Viewpoint

Vulcan Survivability in Nuclear War

By Squadron Leader (Retired) Julian Grenfell

Biography: Julian Grenfell joined the Royal Air Force in 1962 and, after completing Air Electronics Officer flying training, was posted to the Vulcan B2s. Flying on several squadrons during his career he was also the Wing Air Electronics Officer at RAF Waddington responsible for Vulcan aircrew air and ground Electronic Warfare training and assessment. He also flew on Exercise Red Flag and amassed some 4,500 hours flying. After leaving the RAF he worked for several companies specialising in Electronic Warfare. Now retired, Julian is about to publish his book *The Vulcan, Soviet Air Defence, and the Cold War (Vol 1)*, which is due for release later this year.

Introduction

Post the Royal Air Force's nuclear deterrent role, and the end of Britain's V-bomber force, several academic papers have questioned the ability of the V-force to survive long enough over the Soviet Union to release its nuclear weapons onto its Supreme Allied Commander Europe's (SACEUR) targets. Most of the papers argue the V-bomber would come out second best in air-to-air combat at both high and low altitudes. This short paper offers an alternative view to the stereotypical academic paper, this paper based on knowledge of operational matters including aerodynamics, the energy of manoeuvre in air combat, the kinetic and non-kinetic warfare kill chain, electronic warfare, and likelihoods of weapon systems kills, offers an operator's perspective.

History is important to any society for it can show the causes of demographic change, the successes and failures of a society, societal behaviour, and legacies of the past. Most of us of have heard the saying that we learn by history, Winston Churchill said: 'The farther back we look the farther forward we can see'.

However, there seems to be a problem when history includes the application of technology to military operations the nature of which are unfamiliar to many of us. So, our conclusions of V-force survivability are often coloured by a misunderstanding of the way in which technology is applied in war, what I call the sociology of war.[1]

Shortly after the Second World War Britain was to contemplate fighting an air war in an environment that few had flown in. With the dropping of atomic weapons over Japan and the invention of the jet engine, Britain no longer needed to launch thousands of bombers, but could bring about more destruction by using atomic weapons with relatively few high-flying fast delivery platforms. The post war British government's way to the top table of international politics was via possessing a nuclear capability, despite the fiscal strain on the taxpayer and the soaking up of much of the research and development of British industry. Delivery of atomic weapons could be by a bomber, or by an inter-continental ballistic missile (ICBM). Britain lagged behind the US and the Soviet Union in research into inertial guidance and gyros. Britain's home grown BLUE STREAK would not survive a first strike without silos, and Britain's gyros had to be bought from the US. Further, in the early 1960s, the circular error probable (CEP) of an ICBM was some 5 km plus with the warheads measured in kilotons. Whereas the V-bomber CEP was measured in hundreds of metres, with its weapon warhead yield in megatons; consequently, the probability of destruction of an enemy target was very much higher with a bomber, therefore the bomber's target would not need revisiting by other Western nuclear weapon systems.

To write a paper on V-force operations we would need to visit several sources, the sources coming mainly from The National Archives (TNA), professional literature on weapons, operations, politics, the World Wide Web and, sometimes, speaking to the V-bomber crews themselves. The subjects of the sources ranging from political matters to operational matters

such as enemy weapon systems, as well as engineering matters such as aerodynamics and the energy of manoeuvre. One of the most important guides to military operations is its war-fighting doctrine. Thus, here we can argue that air combat is about doctrine versus doctrine, the V-bomber flying at high or low level, and the consequences of the V-force change in air doctrine on the Voiska Protivovos Dushnaya Oberony Strany (PVO-Strany), or Air Defence of the Homeland. The PVO was not the Soviet Air Force, the Voiska Vozdushnya Sily (VVS) was. In no way was the change in British air doctrine to one of low-level a win for the PVO, in my view quite the opposite.

