, he would be right on my tail again. Only

> this time he would have speed to burn! I swung sharp left to pass directly beneath him and he must have been watching me because he kept his stick back too far and stalled out. He spun all the way down from 6,000 ft. I rolled back into a turn, hoping desperately to come out behind him...He recovered and I thought for a moment that I should try to tighten my turn and jump him while he was floundering out of his spin, but he snapped the Yak over and got his flying speed back up in a matter of seconds and, due to the light weight of his fighter, went into a steep climb! This time he slacked off at the top of his loop and followed through gently. Now the pattern has been established... I was flying a tight circle on the horizontal; he elected to fly his sparring circle on the vertical, snapping at me as we passed each other. We held our turns, I looked for a break and as we picked up speed, I saw that we were getting closer each time we closed on the south side of my circle. More and more rapidly, the two fighters got out of phase... The North Korean pilot saw this. He knew that after another pass, I would be coming in behind him as he began his climb. It unnerved him to the extent that he wobbled at the top of his next loop. He fell unevenly this time. I cut wide briefly. At the bottom he recovered and began his pull-up, but luckily my timing was good. I wrapped up my '51 and while I was in my turn began firing. I saw the tracers converge and pour into his wings. I eased the rudder to the right to keep him in my sight... Then a puff of blue smoke spouted from his wing. He wobbled and fell out of his turn. Slowly he rolled over and went into a long glide. I watched him go down...[24]

Although the importance of the OODA cycle was clearly nothing new at the time, Colonel Boyd's conclusions resulted from a study of the experience of American fighter pilots from later in the Korean War, pilots achieved a 10:1 kill ratio – as high as 15:1 at times – over their Chinese and Soviet opponents, despite the technological superiority of the Communists' main fighter, the

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MiG-15, to all Allied aircraft, including the United States Air Force's (USAF) most advanced type, the F-86 Sabre. Colonel Boyd found that a wider field of vision granted by the Sabre's bubble canopy and the superior speed of response granted by hydraulically assisted controls enabled American pilots to gain and act upon information more quickly and so complete the OODA loop before the opposition, effectively forcing the MiG pilots into certain actions, gaining a time advantage until a killing shot could be made.[25] Sometimes the MiG pilot would run out of ideas and panic, making the American pilot's task easier. This phenomenon had been noticed already years earlier, in the First World War; Mike Spick relates an anecdote of the Canadian ace, Billy Bishop:

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And again in the Second World War; Colonel Gentile recalled two German pilots who fought well initially:

> But suddenly, I don't know, something happened in their minds. You could see it plainly. Their brains had dissolved away under the pressure of fear and had become just dishwater in their heads. They froze to their sticks and straightened out and ran right down into their graves like men stricken blind who run, screaming, off a cliff.[27]

From this and other anecdotes cited already, we might conclude that the OODA loop (now also known as the 'Boyd Cycle') did not suddenly impact on fighter combat as a result of technological advance. It follows also that the pilot who acquires and judges information about his situation more efficiently than others has a potentially decisive advantage.

SITUATIONAL AWARENESS

It was not until thirty years after Colonel Boyd's initial findings that these qualities were investigated formally, identified and bracketed under the term *Situational Awareness*, now regarded generally as the most important human factor in piloting in general and fighter combat in particular.[28]

There is no one agreed definition of situational awareness and, indeed, there is some debate as to its nature. While Roscoe and North speak mundanely of the difference between good and bad pilots as 'being able to estimate quickly probable outcomes of different courses of action; having a sense of relative values that allows rapid reordering of priorities as situations deteriorate or improve…',[29] Mike Spick speaks of situational awareness in terms of the 'clue bird' (USAF slang), a mystical, almost paranormal sixth sense, perhaps descended from our animal instincts and akin to Colonel Jim Corbett's 'jungle sense' or Colin Wilson's 'Faculty X', that alerts the pilot to the presence of danger, and in support of his argument cites such cases as that of the Battle of Britain ace, Robert Stanford Tuck, who, apparently on impulse, left a pub shortly before it was struck by a German bomb.[30] This may not be so far-fetched as supposed initially; David Beaty links aspects of pilot performance to deep set instincts passed down from our primate ancestors, who 'coped with their environment by instinct and reflexes. We still use these on certain levels.[31] To Roger Green and his co-authors, situational awareness is more of a state of mind, arrived at from constantly taking stock of a situation, gathering and interpreting data from as many sources as possible, modifying one's hypothesis as the situation develops.[32]

It may be that there is room for all these hypotheses; history shows us that the ranks of the air aces are filled with men – and at least two women – of all nationalities and social groups, and it is self-evident that different individuals gather and react to information in different ways. Combat reports also indicate the possible importance of two types of situational awareness: one involving an awareness of the state and predicament of the aircraft, being required to fly the aircraft safely and efficiently whether it be a MiG-29 or a Boeing 747; the other, more specialised, type being needed to help the fighter pilot cut through the confusion and ambiguities of air combat. This 'combat situational awareness' could be described as an innate quality, sharpened by training and experience, consisting of alertness tied to mental agility, speed and accuracy of judgement and intuition, allowing a pilot to absorb information from a range of sources, interpret it quickly and accurately, keep track of swiftly changing circumstances, and foresee likely outcomes. Such awareness combines with sharp reflexes and physical courage, the latter enabling the pilot to think clearly in circumstances of deadly danger, to enable the successful pilot to come to swift, sound decisions and to act upon them – to complete the OODA loop – in the midst of the confusion of air combat, more quickly than the enemy.

