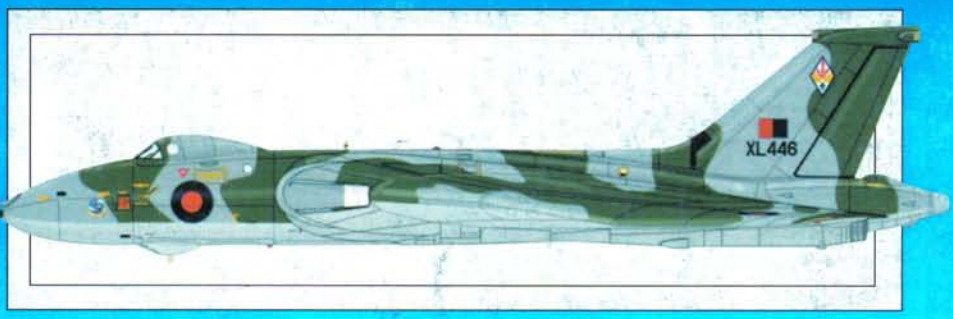


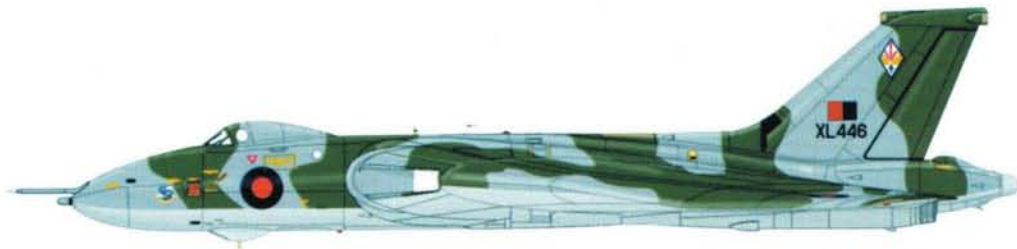
WARPAINT No. 30

Avro VULCAN

B.1, B.1A, B.2 and K.2

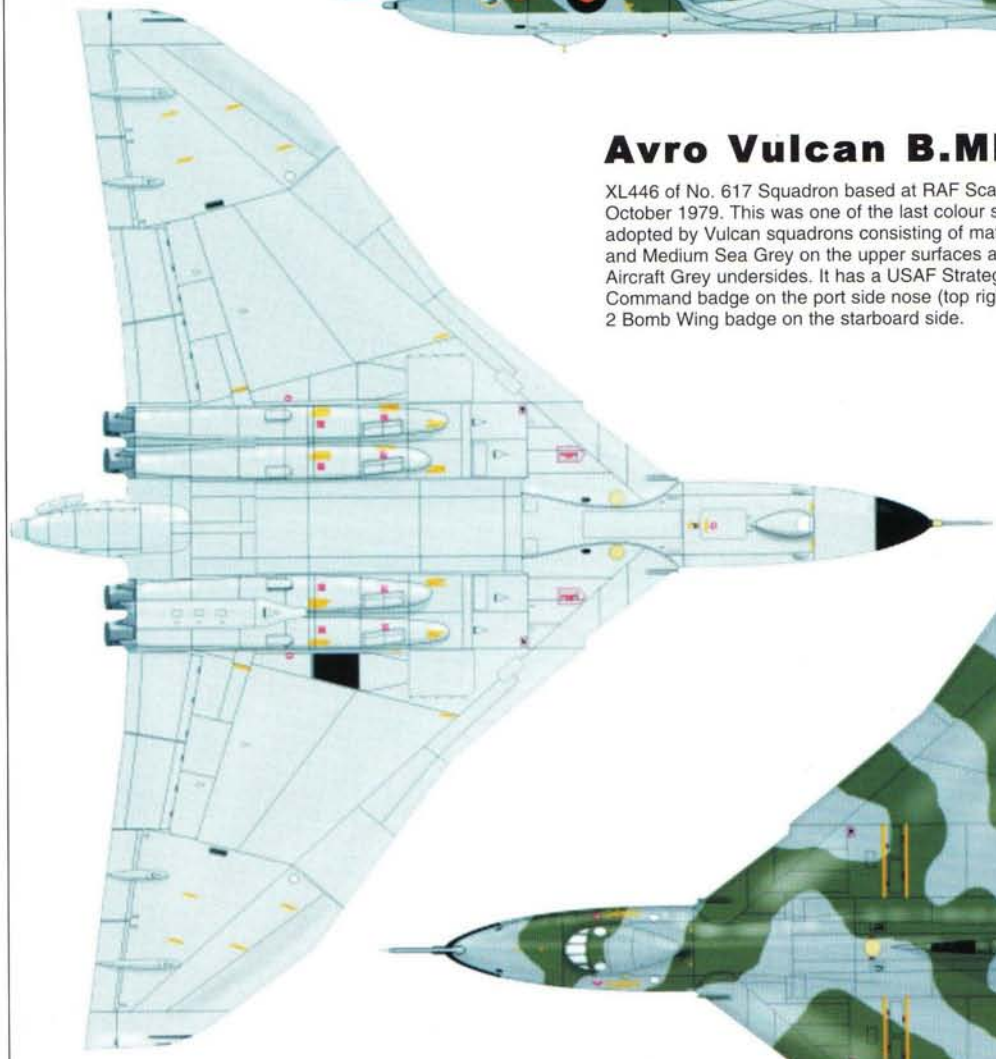
BY KEV DARLING

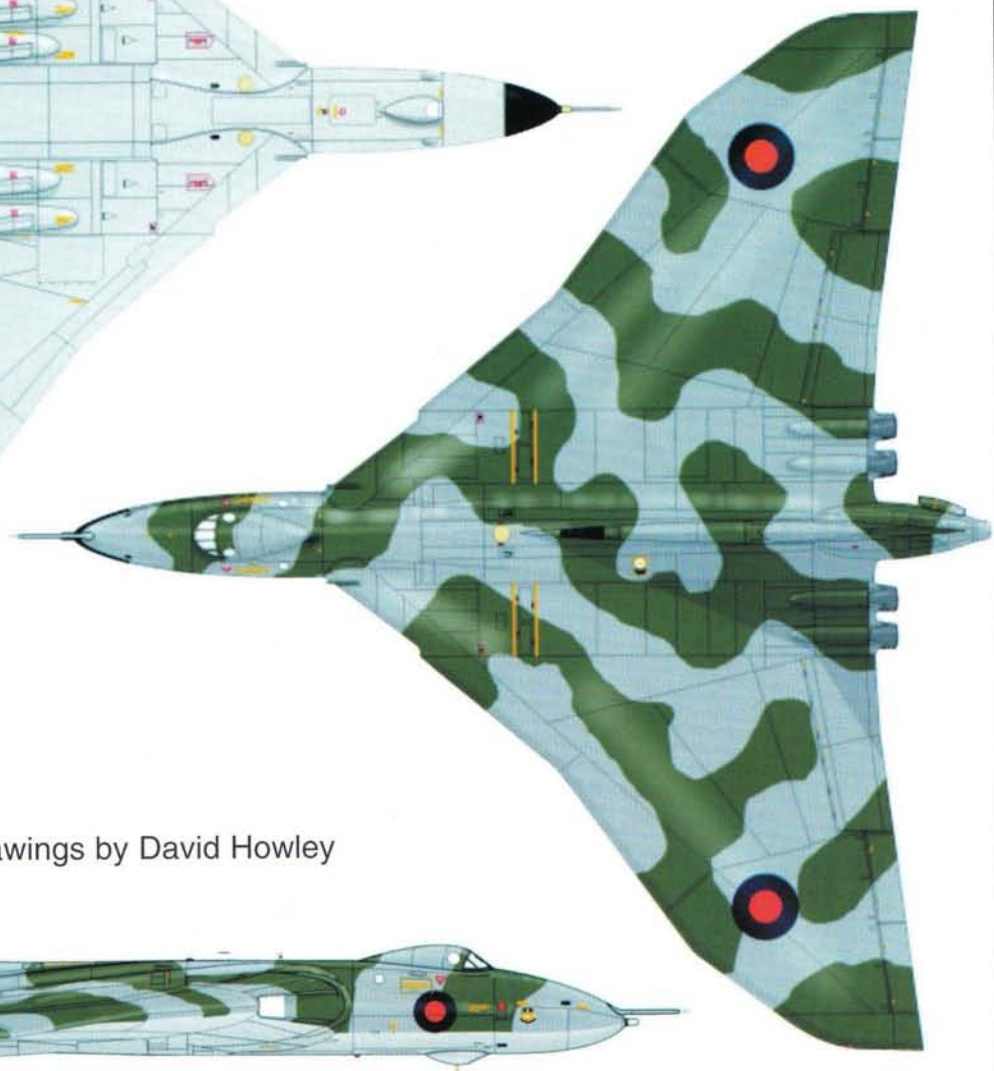
During the mid-1960s Britain's nuclear deterent depended on the Quick Reaction Alert of the 'V' Force and the expected four minute warning of any nuclear attack. These three Vulcans are seen taking part in one of the frequent exercises that took place to test the efficiency of both aircraft and crews to respond within the shortest possible time. (MoD)



Avro Vulcan B.Mk.2

XL446 of No. 617 Squadron based at RAF Scampton in October 1979. This was one of the last colour schemes adopted by Vulcan squadrons consisting of matt Dark Green and Medium Sea Grey on the upper surfaces and Light Aircraft Grey undersides. It has a USAF Strategic Air Command badge on the port side nose (top right) and a No. 2 Bomb Wing badge on the starboard side.





Drawings by David Howley

Avro VULCAN

By Kev Darling

Seen through the eyes of many people, the Avro Vulcan was a star performer at air shows during the summer months and not a vital part of the Royal Air Force's front line deterent. Few will forget the multiple rapid air system engine starts of four of these delta bombers at the end of the runway on the Operational Readiness Platform which was often performed at open days at the Vulcan bases in the north Midlands. Yet this was an essential part of the readiness training programme that was frequently repeated apart from being part of an air show spectacular.

To be able to launch reprisals in the event of an attack on the United Kingdom it was essential that Vulcans, and indeed the other V-bombers that preceded them, should maintain this capability.

The need for rapid reaction of this nature was brought about by three distinctive and important events that were to shape the RAF's policy during peace time. The first of these was the end of World War 2 in Europe and the surrender of all German forces. The discoveries made by evaluation teams sent to discover what secrets the former enemy had been working on revealed, amongst many other things, that their scientists had made great advances in the art of swept wing aerodynamics and the development of the axial flow jet engine.

The second event was the dropping of atomic bombs on Hiroshima and Nagasaki which brought the war to its final conclusion. Thirdly was the creation of the Warsaw Pact alliance centred on the Soviet Union and the threat that this generated to the other European nations who countered by the creation of the North Atlantic Treaty Organisation.

The cold war that was established between these two opposing forces led to a great increase in espionage on both sides which in hindsight could be said to have been weighed in the Soviet Union's favour. They were able to gain knowledge of embryonic nuclear weapons and even built a copy of the American B-29 Superfortress, called the Tu-4 Bull, to carry them.

As far as the RAF was concerned the coming of peace brought massive redundancy with many cancellations of aircraft projects that might have equalled what the Soviet Union was about to achieve. With the main bombing force still equipped with the Lancaster and its, already obsolescent successor, the Lincoln, they were some way behind what was happening on the other side of the Iron Curtain. There was no problem with weight carrying ability, if nuclear weapons were to be used, but the relative slowness of both types made them highly vulnerable to Warsaw Pact anti-aircraft defences. Even the short-term use of the American B-29 Washington in RAF service, was unable to alleviate the situation.