As an aside from my main discussion. On 1st May 1960 Gary Power's Lockheed U2 was shot down by an SA-2 Surface to Air Missile (SAM), with many war studies historians quoting the event as the death knell of the high-altitude bomber. In one sense the historians were correct, but in another sense, they were not correct. In 1958 Britain's Ministry of Supply (MoS) had presented a paper warning that this state of affairs would occur in the mid-1960s; of course, as we now know the event occurred somewhat earlier than the MoS prediction. What was not generally realised was that the Soviet Union had closed all Soviet airspace to non-military air traffic. Powers had entered Soviet airspace from the south at around 75,000 ft flying north for several hours towards Sverdlovsk to take pictures of a Soviet rocket site. The Soviets fired thirteen SA-2s (early missile models) at Power's U2 and scrambled two MiG-19s with orders to ram Powers. It was the first SA-2 that put an end to the U2, but the PVO also shot down one of its own fighters. Despite the lauding of the downing of the U2, the incident was not the success it was made out to be. The PVO learned many lessons from the incident resulting in the Soviet Union refining the world's second integrated air defence system (IADS).

The V-force had two categories of target, a national target and a SACEUR (NATO) target. With the national target it is hard to see a set of circumstances in which the V-force would have been used unilaterally. However, for the SACEUR target it meant the V-force would arrive in Soviet airspace after US ICBMs, but before the US B-52s. The implication here is the physical and electromagnetic degradation of the Soviet IADS owing to nuclear detonation blast and an electromagnetic pulse (EMP). A nuclear detonation comprises blast, radiation, heat, and EMP. The Soviet Union conducted its own surface EMP (SEMP) and high altitude EMP (HEMP) tests and found SEMP to have serious effects on radar, communications, and electric cables even though buried in the ground,

For some, examination of fighter and bomber air combat appears to rest on the metric of co-altitude and ceiling; that is to say, if the fighter is at co-altitude with the bomber the bomber automatically loses. The definition of an aircraft ceiling is when the rate of climb is less than 100 ft per minute, the aircraft possessing very little specific energy. An RAF Lightning at 45,000 ft could not match the sustained 2g turn of the Vulcan B2's 4,000 square ft of wing area, 84,000 pounds of thrust, and low wing loading of less than 50 pounds per square foot. At that altitude the Vulcan's specific excess power (SEP) meant that it could climb in the turn. A Soviet MiG-21 at Mach 1.7 engaging a V-bomber at 55,000 ft, with a ground control intercept

(GCI) stern conversion from head-on, had a two second window between maximum and minimum air-to-air missile (AAM) launch ranges, the MiG-21 itself being limited to no more than 2g at missile launch. At the time in question AAM gyros were caged for half a second after launch, thus at the end of the half second if the target had moved laterally the AAM would have difficulty in tracking the target. The Soviet Infrared (IR) missiles were copies of the US air intercept missile (AIM) 9B, along with beam riders and semi-active AAMs. In the late 1960s and early 1970s in Vietnam, both the AIM 9 and the semi-active AAMs demonstrated very poor performance with an overall probability of kill of less than ten per cent. In order to increase the probability of kill in a stern attack, a first-generation IR missile (of which the AIM-9 was one) had to be launched within ± 30° of the bomber's stern.