It will be apparent that combat situational awareness is a necessary quality, to a greater or lesser degree, of all fighting men, on land, sea and in the air. However, this highly fluid nature of fighter combat places it at a premium here, the absence of extraneous factors such as terrain and the relatively small number of participants making its impact both greater and easier to assess.

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THE TOOLS AT HAND

Colonel Boyd's conclusions on the design features of the F-86 versus the MiG 15 are also of significance, as is Captain Thresher's appreciation of the relative performance of his Mustang versus his opponent's Yak-3. As noted already, air combat pits machines against each other as much as men; this conforms closely with developments in land and sea warfare over the last hundred and fifty years or so, which has led to a fundamental reassessment of the way wars and battles are waged. In the pre-industrial age (before the mid nineteenth century), war had consisted of units of men being given objectives and then seeking to attain them; in other words, operations were shaped by what leaders wanted to achieve. With the increasing importance of technology

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since the 1850s, war has become more of a matter of assessing what can be done with the equipment at hand – capabilities – prior to assigning missions limited by those capabilities.[33] 'Capabilities' is an amorphous, rather fuzzy term; one's capabilities are dependent in varying measures on the quality of technology at hand and the ability, provided by training, education and experience, of personnel to use it effectively. Moreover, they are largely incapable of assessment without reference to the environment or historical context, and especially, the capabilities of the enemy. Victory in modern war hinges on possession of more and better capabilities than the enemy, granting the ability to carry out a wider range of missions and greater flexibility within those missions. This applies to air warfare as much as any other type and it is now generally recognised that a vital component of combat situational awareness is an appreciation of the advantages and limitations of one's own aircraft and weaponry in relation to enemy types, and how its strengths might be successfully meshed with their weakness.

As long ago as 1915, Oswald Bölcke was having his pilots carry out 'dissimilar air combat training' against captured Allied fighters, and Max Immelmann was devising a series of vertical manoeuvres, including the famous 'Immelmann turn', ostensibly to turn the superior speed and rate of climb of his monoplane Fokker *Eindecker* into tactical advantages over the slower but better turning biplane fighters of the Royal Flying Corps. In 1940, in order to make best use of the *Luftwaffe's* principal fighter type, the Messerschmitt Bf-109, the service's leading tactical thinkers, Werner Mölders and

Adolf Galland, introduced the use of swooping, hit-and-run attacks against the more agile types of RAF Fighter Command, the Spitfire and in particular, these latter being placed at a disadvantage in vertical manoeuvre by the absence of a fuel injection system in their engines, therefore running the risk of engine cut out if diving too sharply.[34] Awareness of strength and weakness can produce widely varying, results from similar equipment: in the Falklands War a number of Argentinian Mirages, already hampered by heavy bombloads, were lost when they tried to turn with the slower but more agile Sea Harriers of the British Task Force; yet, years earlier, Israeli Air Force (IAF) Mirage pilots used diving, slashing attacks, capitalising on the type's superior speed and vertical manoeuvrability, with considerable success against slower but nimbler Arab fighters such as the Hawker Hunter or MiG 17.[35] In the 1965 Indo-Pakistan War it was Hunters that utilised swoop attacks against better-turning Sabres, but this conflict was notable in that it was the first in which tactics were shaped not only by the characteristics of the enemy's fighters, but of his air-to-air missiles also: Indian Hunters soon abandoned their diving attacks in favour of low-speed, turning fights when a number were lost to Sidewinders fired by Pakistani Sabres, their often dead-straight, high-speed pullout providing the heat-seeking missile with a perfect target, should they fail to destroy the Sabre on the first pass.[36]

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DEUS IN MACHINA

It will be appreciated by now that fighter pilots have always had a heavy mental workload, increasing as technology has become both more sophisticated and more central to their job. This has implications for a pilot's Situational Awareness and his move around the Boyd Loop. This process hinges on what Green, *et al* call *knowledge based behaviours*, 'those for which no procedure has been established. These require the pilot to evaluate information, and then use his knowledge and experience...to formulate a plan for dealing with the situation.'[37]

This process can be complicated by the quality and quantity of the data the pilot is receiving, and the attention they can devote to each bit of information as it comes in. Data can be ambiguous, and the human mind can be keen to structure information, making inferences based on experience and the balance of probabilities deduced from the data. In many cases, once someone makes up their mind about a situation, it can be difficult for them to change it, even in the face of strong new evidence.[38] In reaction to stressful situations, the body's glandular system will produce adrenalin, increasing heart rate and blood pressure, and giving the body the extra strength and energy needed for 'flight or fight.' Research has shown that under conditions of high stress, thinking becomes more rigid, more stereotyped, more emotional and less rational.[39] The volume of data, the rate at which it comes in, and the amount of time that can be given to its absorption and interpretation, are therefore critical; attention on one group of stimuli inevitably requires withdrawal from others, and as workload increases, attention to detail and standards of performance increase until an optimum level is reached; any increase in workload beyond this point leads to a degradation in performance and at extremely high levels (information overload) important information may be missed due to confusion or the focusing of attention on just one aspect of the job.[40]

Until the 1930s, all that was required of the pilot was that he fly his aeroplane, occasionally monitoring the few gauges available to him, whilst keeping an eye on the sky around him. Douglas Bader describes the cockpit of the Avro 504, the RAF's principal trainer of the 1920s:

> I learned to fly in 1928 when cockpits were open, undercarriages were fixed (as was the propeller pitch), and the instruments consisted of a rev counter, airspeed indicator, altimeter, an oil pressure gauge and a spirit level set horizontally across the dashboard. When you did a correctly banked turn the bubble stayed in the middle. When you hurtled out of a cloud out of control but in a perfectly banked steep spiral the bubble was in the middle also.[41]