To make matters somewhat worse, Britain lacked its own nuclear weapons development programme. In spite of the fact that

Seen overflying Cottesmore during its last flight before retirement, Vulcan B.2, XH558, was unique in that it first served as a B.2, then a B.2(MRR) and finally as a K.2 tanker. (Bob Archer)

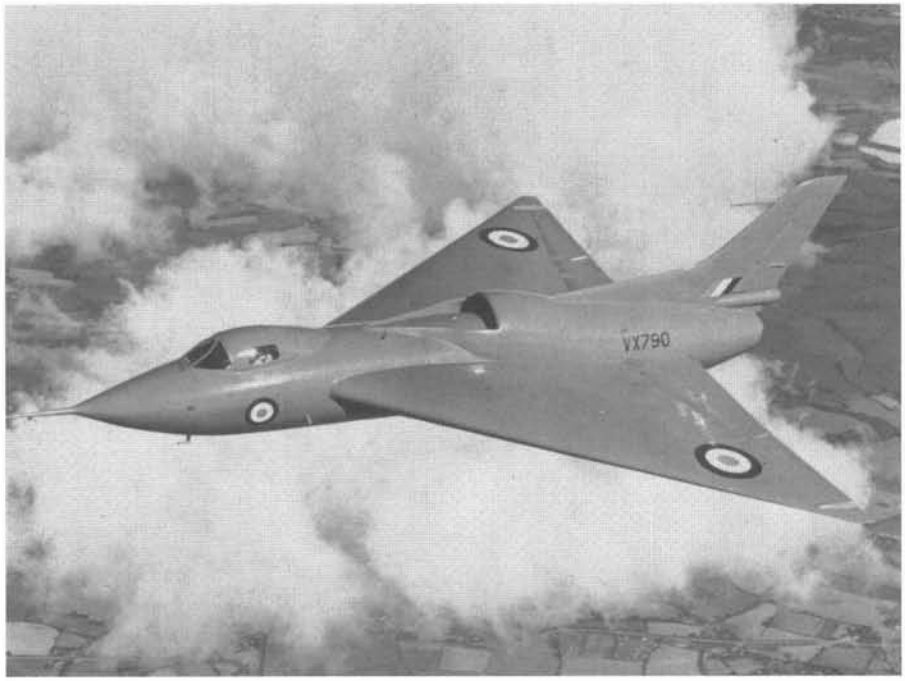
With undercarriage and airbrakes deployed the first Avro Type 707A, VX748, lines up to land at Farnborough. This particular airframe was built to test the low handling performance of the delta wing shape. It was later to be lost when the airbrake circuit malfunctioned, the resulting crash was to prove fatal. (C. P. Russel Smith).

Above: By now named the Vulcan the second prototype is seen landing at Farnborough with its brake chute deployed. By this time many of the features of the production aircraft are now evident including the side mounted tail brake chute bay door. (C.P. Russel Smith)

quite a large number of British scientists were engaged in the American development of atomic weapons and their undoubted contribution to the work going on at the Los Alamos facility, the British team returned home after the defeat of Japan with only a part of the knowledge required to duplicate what had been done during the war due to the passing of the McMahon Act which forbade the export of nuclear technology outside the United States.

The British government realising the importance of having nuclear weapons set up their own research and production facility at the Atomic Weapons Research Establishment at Harwell and were able to produce their first atomic bomb which was then successfully exploded on 3 October 1952 mounted in the redundant warship *HMS Plym* anchored within the bounds of the Monte Bello test area. Code named 'Hurricane' this device lead to the further development of the RAF's own air-dropped weapon shortly afterwards which became known by the code-name 'Blue Danube'.

By present day standards this was a large and heavy weapon weighing some 10,000 lbs. and although current in-service aircraft could easily carry it, the need for much faster, higher flying, jet powered bombers had by then become a matter of great urgency.

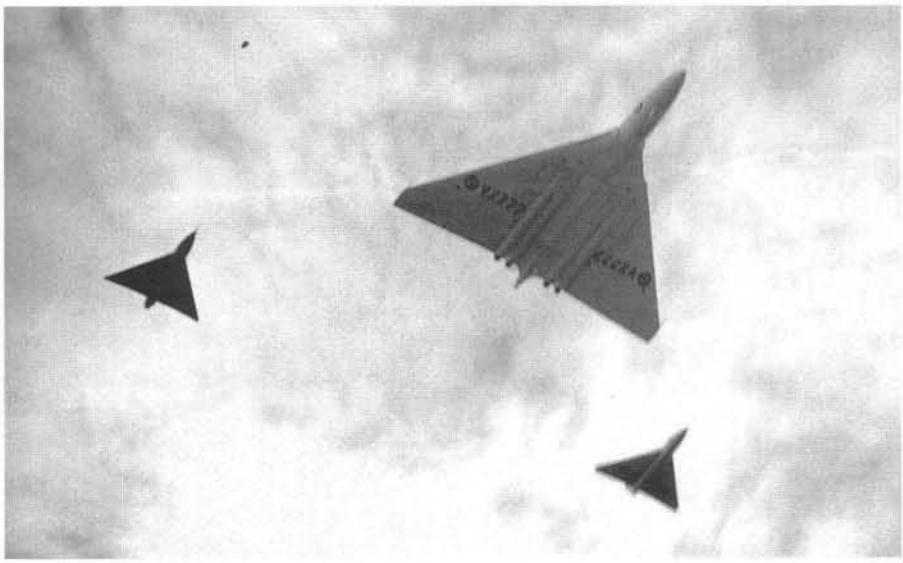


Above: Type 707B, VX790, was built to replace the lost VX784 in the low speed handling programme. Reflecting the developments in the full size aircraft a more defined nose was built into this aircraft. (Avro Heritage/ BBA Collection)

NUCLEAR BOMBER DEVELOPMENT

Britain's development of jet engines, knowledge gained from German research and the undoubted ability of the British aircraft industry was put to work to develop bomber aircraft capable of achieving and surpassing anything else that was likely to come from the Soviet Union.

Transonic flight had by then become well within their grasp although practicabilies had to be overcome. To define policies and establish research leading to new aircraft the government set up the Defence Policy Steering Group in 1947 charged to set parameters for overall new weapon development in the following ten years. Both representatives from the aircraft industry, the research establishments and the armed forces were co-opted to see that, in theory, Britain with a strong nuclear arsenal and acting within the bounds of NATO and the Western Union, could achieve a large measure of equality



The first prototype Vulcan VX770 seen with two Avro 707 small scale aerodynamic test aircraft that helped prove the viability of the design. The picture was taken at the 1954 Farnborough air show. (Alan W.Hall)

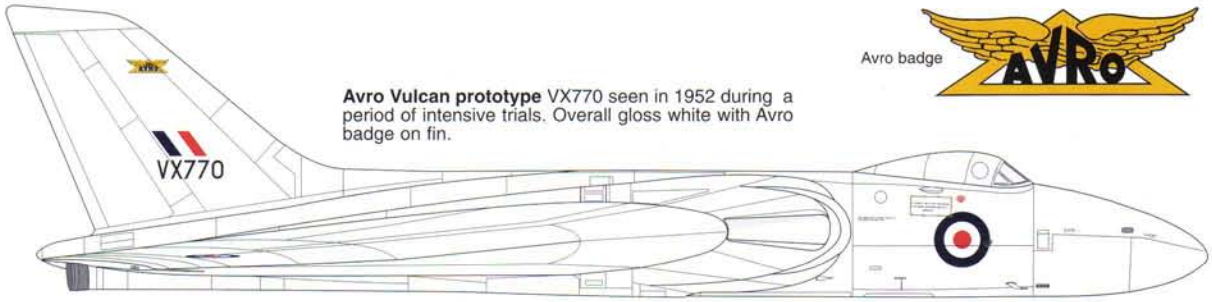
Avro Vulcan camouflage and markings

AVRO VULCAN COLOUR KEY

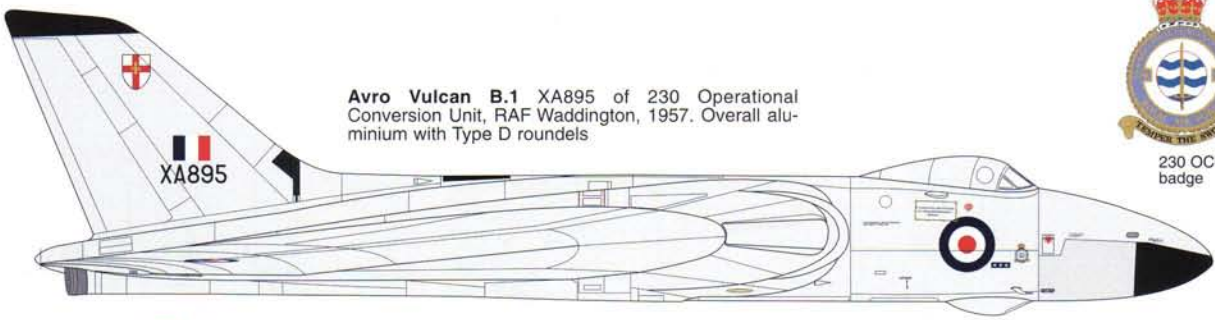
Drawings by David Howley

Black	White	Yellow	Roundel Red	Pale Roundel Red	Roundel Blue	Pale Roundel Blue	Aluminium	Dark Green	Dark Sea Grey 638	Medium Sea Grey 637	Dark Slate Grey	Sky Grey (RCN)

Avro badge



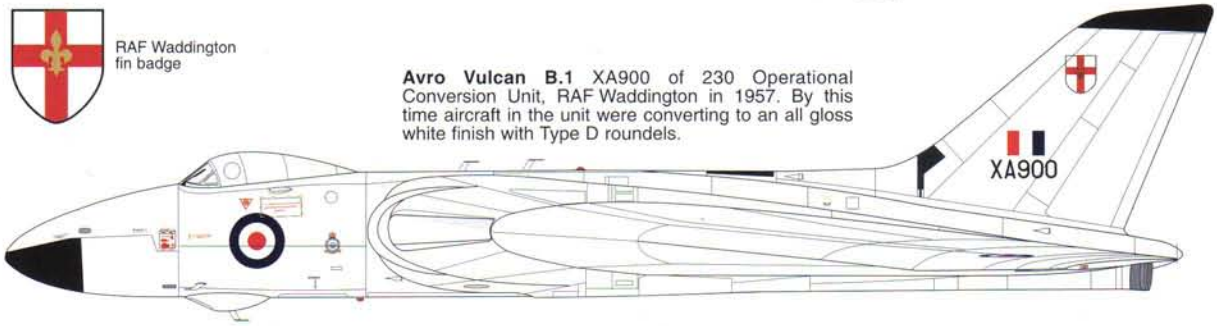
Avro Vulcan prototype VX770 seen in 1952 during a period of intensive trials. Overall gloss white with Avro badge on fin.