The effect of the V-force going low level was to decrease the detection ranges of PVO air defence (AD) radar systems. The PVO IADS radars had different functions such as, long range early warning (EW) radars, examples are TOKEN and TALL KING. The shorter-range higher data rate acquisition radars (ACQ), examples are KNIFE REST and SPOON REST, examples of the fire control or target tracking radars (FC/TTR) are FAN SONG and FIRE CAN. The sequence of events leading up to target tracking are as follows: for a high altitude target the EW radar detects the target at, say, 120 nautical miles (nm) tracks the target in range, height, and bearing. After confirming the target to be hostile, the EW radar hands the target over to the ACQ radar whose job is, with a higher data rate, to provide tracking and hand over the target tracking data to the FC/TTR. The very high data rate FC/TTR will establish the target's speed, direction, height and bearing and will then compute weapon firing solutions for the target in question. For a bomber flying at 300 ft the detection range by the EW radar is relatively short, so the weapon system FC/TTR is now wholly dependent upon the ACQ radar.
We can say for a bomber flying at 300 ft the ACQ detection range is little better than 20 nm. The implication of this is that the ACQ radar does not have too much time to track and hand over the target to the FC/TTR. At 25 to 30 nm from the target, a Vulcan at 300 ft climbs to 1,000 ft and launches its BLUE STEEL stand-off weapon. If the Vulcan is carrying a YELLOW SUN free-fall weapon instead, then at 9 nm from the target the Vulcan would carry out a manoeuvre similar to a toss bombing technique. Headquarters Bomber Command (HQBC) calculated a free-fall warhead detonation would take place before the target defending co-located SA-2 reached the bomber. Assuming the PVO weapon system to be an S-125, SA-3 LOW BLOW/GOA, HQBC's own predictions quoted a sixty per cent survival for a bomber flying at 500 ft. For a bomber flying at 300 ft, the probability of survival was higher; however, should the S-125 fire a salvo of missiles the probability of survival of the bomber was consequently lower. Both the SA-2 and the SA-3 are single fire channel weapons making life difficult for the defenders controlling missile salvos. The high-altitude capability of the S-75 SA-2 was 80,000 ft, while its low-level capability was 3,000 ft on the early models and 1,500 ft on the later models. The search, lock, fire time for the early models was 75 seconds (s) and 45 s for the later models. The S-75 was heavily dependent upon the ACQ radars. The S-125 was used as a low altitude S-75 gap filler. In my opinion, the greatest ground threat to the V-bomber was anti-aircraft artillery.

From the late 1950s towards the mid-1960s the fighter threat was from PVO daylight only fighters with range only air intercept (AI) radars. In the mid-1960s the Soviet fighters began to be equipped with more sophisticated AIs, with look-down-shoot-down AIs appearing towards the mid-1970s. Up until the mid-1970s, the PVO air doctrine was one of rigid GCI. The PVO fighter doctrine for high altitude, was a high-speed single pass attack, the high-altitude training being against non-manoeuvring targets only. For low level altitude attacks, the fighter pilots had to remain in contact with their GCIs and would not engage targets below 1,500 ft (although some may have taken matters into their own hands).

The V-bomber had two concepts of protection. High altitude force protection comprising all eastbound V-bombers switching on their jammers at a certain line of east longitude. For low level, the V-bomber's platform protection was by means of flying the bomber tactically, that is where possible placing high ground between the bomber and the threat system. It is, however, correct to say that the V-bomber's electronic defence equipment did not keep pace with the Soviet threat; in this area V-force crews were let down by those, political and military, who were ill-tutored in electronic combat.

Another aspect of the V-bomber at main and dispersal bases was first strike survivability. The Quick Reaction Alert (QRA) aircraft were at main and dispersal bases and, to begin with, represented the UK's first strike capability. HQBC had in mind a second-strike capability by deploying V-bombers overseas to airfields in Ottawa, Nairobi, St Johns in Newfoundland, and other overseas bases. The second strike foundered on not enough tankers to refuel the second-strike aircraft and, what if the alert was a false alarm? It could be the case that there was a Soviet first strike on or near RAF V-bomber main and dispersal bases. The Ballistic Missile Warning System running from Clear in Alaska to Thule in Greenland, thence to Fylingdales in Yorkshire was an over-the-horizon system that could provide warning of both high and low orbit weapons. The UK warning time of 3.5 to 4.5 minutes (mins) was based on a low orbit weapon detection and the North American Air Defence (NORAD) detection processing time. Of the ICBMs in the Soviet inventory at that time, the most predominant were the 3 to 5 megaton SS-7 and the 1.2 megaton SS-4. A 1.2 megaton weapon dropped on RAF Waddington would have a 2 pounds per square inch (psi) detonation blast radius of some 9 km, meaning that RAF Cranwell, RAF Scampton and RAF Coningsby would be beyond the 2 psi range and the detonation 3rd degree burns range of 12 km. The 2 psi range is important because it was the maximum force the V-bomber could be subject to without damage to the aircraft structure. The implication here is the QRA aircraft on scrambling would have to be beyond the 2 psi range to survive the detonation blast. A reminder here of the V-force alert states. QRA crews would be on a readiness state of 15 mins standby for a launch to war, that is RS-15. A call-out would mean the crews would be at 5 mins (RS-05) for a launch to war. Should the Bomber Controller order 'start engines' or 'taxi', the crew would then be at RS-02, 2 mins to launch to war. If the V-force was scrambled, they were at war. A 4-Vulcan average scramble time was 1 min 53s, the fastest was 56s.