From then on, aircraft speeds, and with them the pace of air combat, increased steadily. By the early 1950s, Hawker's Chief Test Pilot, Wing Commander Neville Duke, was concerned that they would 'outpace the nerve impulses of the human system' in speculating on the likely impact on effective aircraft handling of speeds of around Mach Three – it being assumed at that time that such speeds would be attainable by production aircraft within a few years.[42] Other than those flying MiG-25s, fighter pilots of the post-1960 era have not had to concern themselves with the implications of such speeds: nevertheless, in a contemporary jet fighter flying at around 600 miles per hour, a pilot may well have covered 2-300 feet between his seeing a potential opponent, or a blip on his radar, before it registers in his brain and he enters the Boyd loop, and he may well fly forward another 2-300 feet before his muscles being to tighten on his controls. Should he be in a supersonic dash of, perhaps 1000 MPH he may have covered 1800 feet – over a quarter of a mile – before his brain can interpret messages arriving from outside. Consequently, a potential target

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may cross his path, or the enemy may pounce on him, before his nerve impulses have time to register. However, as, at these higher speeds, the forward momentum of an aircraft will restrict its agility, in particular increasing the size of its turning circle, a modern pilot may have fewer tactical options to mull over than his forerunners in the World Wars.

The increase in aircraft speeds, therefore, has implications for Situational Awareness, but are perhaps less important than the growing volume, complexity and importance of the information that the pilot needs to fly and fight effectively. From World War Two, and the incorporation of fighters into air defence systems utilising radar and radio, incoming information expanded into targets – usually multiple – beyond visual range, their altitude, speed and direction, and greater speeds and ranges required the pilot to navigate, and to keep a constant watch on his fuel gauge. The introduction of missiles and of integrated radar, along with radar warning receivers and countermeasures, expanded the area over which the pilot could attack or be attacked and over which he could observe, and gave him yet more systems to oversee. This problem may be compounded by the growing emphasis on multi-role combat aircraft; most contemporary fighters are designed to have an at least supplementary air-to-ground role, requiring not only an extra set of systems for the pilot to master – or, even more confusingly, the same systems set to different modes – but a considerable adjustment of tactical mindset, from the tight planning and control of air-to-ground to the more free-form approach of air combat and back again, perhaps in rapid succession.[43]

The technology required for all this is formidable. By way of contrast with Bader's Avro 504, the F/A-18 Hornet has three display screens, capable of providing the pilot with nearly 250 types of data, each surrounded by twenty switches, the function of which will vary according to the mode in which the aircraft is flying; an electronic engine display has replaced dial instruments; up to 675 different acronyms may appear on the screens, along with 177 different symbols in three sizes, 73 threat, warning or advisory messages and six auditory warning tones. In common with all current types, the Hornet pilot will have a head-up display (HUD) at the front of the cockpit on which information will be superimposed against the real world outside, and this will have 22 different

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configurations using the same symbology as the cockpit displays. He will have a Hands on Throttle and Stick (HOTAS) system, by which all the major function switches are placed on the control column and throttle; he has nine switches on the throttle and seven on the stick, most of which are multi-function; little wonder that American pilots refer to HOTAS as the 'piccolo'.[44] The proliferation of such systems carried by fighters for such things as weapons control, warning and countermeasures, navigation and communications, all of which must be managed by one or two men, means that pilots have less time to observe the world outside the aircraft. And, as the Task Force XXI exercises in 1993-95 established, information overload is less a consequence of too much information as of too little time in which to process it; the constant, rapid flow of information, combined with the pace of current air combat, could result in information overload, confusion, 'friction' and catastrophic mistakes by even the best pilots.[45] I recall a pilot of the Japan Air Self Defence Force confiding that he preferred flying the F-4E Phantom to the more advanced and considerably more potent F-15J Eagle because the latter type 'gives the human mind too much to do.' He was one of many who argue that modern fighters are over-sophisticated, inflicting on their pilots such a workload that their efficiency is compromised. Retired USAF fighter pilot John Roberts attributes even more serious problems to modern cockpit workload; compare Roberts' description of cockpit technology with that of Group Captain Bader:

> By the time we reached the F-4 in the early 1960s, the need to cram ever more instruments and controls for its many different missions into the same limited space carried us to the high point on the difficulty curve: cockpit tasks in faster, more demanding aircraft were growing beyond the capability of the pilot. The flow of diverse, erratic information that had to be absorbed and processed, and the many different, often simultaneous responses that had to result, were exceeding human performance limitations. Accidents were being attributed to this single cause of cockpit overload.[46]

...modern fighters are over-sophisticated, inflicting on their pilots such a workload that their efficiency is compromised

Even more succinct were a couple of comments made to David MacIsaac by USAF pilots:

> What I really need now, like one more hole in the head, is one more element added to my HUD…When the shooting starts, exceptional pilots who are also lucky become heroes, but the war is fought primarily with average pilots. Some of this gear is 'BUR' (beyond useable range) for average pilots.[47]

The dubious viability of brochure claims for the performance of aircraft and equipment for those who actually have to use them is a common theme in air combat literature. A major problem on new, increasingly sophisticated aircraft – not just fighters – is that predictions of their performance are carried out by *test* pilots, often exceptional, sometimes brilliant natural aircraft handlers, with considerably higher levels of Situation Awareness even than most fighter pilots. There is, therefore, the risk that design, testing and procurement of new equipment can be pitched to the level of performance of the very best pilots, perhaps beyond the range of the front-line pilots who may have to use it in combat.[48] A further problem is that many test pilots are civilians, and the experience even of those who have served in air forces of front-line operations, and their demands, may be limited to non-existent; for instance, night deck trials on the Sea Harrier were carried out by British Aerospace test pilots, apparently formerly RAF – with little experience of Harriers and none of carrier operations, and techniques, and it was not until the type was in service that the Fleet Air Arm gained approval to fly it from carriers at night, after Commander 'Sharkey' Ward, the Harrier Desk Officer at MOD and vastly experienced in carrier operations, demonstrated that it could be done.[49] There is a risk, therefore, that equipment may enter service untuned to the requirements of those who are to operate it.