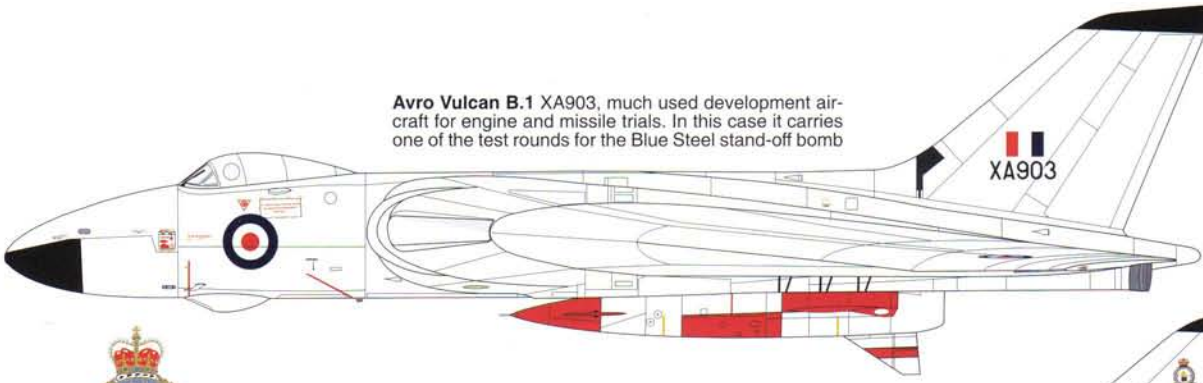
Avro Vulcan B.1 XA895 of 230 Operational Conversion Unit, RAF Waddington, 1957. Overall aluminium with Type D roundels

230 OCU badge

RAF Waddington fin badge

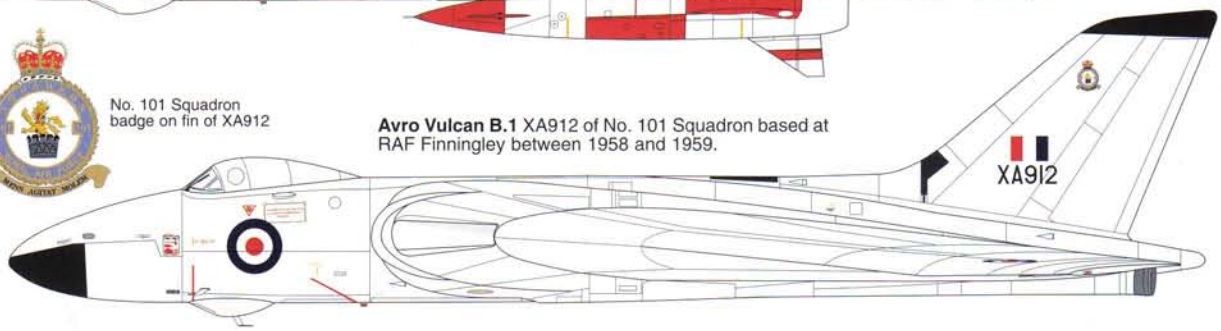


Avro Vulcan B.1 XA900 of 230 Operational Conversion Unit, RAF Waddington in 1957. By this time aircraft in the unit were converting to an all gloss white finish with Type D roundels.

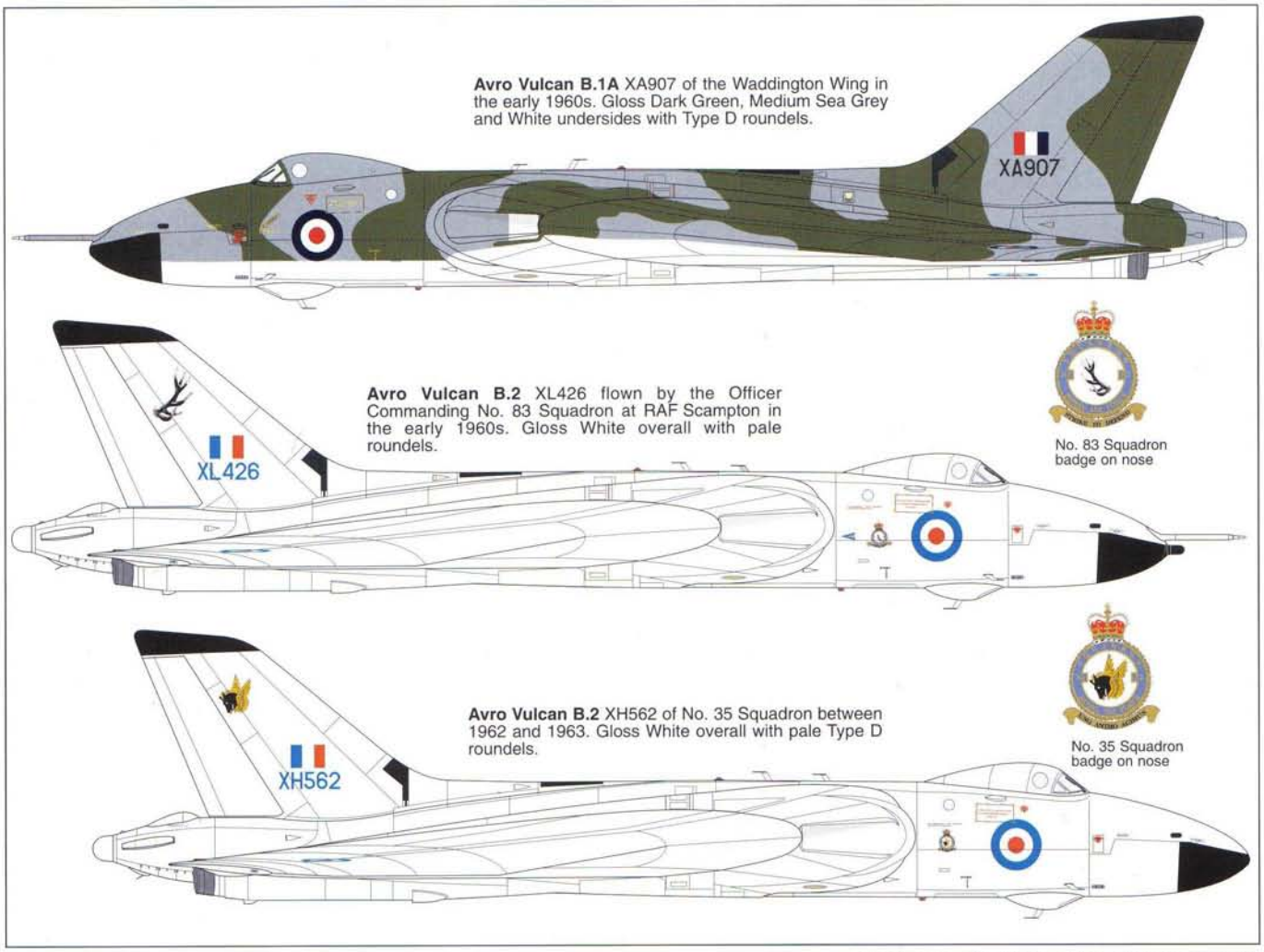


Avro Vulcan B.1 XA903, much used development aircraft for engine and missile trials. In this case it carries one of the test rounds for the Blue Steel stand-off bomb

No. 101 Squadron badge on fin of XA912



Avro Vulcan B.1 XA912 of No. 101 Squadron based at RAF Finningley between 1958 and 1959.



Avro Vulcan B.1A XA907 of the Waddington Wing in the early 1960s. Gloss Dark Green, Medium Sea Grey and White undersides with Type D roundels.

Avro Vulcan B.2 XL426 flown by the Officer Commanding No. 83 Squadron at RAF Scampton in the early 1960s. Gloss White overall with pale roundels.

No. 83 Squadron badge on nose

Avro Vulcan B.2 XH562 of No. 35 Squadron between 1962 and 1963. Gloss White overall with pale Type D roundels.

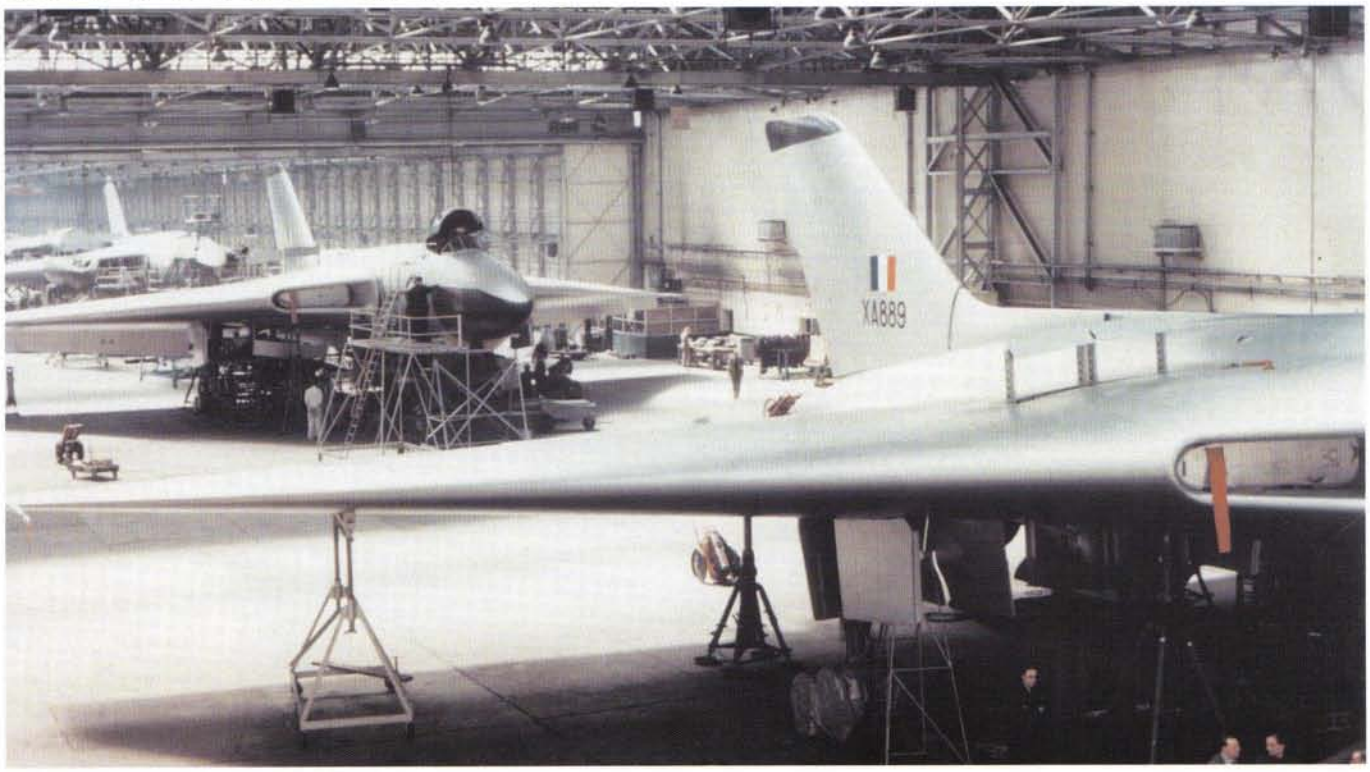
No. 35 Squadron badge on nose

with other major powers.

At this point the Air Ministry issued Operational Requirement OR.229 to define the new bomber part of which was the option to install tail armament should it be required. This called for an aircraft capable of carrying the 'Blue Danube' weapon at a speed of 500 kts and be capable of dropping it from a height of 45,000 feet with a still air range of 3,500 miles. These figures were later increased to cover an altitude of 50,000 ft and a range of 5,000 miles.

Having issued their requirements the Air Ministry passed these to the Ministry of Supply following standard procedures. They in turn contacted those companies within the

Seen on the production line at Chadderton are the first three production Vulcan B.1s. These early airframes featured the extra airbrakes on the lower wing surface although these were later deleted. XA899 was used at Patchway, Bristol, for Olympus engine trials, whilst XA890 was used for avionics testing. The third aircraft, XA891 was also used for engine development in this case for the Olympus 200 series for the Vulcan B.2. (Avro Heritage/BBA Collection).



Above: Vulcan XA899 at a later stage in its life. By this time the modified wing leading edge plus vortex generators had been fitted thus improving the aircraft's performance. The machine achieved a measure of fame when it completed the world's first automatic, hands off, landing at RAE Bedford. (Avro Heritage/BBA Collection). Right: This early picture of the all-white first prototype reveals the underwing air brake, that was later deleted as superfluous, as well as an extra pitot head mounted on the tip of the all-metal nose. The badge at the top of the fin is that of Avro and note the absence of the bomb aimer's blister. (C.P.Russell Smith Collection)

aircraft industry who were thought capable of building such an aircraft and at the same time issued Specification B.35/46 to cover the design work.