The Soviet hierarchy had a problem, its primary targets would have included the US Minuteman silos for which they needed a large number of weapons. A silo was designed to withstand a very large 1 MT nuclear detonation force of some 3,000 psi at half a mile from the silo. So would placing ICBMs either side of outbound V-bomber tracks considered worthwhile by comparison?

In the early 1960s, Strategic Air Command/NORAD held a large-scale air defence exercise over the US called Operation Skyshield and invited participants from the RAF in the form of eight Vulcans. The Skyshield incoming enemy bombers comprising US B-47s, B-52s, B-57s, and Vulcans, with four Vulcans routed through Bermuda and four Vulcans routed through Goose Bay in Nova Scotia. During the exercise, only one Vulcan out of eight was deemed lost to enemy action. In fact there were two Skyshield exercises, another Skyshield exercise was held the following year with the same outcome for the participating Vulcans. The results of the exercises were seen by the Pentagon as so damaging to US air defence interests that the results of Skyshield I and Skyshield II were not made public until the early 1990s,

If one wanted to train your air force in as near real combat as you could get, you would build a replica combat facility in which red assets operated Soviet procedures, using a replicated Soviet IADS, with red fighters painted in PVO colours attacking blue air assets. This type of exercise was as real as you could get. Such a war training exercise was set up in the US to teach combat pilots air combat before being posted to Viet Nam. Red Flag, as the exercise was called, was flown over the US Nevada training area which provided both simulated, stimulated, and real ground and air threats. The red fighter was the F-5 which had much the same performance as the Soviet MiG-21. Although outside the RAF's deterrent period, the low-level flying Vulcans acquitted themselves well, with usually three out of four participating Vulcans achieving weapon release. In terms of manoeuvrability many observers and authors saw the Vulcan as a faster Second World War bomber, but with a bigger bomb.[2] The Ministry of Supply specification B35/46, inter alia, called for the bomber to be manoeuvrable at height, the Vulcan was, it was also manoeuvrable at low level.

In summary then, what we had was a delivery platform, a V-bomber, whose weapon CEP was orders of magnitude smaller than that of an ICBM; however, the transit time for the bomber was two and a half hours versus 13 to 17 mins for an exoatmospheric ICBM. The bomber's accuracy allowed dropping a single nuclear weapon instead of two or more (to ensure fracturing of silos). I have not yet found any studies in TNA that provide a simulation of attrition rates in the scenarios given above. The above also means that in order to say the V-force would or would not survive is dependent, inter alia, on historical sources of information, knowledge of aerodynamics, air combat, strategy, air doctrines of both sides, operation of air defence systems, to name but a few. It was the professionalism of the crews that largely made up the deficit of modern avionics and modern electronic countermeasures. Today a defensive aids suite (DAS) is a computer-controlled countermeasures suite. The Vulcan ECM was mandrolic; by way of example, the Vulcan Air Electronics Officer (AEO) could be looking at attacking

fighters on his RED STEER rear-looking radar, whilst trying to counter the locked-on fighter AI radar with his RED LIGHT jammer, using the chaff controllers to dispense chaff, and at the same time giving a verbal running commentary to the pilots on the position of the enemy fighters; one is minded of the term 'one-armed paper hanger'. The final irony of the Vulcan was that a few years after handing over the nuclear deterrent to the Royal Navy, Britain's long range conventional bombing capability disappeared, a capability that was so desperately needed a short time later.

In my opinion, a Vulcan flying against SACEUR targets over the Soviet Union would have had a much higher survival rate than some historians maintain.

Notes

[1] Julian Grenfell, *The Vulcan B2, Soviet Air Defence, and the Cold War (The Manned Bomber, its Survival, and Cold War Weapons)*, Helion & Co Ltd, July 2023.
[2] John LeBrun, Anthony Wright, James Vinales, Julian Grenfell, *Flying the Vulcan*, Amazon, October 2022.