General Robin Olds' means of preventing information overload was simple:

> We switched it all off – all of it. It got too complicated, even for a two-man crew. We would never have scored the kills that we did if we'd had to take account of all the distracting and sometimes conflicting information coming at us from all that equipment. We need eyes outside the cockpit to see the MiGs, decide on our attack profiles and to get them.[50]

General Olds had, of course, learned his trade flying piston engined fighters with just his own eyes and a radio to give the information on which to base tactical decisions; he had scored 24½ air to air victories flying P-38s and P-51s in World War Two prior to getting another four flying Phantoms over Vietnam. He had, therefore, received a thorough grounding in combat flying, and extensive combat experience, prior to the introduction of modern instrumentation and had learned to trust his own instincts: 'I, for one, haven't the courage to sit there and watch a missile coming at me… and say to myself, 'That's all right, that electronic gadget down under my wing is going to take care of it.' No sir, I'm a prudent man. I make a move.'[51] Since General Olds learned to fly, there appears to have been a major cultural shift, and if, as General Olds' experience indicates, contemporary fighter pilots need not depend on such equipment for their survival, anecdotal evidence from some conflicts indicates that many appear to think they do. In the Bekaa Valley in 1982, the situational awareness of Syrian Air Force fighter pilots, their ground based control system destroyed by Israeli airstrikes and their own airborne radar jammed, was, like that of pilots of World War One, confined to what they could see out of their cockpits. Most of the eighty five Syrian aircraft shot down over the Bekaa fell victim to surprise 'bounces' by Israeli fighters vectored by AWACS into sectors from which the Syrians could not see them coming or were destroyed from beyond visual range by radar guided missiles, attacks carried out by Israeli fighters having the full benefit of their own electronic detection and warning systems and yet, if General Olds is right, many

Syrian pilots over the Bekaa seemed to have been whipped psychologically through the loss of their electronic warning and control systems before they were beaten physically

Syrian pilots *might* have dealt with through the exercise of their own skill and initiative.[52] Whatever the drawbacks of modern electronic systems, at least in this one case their loss by one side seems to have proven decisive. The Syrian pilots over the Bekaa seemed to have been whipped psychologically through the loss of their electronic warning and control systems before they were beaten physically. Why? Firstly, they were tied into a Soviet-style air-defence system emphasising tight control of fighters from ground stations and AWACs and in which pilot initiative was discouraged. The second reason might be linked to another discovery of Task Force XXI, a tendency, in 'digitised' units, towards technology dependence, with traditional skills such as map reading and land navigation atrophying in proportion to the degree of digitisation; Roger Green, *et al*, worry that modern flight systems may command such respect as to make it difficult for the pilot to cope when they fail, this being especially true of young pilots with little or no experience of the 'traditional' instrumentation which Bader and Olds were trained on.[53] And, once their communications had been knocked out, Syrian pilots over the Bekaa seemed to panic; a Western military attaché who watched part of the battle from the ground recalled: 'I watched a group of Syrian fighter planes fly figure-eights. They just flew around and around and obviously had no idea what to do next.'[54] The same confusion and indecision could be observed in the few sorties made by the Iraqi Air Force during *Desert Storm*. Over-trust in equipment may, therefore, be a key factor in a pilot's progress around the Boyd loop.

SOLUTIONS

One means of relieving pilot workload is through spreading it among two or more crew members. From 1915, Bölcke and Immelmann flew in a pair, each watching out for the other; from the late 1930s, and its devising by Mölders, the most basic fighter formation has been the pair, consisting of the leader, who carries out the actual attacks, and the second or wingman, who watches out for potential threats and covers the leader's back while he is attacking. The Second World War night-fighter's division of labour between pilot and radar operator (or navigator, according to air force) has been retained on many contemporary types, most notably the F-4 Phantom, F-14 Tomcat, Tornado F3 and MiG-31. On such types, the pilot can concentrate on flying the aeroplane and, in close range combat, firing the cannon and infra-red missiles, while the navigator, in most of these types, handles the radar (including Beyond Visual Range missile combat), information gathering and electronic warfare systems. The testimony of several fast-jet pilots indicate that pilot workload is considerably less of a problem on two seater than single seater types, even in combat.[55] Indeed, at least one senior RAF officer of the early 1960s argued the

The testimony of several fast-jet pilots indicate that pilot workload is considerably less of a problem on two seater than single seater types, even in combat

benefits of converting the English Electric Lightning, the RAF's first supersonic fighter, into a two-seater, and many pilots who failed to qualify on the Lightning later did perfectly well on Phantoms.[56] A young Flight Lieutenant RAF opined to me that the RAF was 'asking for trouble' in ordering Typhoon, its first new single seater type for over forty years, because 'modern fighters need two blokes in them to oversee all the systems…the Navy are finding this out the hard way with Sea Harrier.' I later ascertained that the Flight Lieutenant was a navigator himself, and so some vested interest might be supposed. However, aside from the problem of what to do with hundreds of redundant F3 navigators, the RAF might wish to consider the adjustment required to selection and training of fighters pilots entailed by switching, to a smallish, high-agility, single seat, air superiority type after nearly forty years of flying big, two-seated, not very agile bomber-killers such as the Phantom and F3.