Officialdom added further requirements to the original Specification which included the ability of the aircraft to accommodate any other weapons that were then being developed and to be able to carry a reconnaissance package in the bomb bay. The all up weight was set at 100,000 lbs although this grew to 115,000 lbs on the premise that the operating airfields infrastructure would be strengthened to carry the new bomber. Further definition of altitude set the initial operating height at 45,000ft although this was required to increase to 50,000 ft some two hours into a mission as fuel was consumed.

Wartime experience of bomber crews also led to the belief that greater manoeuvrability would be an asset especially over a great range of heights and speeds. A throw back to the war also required the fitting of tail armament though the exact nature of this was not specified.

Radar emerged as one of the primary advances fitted to aircraft during the war. That fitted to the then current Bomber Command aircraft, the H2S, was chosen as the primary navigation and attack system due to its ability to define targets clearly from an altitude of 20,000 ft. To operate the new aircraft a crew of five was settled upon. This was to consist of two pilots, two navi-

One of the first Vulcan B.1s to reach an operational RAF Station was XA898 which went to 230 Operational Conversion Unit at Waddington. (APN)

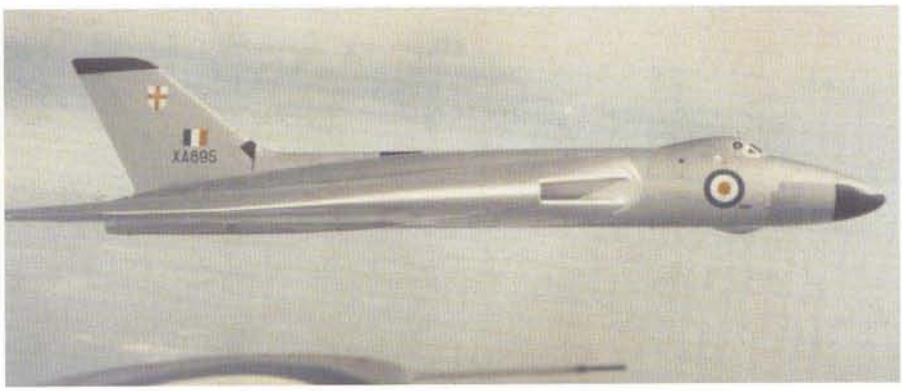
Three operational Vulcan B.1s in formation showing off their distinctive delta planform. The lead aircraft, XA896, later moved to Bristol Siddeley for use in the later cancelled BS100 vectored thrust engine. The left hand Vulcan, XH504, later became a B.1A with the Waddington Wing and a similar fate befell the final aircraft, XH503. (via Tony Buttler)

gator-bombardiers and a radio-ECM operator. The latter was to be a first in British military aircraft. Unlike previous bombers the complete crew were to be housed in a single pressure cabin that could, in theory, be ejected from the airframe by means of explosive bolts.

This project was very advanced technically and was to take British aeronautical engineering further than ever before. The Ministry of Supply decided that a limit of six companies in the industry should be allowed to bid which included Avro, Armstrong Whitworth, English Electric, Handley Page, Short Bros and Vickers.

On 9 January 1947 all were asked to tender for Spec B.35/46 and each delivered their proposals during that year. Because these designs were so far in advance of the Avro Lincoln that equipped Bomber Command at that time, the decision was also taken by both the MoS and Air Ministry to pass the proposals on to the Royal Aircraft Establishment, Farnborough for further analysis.

A committee known as the Advanced Bomber Group whittled down the design proposals to the Avro 698, later known as the Vulcan, and the Handley Page HP.80, the Victor. The third aircraft chosen was the Vickers entrant, later the Valiant, which because of its simpler design became the first 'V' bomber to enter service. A standby



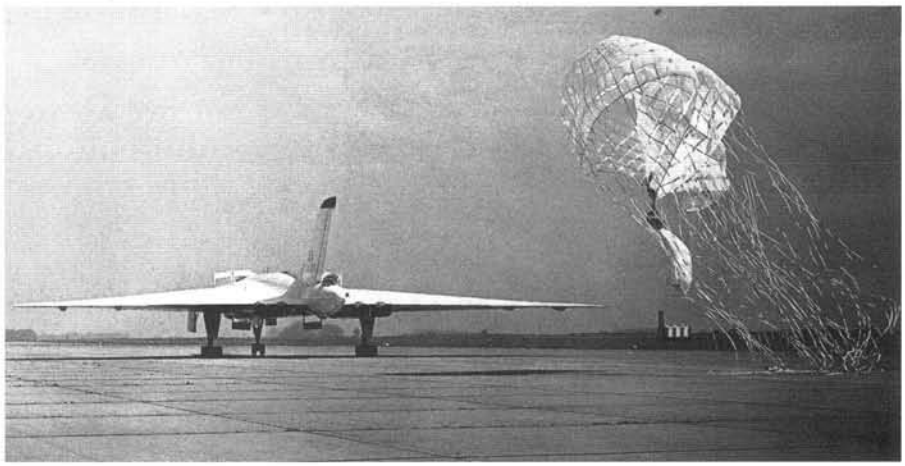
Above: Photographed from a Meteor chase plane, Vulcan B.1, XA895, wears the fin badge of 230 OCU. Even after conversion to B.1A standard, the aircraft remained with the OCU although it did spend some time with the Bomber Command Development Unit. (Avro Heritage/BBA Collection). Below: Vulcan B.1, XA903, eventually became the test aircraft for almost every possible project. Here it carries the gaudily painted Blue Steel test round. By the time the airframe was retired it had been modified so much that a regular Vulcan crew would not have recognised much in the cockpit.

design to a different Specification, B.14/46 was awarded to Short Bros to build the SA.4 Sperrin. Although the prototype flew in August 1951, the aircraft was already slated for cancellation as its technology was seen as 1940s plus jet propulsion. In contrast the MoS issued an 'instruction to proceed' to Avros as by then the need for a new bomber had become paramount.

EARLY STAGES

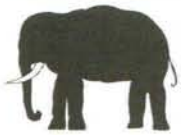
Design work on the Avro Type 698 began almost immediately under the aegis of the Avro Project Office. It was understood from the outset that swept wings and jet engines were to be the basis of the design but Avros had little pervious experience in this area of aeronautical engineering - they were starting with a completely blank sheet of paper. A decision was taken that the aircraft ought to be of delta wing shape which would allow the aerodynamicists the opportunity of being able to alter the angle of sweep back on the wing leading edge whilst at the same time allow internal fittings plenty of room to be accommodated.

Avro's Technical Director, Roy Chadwick, famous for his design of both the Lancaster and Lincoln, oversaw the project, though his input was more political than practical, albeit that he was involved in the first stages of the design. Concern had been expressed by news from America that the Northrop



Above and below: These two picures were taken at the Press open day at RAF Scampton when No. 83 Squadron was on show. A demonstration flight was accompanied by the use of the tail braking chute seen deployed above, and below, its release. Normally this would have been done at the very end of the runway to be collected by the Safety Equipment Section for repacking but, in full view of the cameras, it was released early as part of the demonstration. (Alan W.Hall)

Nine of No. 83 Squadron's all-white Vulcans were shown off to the Press at Scampton in the early 1960s. Normally the aircraft would have been dispersed around the airfield perimeter.



No. 27 Squadron green elephant on fin

Avro Vulcan B.2 XM570 of No. 27 Squadron at RAF Scampton between 1962 and 1963. Gloss white overall with pale Type D roundels.

No. 12 Squadron badge on nose partly repeated on fin

Avro Vulcan B.2 XJ781 of No. 12 Squadron at RAF Coningsby during 1963. Overall gloss white with pale Type D roundels.

No. 617 Squadron badge on nose

Avro Vulcan B.2 XL321 of No. 617 Squadron at RAF Scampton between 1963 and 1964. Fitted for Blue Steel operations. Overall Gloss White with pale Type D roundels and squadron insignia on fin.

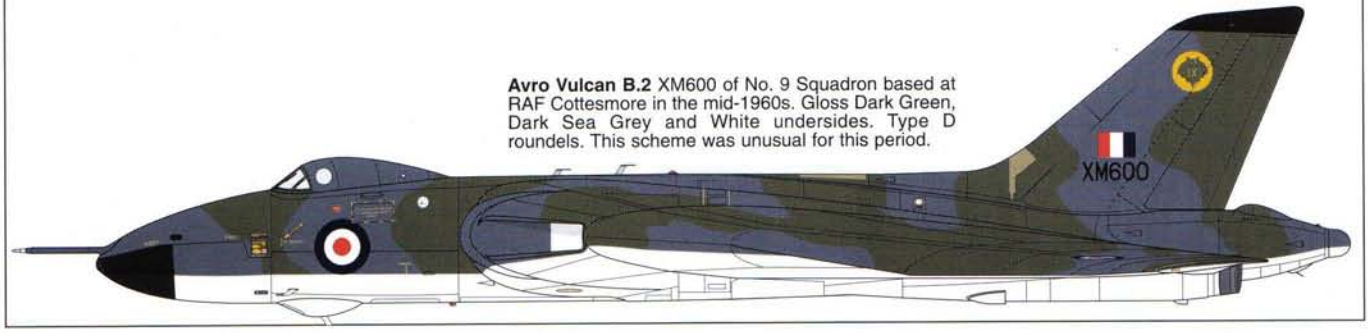
230 Operational Conversion Unit badge on nose and fin

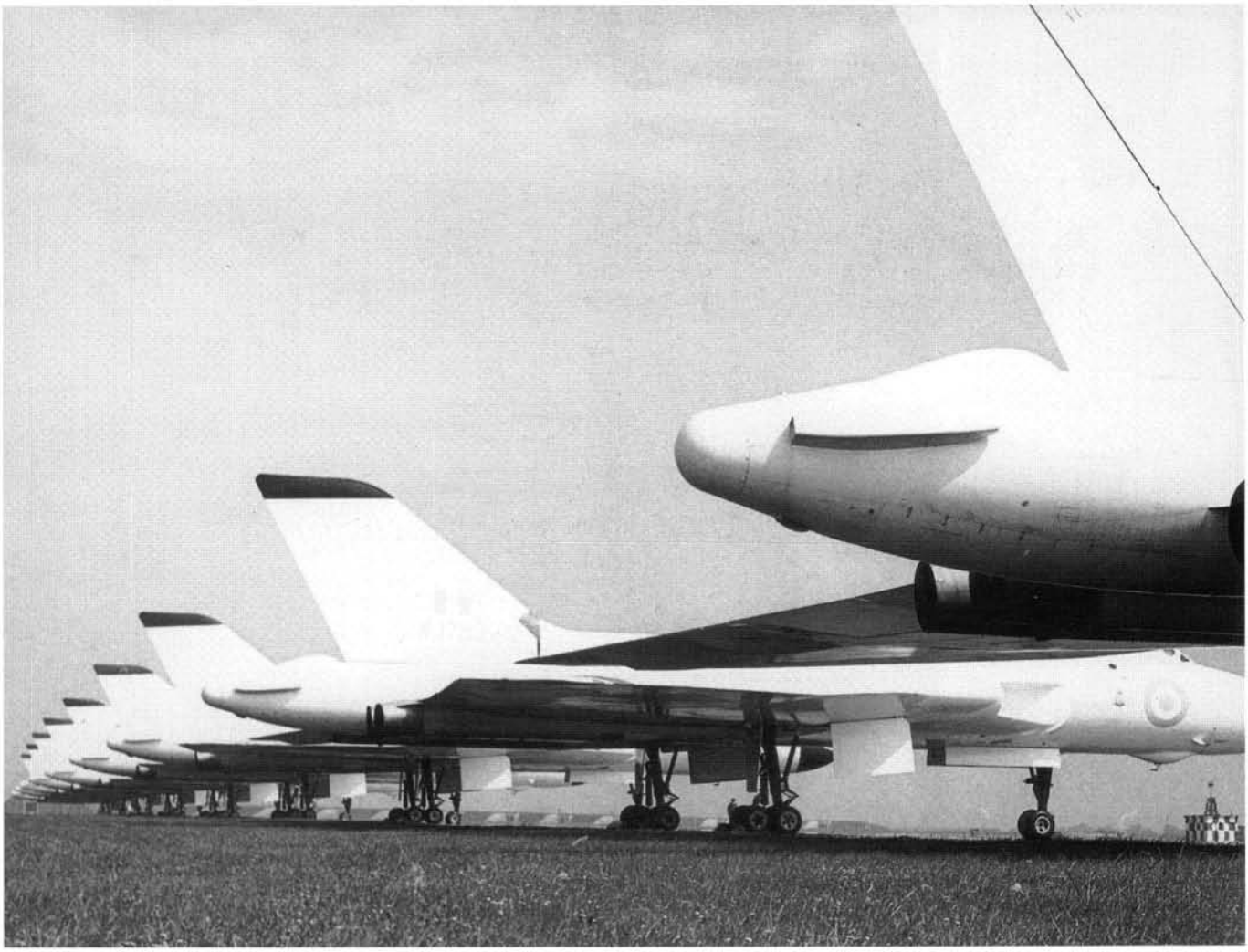
Avro Vulcan B.2 XJ824 of 230 Operational Conversion Unit, RAF FInningley between 1963 and 1964. Overall gloss white with pale Type D roundels and unit insignia.