Technology may provide an alternative solution. Within the aviation industry – commercial as well as military – pilot and aircrew workload is now of primary importance, being used as a predictive tool in the development of new systems in order to ensure that the pilot will have sufficient spare information processing capacity to deal with unforeseen circumstances.[57] Previous complaints about workload could be linked to the fact that this was certainly not always the case, many of the problems of pilot workload alluded to have been exacerbated by inattention to cockpit ergonomics;

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Mark Linney, a form RAF Harrier pilot who flew the Imperial War Museum's MiG-15 at air displays in 1995, compares their cockpit layouts; the impact of technological change is obvious:

> The Harrier GR.7 had a modern ergonomic cockpit with up-front control, wide angle head-up display, multi-function colour displays and a HOTAS (hands on throttle and stick) interface...In contrast, the MiG-15 was designed before ergonomics were considered important. Consequently its controls and switches are scattered about in a seemingly random fashion. For example, it's necessary to search along the left cockpit wall to find the airbrake control and trim switches, none of which fall easily to hand or eye. The cockpit's only likeness to the Harrier's HOTAS controls are a transmit button on the throttle and a trigger and airbrake 'blip' switch on the stick. The MiG is a delight to fly, but I suspect not a great aircraft to operate on a dark night or in combat.[58]

As this passage implies, technology is making some difference in pilot workload on many current or developing types. This began in Germany during World War Two, where Focke-Wulf fitted a

Kommandogerät, or 'brain box' to its Fw-190; this was a primitive computer intended to set such things as propeller pitch, fuel mix and revs per minute, so relieving the pilot of these routine chores.[59] The use of Head-Up-Displays to combine visual and radar acquisition into a single function is perhaps the most obvious example on contemporary types. More recently, automation has allowed flight computers to receive data from many sources and integrate it into a single, comprehensive display, and can filter the amount and type of information displayed at any one time, perhaps prioritising it via coloured lettering or icons, and tailoring it to the aircraft's condition and the stage of the flight. The pilot is freed from the need to integrate information from the sources such systems replace, and from the many inferential tasks – such as assessing enemy speed, altitude and direction – that are now carried out by computers, so leaving him free to make tactical decisions and improving his situation awareness – in theory. The previously mentioned F/A-18 Hornet is the first example of a fighter with such a 'glass cockpit' – an arrangement found also on numerous contemporary airliner types and now being retro-fitted to F-15s and F-16s of the USAF, and, as noted, to RAF Harriers – much of its instruments and gauges being replaced by three cathode ray tube displays which can give required information at the press of a button. While the pilot still has systems to monitor, the number of displays are reduced, and he can now at least focus on what information he needs at any one time – in theory. However, the glass cockpit will present a whole range of new problems which we have touched on already, and so will require some degree of improvement, simplification or augmentation if it is to fulfil its intended purpose.

Such augmentation might include helmet mounted displays, new cockpit displays, and line of sight, voice and psychomotor control inputs. Helmet mounted sights are by far the most commonplace of such developments, being now incorporated in most attack helicopters and in the MiG-29, Su-27 and Rafaele. Their most obvious benefits are the ability to project information into the pilot's line of sight regardless of where he is looking, so reducing the need to check the instrument panel, and to point and shoot the fighter's weapons over a far wider arc than with orthodox sights. However, one particular problem pertaining to helmet mounted displays has been complained of already by Apache crewmen of the US Army; the sight is intended to present the pilot with much the same information as a HUD, this involving the projection of multiple figures and symbols onto a 2.5 cm panel over one eye; not only must the pilot absorb this information, but he has to attend to peripheral matters, like the control panel and what is going on outside, simultaneously, with the eye![60] Could a fighter pilot manage this in the midst of a close range turning fight with multiple bandits?

The most interesting concept currently mooted in cockpit displays is the *Big Picture*, a computer screen filling the whole instrument panel area, on which presentations and data can be summoned by touch or lightpen; the *Big Picture* will, amongst other functions, display detected air and ground threats, identified and with the weapons envelopes projected, onto a scrolling map of the terrain over which the mission is taking place, along with the status of one's own weapons, bringing the benefits of having just one source of information to monitor. The *Big Picture* might be linked with the 'Pilot's Associate', a computer matched to the abilities of an individual pilot as well as the capabilities of the aircraft, which can advise, prompt and warn; currently being tested for the US Army's new attack helicopter, the Pilot's Associate will monitor all on-board systems, including the pilot, and, it has been mooted, may be programmed, when circumstances demand, to make certain tactical decisions without reference to the pilot, so blurring the distinction between the manned and pilotless aircraft.[61]

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This begs further questions. Firstly, there is some questions as to the degree of autonomy the machines should be allowed. Should the computers be free to execute decisions without reference to the pilot or crew – like the defence systems on many modern warships – or should it remain in its traditional role of presenting information and executing the pilots commands? For instance, should a Pilot's Associate system be allowed to steer the aircraft out of combat situations its pilot cannot handle? A range of aircraft accidents illustrate the dangers of removing the pilot from the decision making loop. Many modern combat types are fitted with autopilots and Automatic Flight Control Systems (AFCS) which automatically control airspeeds, altitude, descent and climb and flightpath, according to the stage of the mission; in 1988 two RAF Tornados collided over Cumbria, killing all four crew because their computers had been programmed exactly the same, bringing them together at the same place and the same time.[62] Apparently, the pilot must now learn a new skill – judging when to override the machine and exert his own control: however, the plethora of automated systems means he may have little practise at doing this, and fly-by-wire controls may reduce the pilot's 'feel' for the condition of the aeroplane, its reactions to turbulence and atmospheric conditions or its responsiveness to control movements, for instance, which may tell him much about his predicament; he is completely at the mercy of the computer. There are, therefore, hidden dangers even to 'carefree' flying, and one wonders if a warm-up period of delay in this change-over might be allowed for.[63] One wonders also how the operators or remotely piloted fighters might overcome this problem.