No. 9 Squadron badge on fin

Avro Vulcan B.2 XM648 of No. 9 Squadron based at RAF Cottesmore in the mid-1960s. Gloss Dark Green, Medium Sea Grey and White undersides with Type D roundels.

Avro Vulcan B.2 XM600 of No. 9 Squadron based at RAF Cottesmore in the mid-1960s. Gloss Dark Green, Dark Sea Grey and White undersides. Type D roundels. This scheme was unusual for this period.





Another view of the Press open day at Scampton when No. 83 Squadron's nine aircraft were on display. (Alan W.Hall)

Flying Wings, which at that time had just made their maiden flights, were experiencing longitudinal stability problems. Consequently the Avro design grew a short forward fuselage which allowed the bomb bay to be placed in the middle of the aircraft instead of outboard of the undercarriage bays as originally conceived. A further change also saw the disappearance of the wing tip fins and moving wing sections. These were replaced by a more conventional swept fin with ailerons and elevators being located along the wing trailing edges. It was at this time that tragedy struck Avro's when Roy Chadwick was killed in the crash of a prototype Avro Tudor.

RESEARCH PROTOTYPES

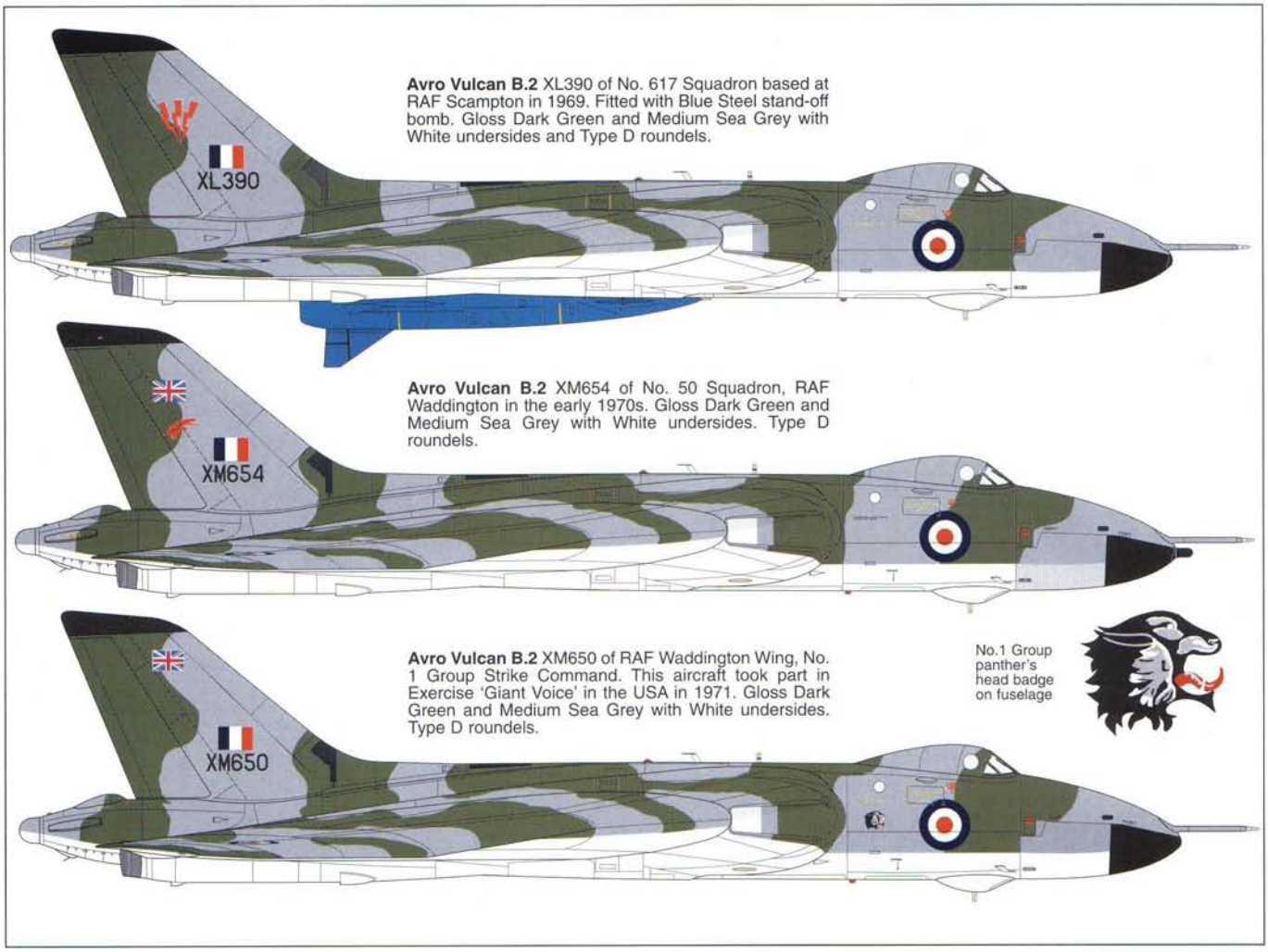
Although Chadwick's death was a great loss to the company, design work carried on. Due to the advanced nature of the design and the need to provide practical definition of the delta shape both Avro and the Ministry of Supply agreed that some sort of research vehicle would be required to confirm the behaviour of the delta wing and eventually the power controls used to drive the flying control surfaces.

The additional programme was to be known as the Avro Type 707 and 710. The former was a Derwent-powered low speed handling aircraft whilst the latter was intended for high speed, high altitude research powered by a pair of Rolls Royce Avons.

Further consideration led to the cancellation of the Type 710, the programme being concentrated on the Type 707 only. Construction of the first of these began in 1948 with the first version VX784, being rolled out in August 1949. Taxi trials and engine runs were followed by a move to A&AEE Boscombe Down where the first flight took place on 26 August. In the following month enough test flying had been accumulated to allow the 707 to appear at that year's SBAC show at Farnborough. Once the public appearances were over test flying continued although the aircraft was to crash on 30 September because of a failure in the airbrake control circuit that led to an un-recoverable stall.

Subsequent investigation proved that the basic design was faultless therefore another Type 707 was authorised. Designated the Type 707B, VX790 was built to Specification E.10/49 and made its first flight after rollout on 6 September 1950. Changes from the first aircraft included the installation of an ejection seat in a more

RAF Scampton's Operational Readiness Platform with four Vulcan B.1As of No. 35 Squadron ready for a four minute take-off. Two of the aircraft have yet to be fitted with in-flight refuelling equipment and lack the nose probe.



Avro Vulcan B.2 XL390 of No. 617 Squadron based at RAF Scampton in 1969. Fitted with Blue Steel stand-off bomb. Gloss Dark Green and Medium Sea Grey with White undersides and Type D roundels.

Avro Vulcan B.2 XM654 of No. 50 Squadron, RAF Waddington in the early 1970s. Gloss Dark Green and Medium Sea Grey with White undersides. Type D roundels.

Avro Vulcan B.2 XM650 of RAF Waddington Wing, No. 1 Group Strike Command. This aircraft took part in Exercise 'Giant Voice' in the USA in 1971. Gloss Dark Green and Medium Sea Grey with White undersides. Type D roundels.

No.1 Group panther's head badge on fuselage

defined forward fuselage. The undercarriage nose leg was also longer which improved the wing's leading edge angle to the airflow thus shortening the take-off run.

In spite of the first two Type 707s having proved the aeronautical concept it was decided that a third airframe would be needed to speed the design studies. Designated the Type 707A this machine was a further stage ahead in Avro's eventual concept of what the Type 698 would be like. Serialled WD280 it had wing root air intakes, powered flying controls and was in fact very similar to the eventual full sized bomber. Further versions of the Type 707 were later built for use by the RAE for their own experimental purposes.

ENTER THE VULCAN

The first Type 698 prototype continued with Avro's having received a contract for the first 25 airframes. Type 698, serialled VX770, was rolled out in early August 1952 in a gleaming white finish and the first flight was undertaken by the Chief Test Pilot Roly Falk on the 30th of that month.

As it was of importance to get the prototype into the air many of the systems were either missing or disconnected. Chief amongst these was the second pilot's seat and the wing fuel system. The original design of the aircraft was always conceived, up till then, as being a single pilot operation but as the work advanced it was seen as being ridiculous that such a complex aircraft and the lives of three other aircrew would be

Above: Vulcan B.1, XA894, was used as a testbed throughout its short career. Here it sports the test installation required for the Gyron Junior engine. This aircraft was later used as a trials vehicle for the Olympus 22R engine destined for the TSR.2. It later burnt out on the ground during full power engine runs. (C.P.Russell Smith Collection). Below: The test installation for the forthcoming Tornado engine, the Turbo Union RB.199, seen under XA903 at the 1979 Farnborough air show, (RAE Farnborough)

Not the normal sight of a Vulcan, however, it does display the aircraft in its landing configuration. The main gear bogies are in the normal trailing attitude whilst the airbrakes are in the mid-drag position. The aircraft is a B.1 version and this view reveals the cranking of the wing's leading edge required to improve the type's performance. (Tony Buttler Collection)

entirely dependent on one man.

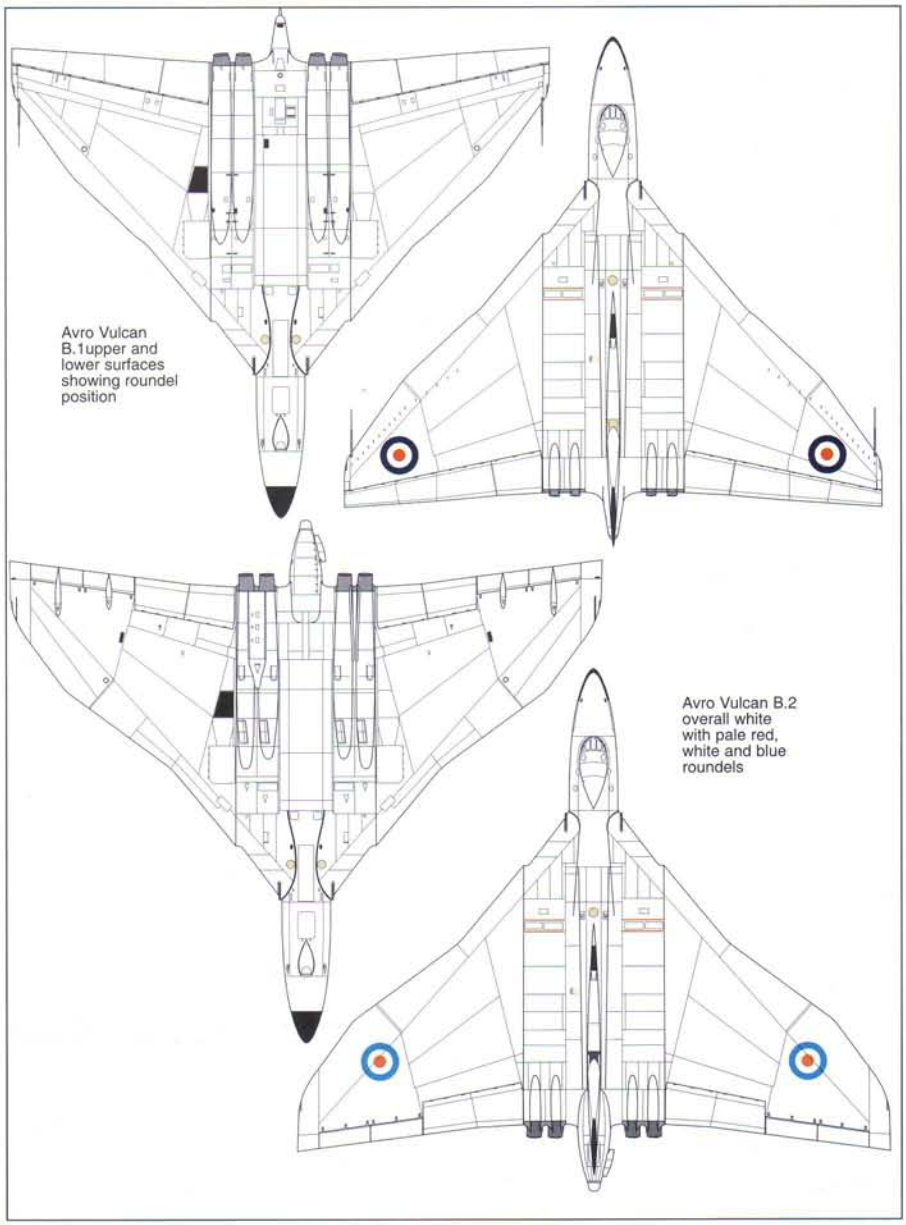
The first flight was not without incident as the nosewheel leg gave a red light indication on retraction whilst the fairings to the rear of the main legs were torn off by the slipstream. The red light was traced to a maladjusted microswitch whilst the fairing problem was cured by strengthening the mountings.

In October 1952 the aircraft was finally named the Avro Vulcan, a continuation of the 'V' Bomber theme.

With the name having been chosen, the real work of updating the prototype to full status continued, thus the fuel system, cabin pressurisation and the second pilot's seat were installed. Other improvements included a revamp of the ergonomics of the pilot's instrument panel, at the suggestion of the Chief Test Pilot, and the inclusion if a fighter-type control column which was seen as a great boon by service pilots.

In their haste to get the prototype airborne Avro had to settle for the installation of Rolls Royce Avon engines instead of the intended Olympus power plants. First runs of the BE.10 Olympus were undertaken on 6 May 1950 with pre-production versions first appearing in the second Vulcan prototype, VX777, which was rolled out in August 1953. This aircraft made its maiden flight on 3 September 1953, a week before its appearance at the SBAC show. This was the occasion when the first prototype flew past the crowds in formation with two of the Type 707s and resulted in some excellent publicity photographs

Flying with VX777 was interupted whilst a fuel and engine imbalance problem was



Displaying the full plethora of anti-flash white, Vulcan B.2, XJ781, was in use with No. 83 Squadron. It was later damaged beyond repair during a crash landing at Shiraz, Iran. (Avro Heritage/BBA Collection)

cured although it was suspended for far longer than intended after the aircraft was damaged in a heavy landing on 23 July 1954. The repair period allowed time for the installation of uprated Olympus 101 engines. At the same time the original prototype was also re-engined with Olympus power plants allowing the full flight test programme to be resumed.

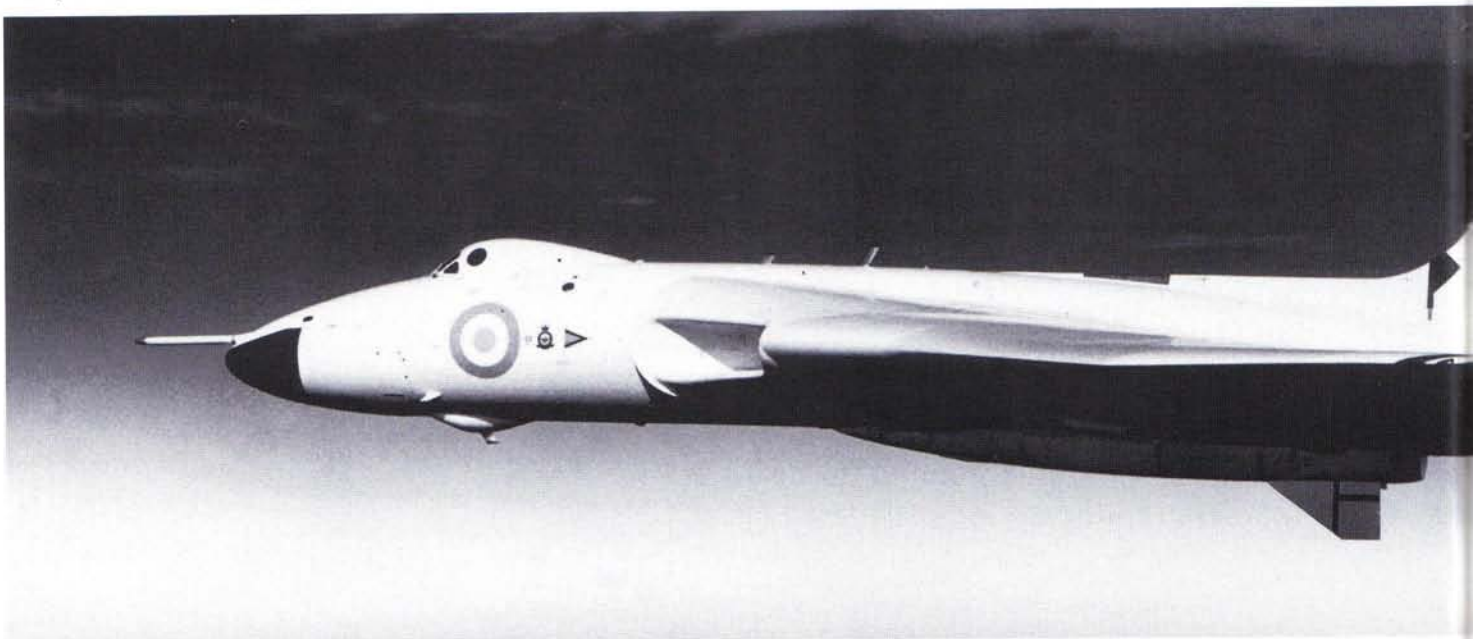
WING REFINEMENTS AND PRODUCTION

It was at this point that a serious and unforeseen problem arose. The ability to fly faster and higher revealed that the wing compressibility had been miscalculated. This showed that if the aircraft was manoeuvred by more than a gentle 'g' application there would be a mild high frequency buffet. Although this occurs to some degree with most aircraft its consequences, should it not be rectified, could cause the aircraft to break up. From Avro's point of view, however, their main worry was that if uncorrected there would be a deprecation in range, performance and bombing accuracy.

Curing this problem required the installation of a new wing leading edge although this remedy was too late to incorporate in the first production aircraft. To reduce the Vulcan's tendency to pitch nose downwards auto mach trimmers were installed into the flight control system whilst pitch dampers were installed to control the pitching at high speed. To improve the airflow over the flight control surfaces a series of vortex generators were installed on the wing uppersurfaces.

With the changes to the wing shape and other refinements, the rollout of the first Vulcan B.1 took place in January 1955. Changes from the prototypes included the provision of a Hycar fibreglass radome in the nose that covered the H2S radar scanner. A slightly longer fuselage meant that the original telescopic nose leg could be replaced by a normal unit. The increase in fuselage length also meant that the fuel load could be increased thus extending the aircraft's range.

The success of the prototypes and the roll out of the first production Vulcan allowed the Ministry of Supply to review the situa-



tion with the consequent increase in the numbers of aircraft ordered to 45.

Meanwhile the protoypes continued their use in the development programme including the installation of Rolls Royce Conway engines in VX770. It was during these tests that this aircraft was destroyed in a mid-air explosion over Syerston, Nottinghamshire, on 20 September 1958 with fatal consequences. The other prototype, VX777, later served as the Vulcan B.2 aerodynamic prototype before being broken up at Farnborough in July 1963.

The first two production aircraft XA889 and XA890 joined the second prototype VX777 for pre-service trials, the latter having received all the latest modifications including the standard Olympus 101 engines. In this state the aircraft went to A&AEE Boscombe Down for engine handling trials which included high altitude restarts, engine out performance and asymetric handling.

The prototype's wings were later modified to include the new leading edges with flying being resumed on 5 October 1955. Further modifications would see VX777 fitted with the Phase 2 wing destined for the Vulcan B.2 and an auto-stabilisation system.

Additional aircraft also joined the evaluation programme. The first prototype VX770, was already at A&AEE undergoing flight handling trials when XA889 arrived in March 1956. The primary task for these aircraft was Controller (Aircraft) clearance which was granted in May 1956.

From Boscombe Down XA889 was flown to Patchway, Bristol, where it was involved in Olympus trials. By July 1957 it was test flying the Mk.104 version of this engine.

Radio and radar trials were the province of the second production Vulcan XA890, which was to see service with various departments of the Royal Aircraft Establishment both at Farnborough and Bedford for work with the Blind Landing Experimental Unit. Fuel system trials were allocated to XA891 and included tank pressurisation which was required to reduce the risk of fire and explosion. Three Vulcans including XA892, were involved in weapons carriage and release where bomb bay clearance and sequence timing were investigated.

Avro Vulcan Production List

Prototypes	(2 built) To Spec.B35/46 VX770 VX777
Avro Vulcan B.1	to Contract 6/Acft/8442/CB.6(a) dtd 140852 (25 built) XA889 to XA913 Converted to B.1A XA904, 906, 907, 909, 910, 911, 912, 913
Avro Vulcan B.1	to Contract 6/Acft/11301/CB.6(a) dtd 300954 (37 built) 20 built as B.1 17 built as B.2 As B.1 XH475 to XH483, XH497 to XH506, XH532 Converted to B.1A XH475 to XH483, XH497 to XH506 , XH532. As B.2 XH533 to XH539, XH554 to XH563 Converted to B.2(MRR) XH534, XH560, XH563 Converted to K.2 XH558, XH560, XH561
Avro Vulcan B.2	to Contract 6/Acft/11830/CB.6(a) dtd 310355 (8 built) XJ780 to XJ784, XJ823 to XJ825 Converted to B.2(MRR) XJ780, XJ823 Converted to K.2 XJ825
Avro Vulcan B.2	to Contract 6/Acft/13145/CB.6(a) dtd 250256 (24 built) XL317 to XL321, XL359 to XL361, XL384 to XL392, XL425 to XL427, XL443 to XL446 Converted to B.2(MRR) XL361 Converted to K.2 XL445
Avro Vulcan B.2	to Contract KD/B/01/CB.6(a) dtd 220158 (40 built) XM596 to XM576, XM594 to XM612, XM645 to XM657 Converted to B.2(MRR) Converted to K.2 XM571

All built at Chadderton

This impressive picture of Vulcan B.2 XL321 of No. 617 Squadron is emphasised by the dark sky which silhouettes the aircraft and its Blue Steel stand-off weapon as part of Britain's deterent force in the 1960s.