The second major problem concerns the reliability of data; presently, even when flying straight and level automated systems do not give the pilot any estimate of the reliability of the data it presents, only displaying the systems' best guess; in the speed and high fluidity of modern air combat, the system will need to process greater quantities of information, and more quickly, and so the solutions it arrives at will become less clear-cut and more probabilistic: it will be apparent from this that the predicted replacement of manned fighters with remotely piloted vehicles, their controllers entirely reliant on electronic data, will present a whole new range of problems. A third issue concerns the pilot's trust in his equipment; this is important as overtrust can lead to a dangerous level of overconfidence and undertrust can lead to stress, unnecessary workload and a drop in combat efficiency. The known level of reliability of a piece of equipment is clearly a determinant of how much its pilots trust it, but, as Green, *et al*, point out, it is also possible that modern displays are so compelling that pilots trust them more than they merit.[64]

Whether future aircraft should be human-centred or automation-centred will be a subject of debate for some time to come, and many fighter pilots have strong opinions on this issue. A Turkish Air Force Colonel told me that he preferred flying the F-104 Starfighter (a type remembered with scant affection in the other air forces, where its sometimes malicious handling characteristics earned it the nickname of the 'widowmaker') to the far more advanced F-16 because it was a 'pilot's aeroplane' and he was 'a pilot, not a computer programmer.' All pilots are proud men and, as we shall see, confidence in their skill and their ability to influence events rather than have events influence them has a major input into combat effectiveness. Many feel that the growing automation of flight and combat systems reduces their relevance to the outcome of events and will perhaps even result in the aeroplane flying *them*, rather than the other way round.[65]

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LIGHT FIGHTERS AND MONKEY FIGHTERS – ANOTHER POSSIBLE SOLUTION?

Another issue is linked to training. It stands to reason that certain minimum standards of technological knowledge and education will be required in order to operate the kind of equipment found in contemporary fighter types and it may be that in some societies, particularly those in the 'Third World', such knowledge and education may be wanting to the point where pilots and technical personnel may not even be trainable on such equipment. This problem may be rectified via technical training provided by more advanced nations but it has also attracted some attention from combat aircraft designers. The demand for fighter aircraft which export customers could both afford and use effectively lay behind the clutch of light fighters produced by certain western nations in the 1960s. These types, the best known of which were the Northrop F-5 Freedom Fighter and the Folland Gnat, were generally smaller and lighter than the bisonic fighter types then appearing,

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and lacked their complex radar and detection systems; indeed, in the F-5, Northrop offered a supersonic, missile armed fighter with systems otherwise not much more complex than those of the Sabre, and sold widely, including to the USAF who used it to simulate Soviet types during fighter training, while the combat prowess of the Gnat – manufactured under licence in India as the *Ajeet* – was demonstrated in the 1965 Indo-Pakistan War, where it brought down a number of Sabres.[66] The Russian approach to the problem was to offer simplified export, or 'monkey' versions of their front line fighters, up to and including the MiG-29, these had less advanced radar, avionics and fire control systems than those available to the Soviet Air Force, this also reflecting the Soviet's reluctance to provide their most advanced technology to possibly unstable allies. With the collapse of the Soviet Union and the resultant in the 'New World Disorder', some manufacturers, seeing potentially lucrative markets, have revived the light fighter concept, recent examples including the BAe Hawk 200 and the Northrop F-20 Tigershark, an up-engined, fly-by-wire derivative of the F-5. It has to be said, however, that these include electronic systems as advanced as those on many front-line types, which perhaps rather defeats the object.

G AND AIRSICKNESS

Another factor possibly influencing the fighter pilot's journey around the Boyd Loop, which is associated particularly with fighters of the jet age, is the physical stress and strain exerted upon him by violent manoeuvre. This is unavoidable; the essence of air combat is to keep one's weapon systems pointing at the enemy no matter what he tries, and this will necessitate increasingly violent manoeuvre as the range closes. The wings of today's jet fighters are stressed to take wing loads of several hundred tons in turns exerting up to ten G: the human frame is not so well-stressed, and G is a perennial problem for fast-jet pilots. If one accepts the models of the Boyd Loop and situation awareness, G can result in the blood column between heart and brain becoming sufficiently heavy to reduce the flow of blood to the brain and upper body, leading to a rapid drop of blood pressure in the eyes and brain, loss of concentration and awareness, blackout and, eventually, to G-Induced Loss of Consciousness (GLOC), a condition which can come on suddenly and without warning, and can last for ten to fifteen seconds. GLOC is a risk usually only in manoeuvres of seven G or above, and so was first encountered regularly during test flights of the F-16, the first type capable of performing such turns without risk to the airframe.[67] Negative G, which occurs during inverted flight, outside turns or loops or in sudden sharp dives, presents problems of its own. The upward rush of blood can result in slowing of the heart, light headedness (at low levels of negative G), severe head pains and haemorrhaging of blood vessels in the brain and eye (at high levels).

The human frame can withstand 3.5 G and minus 3 G in its normal state.[68] The symptoms of G can, to an extent, be reduced by physical fitness, and a pilot can hold off its effects for the few seconds necessary to decide upon and execute a manoeuvre by tensing the muscles in his legs and lower body in order to keep the blood in his head and upper body. He has also received artificial help; anti-G suits were introduced by the USAAF in the Second World War and are now standard issue for all fast-jet pilots. These suits allow the pilot to remain functional, if not exactly comfortable, at stresses of up to seven or eight G. However, as the impact of G on the human frame is largely physiological condition, technology can only reduce its frequency and intensity, not eradicate it altogether; G-suits counteract the symptoms of G, not the effect itself, and then only to around 1.5 G at high G.

Even given G-suits, reclining seats, physical fitness and regular exposure there are few pilots who can withstand more than a few seconds of high G at a time, and it does not take a great deal of imagination to estimate the chances of survival of a 'GLOC-ed' pilot in a close-ranged fight. It may, therefore be that, until we can produce a robot fighter as efficient as a manned one – an impossible dream, in my view – high G turns will have to be used sparingly and sustained G turns kept down to below six G, unless it is necessary to point the aircraft rapidly at a potential target or to turn suddenly to avoid attack.

Less often alluded to is airsickness, which is encountered among combat aircrew rather more than the layman might suppose. Chuck Yeager suffered from violent airsickness on his first flight, but this cleared up once he qualified as a pilot;[69] this seems to confirm Flight Lieutenant John Nichol's suggestion that, as with other forms of motion sickness, the causes of airsickness are partially psychological and 'Navigators are particularly prone to it, just as car passengers are more likely to be carsick than the driver…they are thrown into turns and rolled upside down, with little or no warning.'[70] He goes on to say that there are many experienced RAF Tornado navigators 'who are still sick every single time they fly.'[71] As the navigator plays a vital part in any two-seat type's acquisition and amendment of information this may, in a few cases, affect combat effectiveness, and the RAF at least has given some attention to dealing with this problem, largely through de-sensitivity therapy rather worse than the condition itself.

Chuck Yeager suffered from violent airsickness on his first flight, but this cleared up once he qualified as a pilot...

HUMAN, ALL TOO HUMAN

There are some human factors in fighter combat that are undoubtedly unrelated to technology and never will be. As noted above, the effective completion of the OODA Cycle depends on the efficiency with which one absorbs, interprets and acts upon information. A number of psychological factors can impinge upon this process. Stress results in an increase in the general activation of an individual, which, in turn, affects his perception of information. Under conditions of high stress the rate at which a pilot 'samples' information from his environment will increase, but his pattern of sampling will be reduced to a narrower range as a consequence of his attention being restricted to what he deems to be the primary task, the completion of the mission. This can lead to important information being missed because a pilot's stress response to a situation causes his attention to be blinkered onto the main sources of stress. Of course, individuals differ in the amount of stress that can produce a fall in performance, and how they react to it. As Green and his co-authors point out, the facts of a situation are often of less importance than the interpretation that the individual places upon it, and his perception of his ability to deal with it – and, in our case, that of this aircraft and weaponry.[72]

HUNTERS AND WARRIORS

Probably the most stressful predicament a pilot can find himself in is that of another individual deliberately trying to blast him out of the sky. In the words of the US Air Force song, pilots either live in fame or go down in flame, and the self preservation instinct contributes much towards 'friction.' Fear, panic and excessive caution are certainly not unknown in air combat, Chuck Yeager describing in detail the numerous forms this could take:

> There were guys who became so terrified being in the same sky with krauts that they began to hyperventilate and blacked out; a few actually shit their pants...There were others who talked big during training, but once in combat turned tail at critical

> moments...We also had a few abort artists, guys who would fly with you until a gaggle of Germans was sighted and then radio they were turning back with engine trouble. There were still others who would fire a burst, then quickly break off; or watch somebody else hammer an aeroplane, then, when the German was already windmilling and going down, dive in and fire a quick burst, then try to share credit for the kill...Worst of all were wingmen who left you naked in a tight spot.[73]

General Yeager dismisses these people as cowardly 'weak sisters', and while it is generally accepted that some men are braver, or at least calmer, than others, we might speculate on other factors affecting a pilot's decision to fight or run away. As we have hinted already, confidence in one's equipment may play a part; Mike Spick alludes to a form of 'reverse situational awareness' during the Fokker scourge of 1915, a form of inferiority complex resulting from the perceived invincibility of Fokker *Eindecker*, which often affected RFC pilot's will to fight back.[74] Physical courage, the ability to keep a clear head and so function effectively under conditions of stress bordering on deadly danger, can be expressed in numerous ways – the icy detachment of a Richthofen, the reckless aggression of a Ball, the nonchalance of an Olds, the bloody-minded refusal to give in of a Bader – but at its heart lays supreme confidence in one's equipment and one's ability to make best use of it.