This undersurface picture of a Vulcan B.2 reveals much interesting detail. Close observation of the bomb bay reveals an 8,000 lbs fuel tank in the forward position. For those interested in 100 per cent accuracy, all the aerial covers surrounding the nose wheel bay are a faded brown in colour. (John Nickolls)

FIRST ACCIDENT

All of these trials had heightened the RAF's desire to get their hands on the new aircraft. However, it was not to the squadrons that the first aircraft went but to 230 Operational Conversion Unit. Their first Vulcan was XA895 which arrived at RAF Waddington on 20 July 1956. The arrival of this aircraft was largely symbolic as it was soon replaced by XA897, the earlier aircraft having been returned to Woodford for modifications.

On 2 September this machine left the UK on a flag waving tour of Australia and New Zealand proving without doubt that the air forces of both countries were seriously lacking in a good air defence fighter.

The return journey was routed via Aden which XA897 left in the early hours of 1 October. Scheduled to land at Heathrow for a VIP welcome a succession of minor errors were to lead to the aircraft landing short of the runway. The impact tore off the main legs of the undercarriage and the resultant damage to the rest of the aircraft's systems left the Vulcan uncontrollable. At 800 feet AGL the Captain realised the situation was

Above: This excellent rear view of Vulcan B.2, XL317, has the flashes of No. 617 Squadron on the fin. The Blue Steel round under the fuselage is a blue painted training weapon. This view shows to great advantage the angles of the jet pipes of the Olympus 201 engines. (Tony Buttler Collection) Right: Once airborne the lower fin on the Blue Steel was deployed. When approaching to land the fin was folded up to clear the ground. This view shows XL320 climbing to height, of note is the faded paintwork on this Vulcan. (Avro Heritage/ BBA Collection)

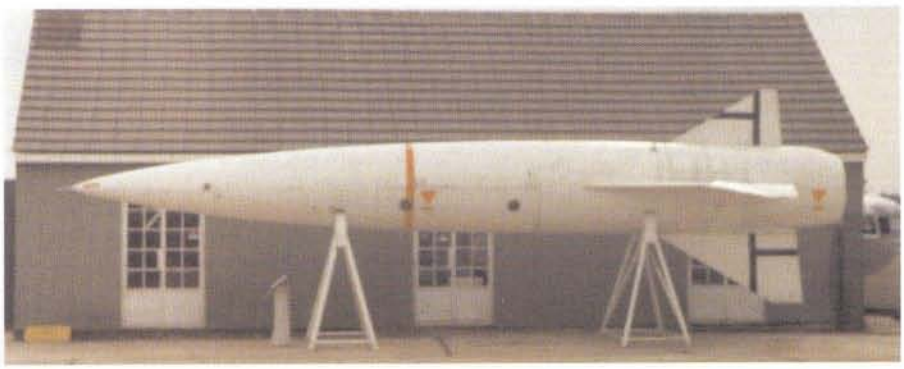
beyond recovery and called the crew to abandon the aircraft. He and the occupant of the co-pilot's seat, Sir Harry Broadhurst, C-in-C of Bomber Command, ejected safely. The rapidly decreasing altitude left the four rear crew no chance of escape and they died in the ensuing crash. At the subsequent Board of Inquiry no one person was deemed to be at fault although officialdom's attempts to influence the inquiry left a bitter taste in the mouths of those involved.

One concern that did emerge, and would continue to do so, would be the provision of better escape systems for the rear crew members. All were doomed as unworkable either on cost or technical grounds. One idea that nearly made it to fruition was the installation of ejection seats for the rest of the crew. Another idea that was more feasible due to the Vulcan's method of construction was that of an ejectable crew capsule which would be released using explosive bolts and had been actually considered when the aircraft was originally designed.

Although the loss of XA897 was tragic, the Board's vindication of the aircraft's design meant that deliveries to the RAF could continue. More Vulcans arrived at RAF Waddington for the OCU and the re-training of crews for the first operational squadrons began in earnest.

Pilots were drawn from current Canberra, Lincoln and Washington squadrons and from the same source came navigators whose experience with the earlier versions of the H2S was invaluable.

In its latest form the radar system had dual capabilities in that it was not only able to map a target area but was also used for navigational purposes. Integrated with the basic instruments was the Nav-Bomb System Mk.1, the Nav-Bomb-Comp Mk.2 and the APQ-13 navigational aid. Also integrated into the navigation side was the Green Satin Decca Doppler which fed it's results onto a display as a geographic position via an analogue computer. In the event of a total avionics failure Vulcan navigators also had access to periscope sextants, mounted one each side



When the Vulcan gave up its primary nuclear role the live Blue Steel missile rounds were disposed of, however some of the training rounds ended up in museums such as that at Newark. Normally seen with the lower fin folded this view shows the fin fully deployed. (BBA Collection)

This view of the Vulcan K.2 conversion line reveals many interesting details not normally seen on an in service aircraft. On the nearest aircraft the tail brake chute door reveals the box like shape of the bay whilst the missing radome on the following aircraft shows much of the plumbing for the refuel system normally hidden by the Hycar and Fibreglass nose. (Avro Heritage/BBA Collection)

of the cabin.

Due to the complexities of new equipment and as the older ranks were by then somewhat obsolete, the RAF introduced a new aircrew appointment known as the Air Electronics Operator (AEO). Initially the duties of this fifth member would involve the management of the Vulcan's electrical system plus aircraft communications. The original idea was that NCO Signallers would be able to transfer across without much trouble but with the introduction of Electronic Counter Measures (ECM) the demand for a greater depth of education was found to be necessary. Although it was to be some years before the Vulcan gained ECM in an enlarged tail cone, the theory was being taught from the outset. Also included in the AEO course was the management of the primary defence system including chaff dispensers that were located behind the main undercarriage bays. There was an attempt to introduce a tail warning radar called 'Red Garter' but although a few Vulcans were fitted with this device it was not a success even though it had been developed from the 'Orange Putter' fitted to the Canberra. The equipment was therefore removed pending

Ground crew working on a Vulcan B.2's port engines. As aircraft were dispersed round an airfield this work could often be a cold and difficult job in winter.

Technical briefing. Crew Chief (standing) looks on as Captain and crew pore over the Aircraft Servicing Log. The size and thickness of the document give some idea of the mass of information required to be checked and certified before flight. (MOD)

more sophisticated replacements

FIRST SQUADRONS FORM

After the establishment of 230 OCU and the first conversion courses being completed it became the turn of the first operational squadrons to form.

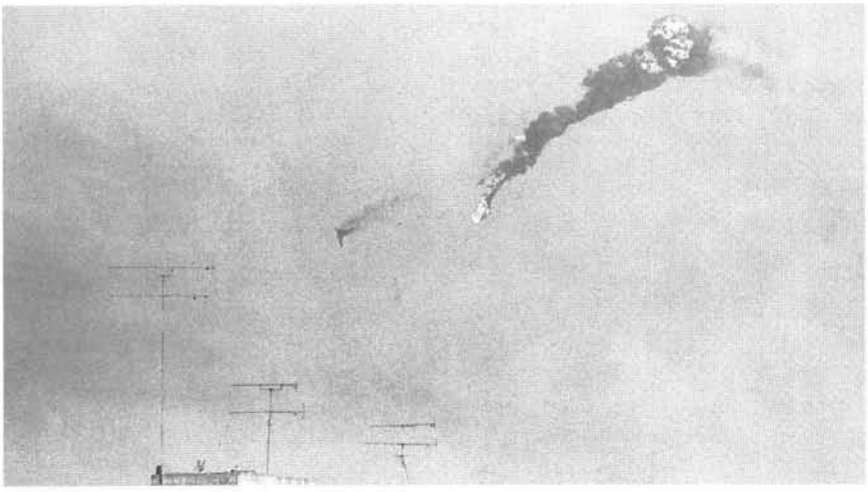
The first of these was No.83 Squadron on 20 May 1957 also at Waddington.

After the operational work up period had been completed the squadron sent two Vulcans to the United States to take part in Strategic Air Command's Navigation and Bombing competition at Pinecastle Air Force base. Known as Exercise 'Iron Horse' to SAC and 'Longshot' to the RAF, the Vulcan crews settled down to their task throughout the month of October. This competition later became an annual event that was known as 'Giant Voice' held within the bounds of the United States whilst its UK equivalent became known as 'Double Top'. The RAF's success in this all-American competition was such that they eventually won the most coveted trophies. Thereafter the USAF changed the rules.

Twelve months later, on 24 October 1958 No. 83 Squadron was to lose its first aircraft to a set of unforeseen circumstances. En-route from Goose Bay, Labrador, to Lincoln Air Force Base, Vulcan XA908 suffered complete electrical system failure. In theory the onboard batteries should have generated enough power to drive essential services for at least 20 minutes. But in fact the aircraft suffered a complete shut down after only three minutes which caused the solenoid valves within the Powered Flying Control Units (PFCU) to lock the flying controls. The resulting crash killed all six crew members on board plus the co-pilot who had managed to eject. Investigations revealed that there was a short circuit across the vital services busbar which had robbed the aircraft of all electrical power. As a result of

Vulcan tragedy

ON 14 October 1975 Vulcan B.2 XM645 of No. 9 Squadron, RAF Waddington, crashed with a tragic loss of life, on the village of Zabbar, Malta. These two pictures show the course of events leading up to the crash which resulted in the deaths of five out of seven aircrew on board and one civilian on whose house the flaming wreckage fell. Flown by Flt Lt G.R.Alcock, the aircraft was on a routine Lone Ranger flight but as it was about to land at Luqa airport, the port undercarriage hit the ground and broke off. Parts went into the aircraft itself cutting fuel lines and although warned by air traffic control that the undercarriage leg had been left on the runway, the pilot initiated a climb to try and recover. A major fire broke out and as the Vulcan gained height it exploded showering wreckage over the village. This was one of the most tragic of the few fatal accidents suffered by Vulcans during their service. (Godfrey Mangion)



230 Operational Conversion Unit fin badge

Avro Vulcan B.2 XL427 of No. 230 Operational Conversion Unit, RAF Scampton in 1973. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Toned down tactical roundels.

Avro Vulcan B.2(MRR) XM570 of No. 27 Squadron, RAF Scampton in 1973. The fin badge preceded the 'Dumbo' badge which later replaced it. Matt Dark Green and Medium Sea Grey with White undersides. Toned down tactical roundels.

No. 27 Squadron Elephant on fin

No. 1 Group badge on nose of XM606

Avro Vulcan B.2 XM606 of No. 1 Group Strike Command which took part in the 1974 'Giant Voice' bombing competition in the USA. No. 1 Group panther's head on nose and Union Jack on fin. Otherwise standard Vulcan Force colour scheme.

No. 101 Squadron badge on fin

Avro Vulcan B.2 XM575 of No. 101 Squadron at RAF Waddington in 1975. Matt Dark Green and Medium Sea Grey with Light Aircracft Grey undersides. Note that the camouflage extends over the nose radome.

No. 35 Squadron badge on fin

Avro Vulcan B.2 XJ825 of No. 35 Squadron at RAF Scampton in 1975. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Tactical roundels.

Avro Vulcan B.2 XM597 of No. 50 Squadron at RAF Waddington in 1977. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Tactical roundels.