Conversely, Mark K. Wells argues that there is considerable evidence that some steeling of the will is required before opening fire, born from the realisation that the target is not merely a machine, but a vehicle containing one or more human beings whom one could be consigning to a horrible death.[75] History bears him out; Ernst Udet admitted freely that he did not open fire on his first opponent, a French Caudron encountered in December 1915, because he was simply too scared; James McCudden later let a German two-seater go 'because I did not at that time possess that little extra determination that makes one get one's sight on a Hun and makes one's mind decide that one is going to get him';[76] even von Ritchthofen admitted to suffering nightmares about the first British pilot he sent down in flames[77] and the supremely confident Chuck Yeager admitted that years later, he still had images of a German pilot, who jumped from a burning aeroplane without a

Years after the event Chuck Yeager admitted that he still had images of a German pilot, who jumped from a burning aeroplane without a parachute

parachute.[78] Astute leaders would recognise this phenomenon and allow for it; for instance, Werner Mölders, a deeply compassionate man and a committed Christian, was known to have given considerable thought to how a young pilot could gain his first kill without too much trauma.[79] Oswald Bölcke had no such problem with Manfred von Richthofen, recognising, Air Vice Marshal Johnson tells us, that his potential as a fighter pilot was greatly improved by his love of hunting, 'if he had the luck to survive his first few combats he might develop into a ruthless killer, for he was a killer by nature'[80] and one of Richhofen's less endearing practices was the awarding to himself of trophies for Allied aircraft shot down.[81] Hunting is a pastime shared by Mölders, Adolf Galland and Johnson himself, none of whom could remotely be described as 'cold blooded killers.' However, one may wonder whether experience of the stalk and the kill might have additional input into situational awareness and overcoming the psychic barrier against opening fire. The questions on a candidate's sporting interests and knowledge of hunting which formed part of RAF selection boards up to and during the Second World War may have produced a beneficial effect their originators did not intend.[82] Chucker Yeager was also a keen hunter, but he adopted an alternative method of de-sensitisation, by attempting psychologically to de-personalise the fight as much as possible: 'There was no joy in killing someone, but real satisfaction when you outflew a guy and destroyed his machine. That was the contest; human skill and machine performance.'[83]

The questions on a candidate's sporting interests and knowledge of hunting which formed part of RAF selection boards up to and during the Second World War may have produced a beneficial effect their originators did not intend

General Yeager's love of competition, and the Red Baron's trophy hunting, are perhaps rather more significant than they may appear at first glance. Air combat pits against each other relatively small numbers of carefully selected and highly trained young men, in the prime of life and at the very peak of physical fitness. As such, it bears more than a passing resemblance to the clash of champions observable in the warfare of many pre-technological cultures. We can detect in the words, deeds and attitudes of many fighter pilots a survival of the warrior ethic, in which a man's standing amongst his peers is set by his desire to get to grips with the enemy, and kill him in large numbers. It is perhaps not for nothing that Saburo Sakai entitled his memoirs *Samurai*, or that Erich Hartmann was known as the 'Black Knight.' Nor should we ignore the decoration of fighters, from P-40s to Su-27S, with the faces of sharks and mythological monsters, like the shields of ancient Greek hoplites. These may all be eloquent cultural indicators.

LEADERSHIP

Positive psychological factors can be enhanced and negative ones nullified, to an extent, by leadership. The impact of leadership on combat can be measured in terms of results, and it is a noticeable facet of air warfare that, regardless of technological advance, certain units with outstanding leaders, such as Oswald Bölke's *Jasta II*, Douglas Bader's Duxford Wing or Robin Olds' 8th Tactical Fighter Wing, score more victories than others.[84]

It is also noticeable that the commanders of these units were all high-scoring aces themselves; indeed, most outstanding fighter leaders have usually been very effective fighter pilots before and after rising to command. This may arise from a range of factors: as formation leaders, they may have greater opportunity to attack, while their subordinates watch their back, but the ability to awe the enemy and inspire one's own men by personal example is perhaps more obvious. However, we may also argue that the exceptionally high levels of situational awareness required to attain ace status also bestow the ability to appreciate and react to situations beyond one's own personal perception and that leadership itself stems from a form of situational awareness, the recognition of the individual strengths and weaknesses of each man under command, how he will react in any given situation, and how to get the best out of him – a gentle push here, a touch of cajolery there, a boot up the backside somewhere else. Such knowledge can only be acquired through extensive observation of the people under one's command; when Robin Olds assumed command of 8th TFW, he initially flew as 'tail end Charlie' allowing him a good view of how the Wing performed on operations.[85]

A brief overview of fighter combat shows that there are a range of human factors and phenomena affecting the pilot's tactical decision making, observable from the earliest days of air warfare to the present. Some of these factors, such as fear and courage, and an appreciation of the strengths of one's own aircraft against the weakness of one's opponent's have been constant while others, most notably the pace of combat and the impact of pilot mental workload on performance, have become more important over time. All of these have implications for those who must fight in the sky and for those who design the technology they use: it appears that each new labour-saving device carries with it new factors to take into account. We have established that the current emphasis on producing 'neat cockpits' along with the trend towards multi-role capability, will force the pilot to manage more systems, and to make more decisions, at a faster rate, than before, suggesting that an integrated, mission-driven and pilot-centred approach (centred, that is, around the needs of the front-lint pilot) to technology has been lacking in the past and might be of benefit if applied in the future. Ideally, cockpit technology should be designed specifically to smooth the pilot's journey around the Boyd loop at each stage of the mission, not to swamp him with information he might not need; the aim should be to allow the pilot to run his own battle and co-ordinate his actions effectively with his comrades, and to enable him to use his own skill and aggression to hit the enemy hard at the right time and place.

Therefore, it is vital to remember that the fighter is a man-machine system which stands or falls on the performance of the men using it, and the mechanical part of the system only works insofar that it enhances that human efficiency; it must *not* become so dominant that it atrophies the traditional skills and attributes of the pilot. The ideal approach was best summed up by Dr Irving C Statler in a paper on pilot ergonomics presented in 1986.

> The aircrew-aircraft integration problem is to define the satisfactory stability, control and performance characteristics…that, combined with appropriate displays…allow adequate mission performance with tolerable aircrew workload and training (initial and sustainment) for the minimum life cycle cost. (*emphasis* Dr Statler's).[86]

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