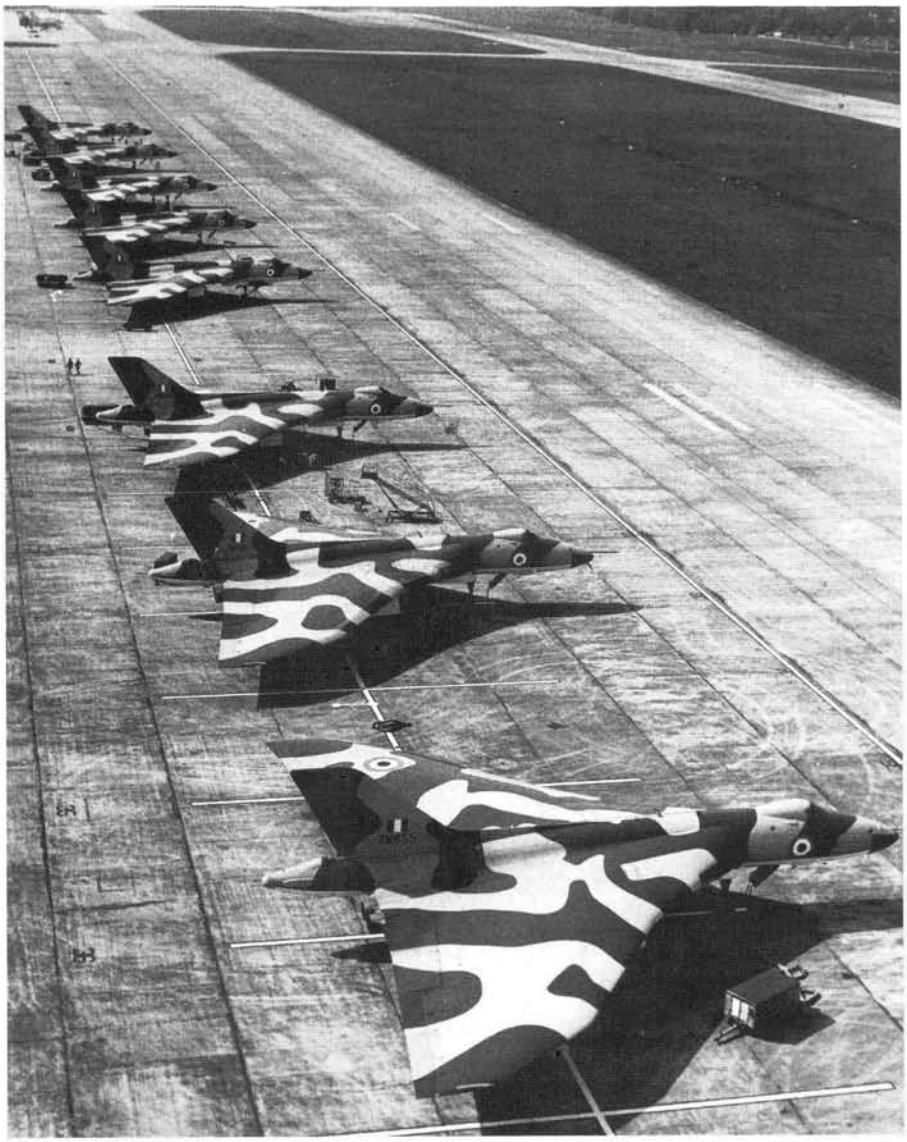
RAF Waddington and No. 50 Squadron badges on fin

this accident all Vulcans immediately had their main busbars divided into two.

Also giving rise for concern were the results generated by engine failure. The repercussions of such an event frequently resulted in the loss of the adjacent engine as the compressor sucked in blades from the disintegrating power plant. Further damage was caused by compressor and turbine blades penetrating other parts of the airframe including the fuel system. The conflict between hot blades and cold fuel frequently resulted in the loss of the aircraft and its crew.

The consensus of opinion was that the loss of a second engine was almost inevitable and that steps should be taken to limit the damage to the rest of the airframe. This was achieved by strengthening the structure and adding damage suppression blankets not only to the engine but to the engine bays themselves. Although in most cases these measures worked there were occasions when it was not so effective. Such circumstances were later to cause the loss of Vulcan B.2 XM610, when a particularly violent engine failure not only damaged the adjacent powerplant, it also caused extensive damage to the rest of the aircraft and started a serious fire in the fuel system. Fortunately in this case the crew escaped without loss.

Although Bomber Command had suffered these early losses, they were not allowed to stop the re-equipment of operational units.



Vulcans overseas. To ensure the mobility required and in many cases to show the flag, the Vulcan force either singly, in threes or fours or in the case of (left) in squadron strength, many overseas deployments were made. In this case No. 44 Squadron was visiting Singapore. Exercises in the United States and elsewhere were encouraged and Vulcans were frequent visitors to 'Red Flag' in the Nevada desert and based at Nellis Air Force base, as shown below.

When the RAF won the USAF 'Giant Voice' bombing competition at Barksdale AFB outright, the pilot of the winning Vulcan put on a display to impress his American colleagues. They said it couldn't be done but this picture was taken from the top of the air trafic control tower as the aircraft sped down the ranks of B-52s, F-111s and KC-135s at a height of 50 feet. Then he pulled up into a slow roll. Try doing that with a B-52! (Alan W.Hall)

Thus No. 101 Squadron exchanged its Canberras to begin a long association with the Vulcan on 15 October 1957 whilst based at RAF Finningley.

It was quickly followed by No. 617 Squadron which received its new aircraft in May 1958.

With three squadrons operational a long period of co-operation began between Bomber Command and the USAF's Strategic Air Command. Vulcan crews practised training with the nuclear 'Blue Danube Mk.1' and American weapons. Of the former the Vulcan could only carry one but two of the smaller American bombs could be accommodated.

Above: A No. 44 Squadron Vulcan B.2 taxies to the runway for a late evening take off at Nellis AFB during one of the frequent Vulcan detachments to 'Red Flag' . Below: With a background of B-52s and KC-135s this Vulcan B.2 was being serviced overnight ready for an early start the following morning during one of the'Giant Voice' bombing competitions at Barksdale AFB. (MoD)

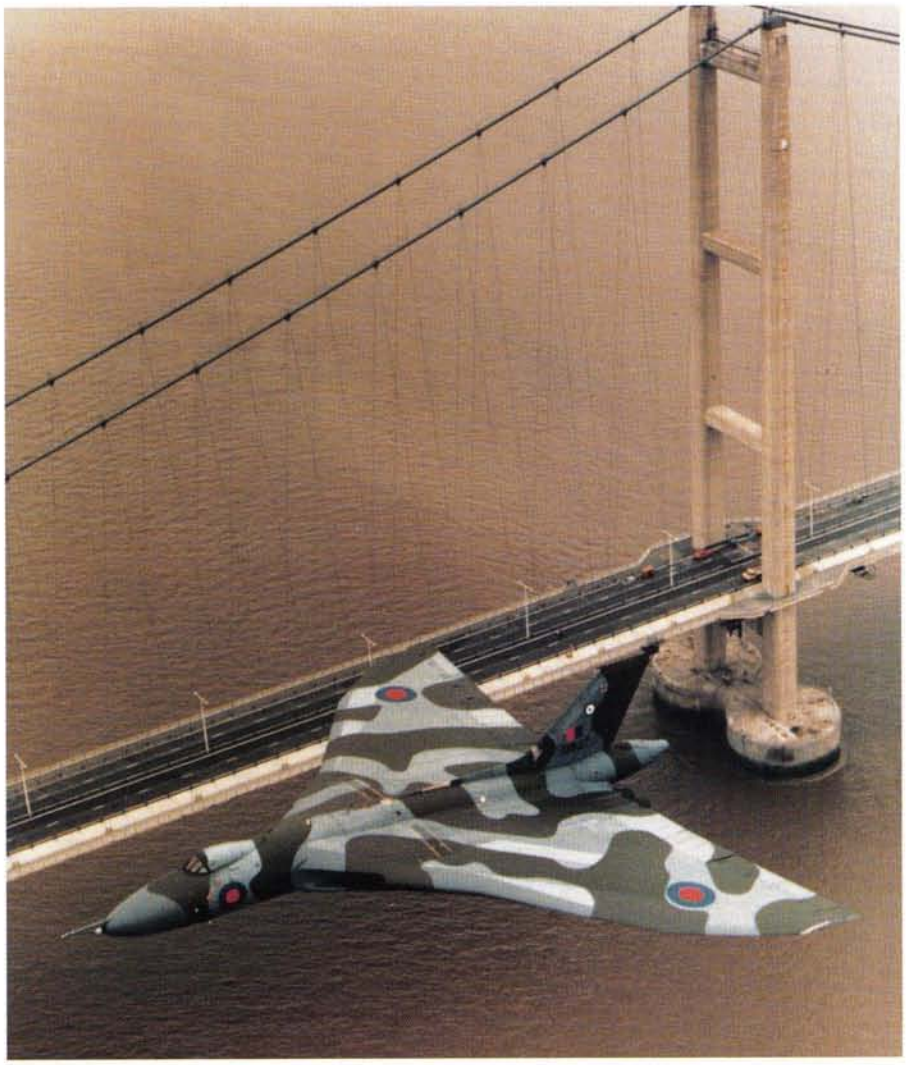
UPGRADING AND TEST BEDS

This period in RAF history was marked by a number of political upheavals and interference. Fortunately for Avro and the Vulcan most of these policy changes passed them by and allowed the design to be improved and furthered. The result was the appearance of the Vulcan B.2 which began to enter service in 1960. Although considerably more advanced than the B.1 the latter were still comparatively young aircraft.

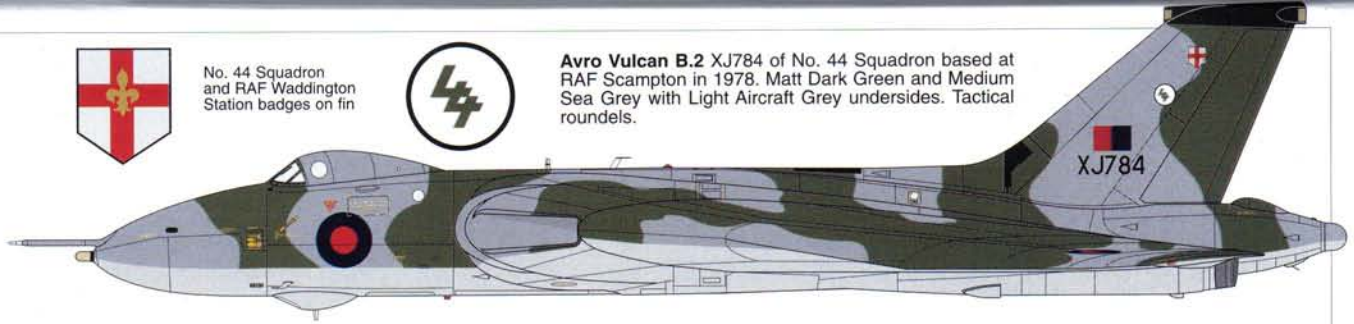
It was decided to upgrade the B.1s to close to B.2 standard. This included the fitting of a bulged tail cone which extended the fuselage length by nearly three feet. But this modification resulted in changes being made to the rudder in light of the relocation of the tail brake chute from the B.1 tailcone side position to one on top of the new tail cone. Within the new tailcone were the ECM facilities that contained both transmitters and power units. The heat emitted from these required considerable cooling for them to remain efficient and accordingly a water glycol coolant system that passed through a vapour cycle cooling pack was fitted.

In total 29 of the 34 remaining B.1s were modified. Other changes resulted in the Vulcan being given an in-flight refuelling system and increased power supply to provide energy for the ECM fit. After completion these Vulcans were re-designated as B.1As.

As the Vulcan B.2 came into service it was obvious from a logistics point of view that each variant of the Vulcan would be better if grouped together. Thus Nos. 44, 50 and 101 Squadrons were based at RAF Waddington with their Vulcan B.1As where they undertook training in the conventional bombing role. The nuclear task was then transfered to the more capable B.2 version although the B.1As retained a secondary strike option.



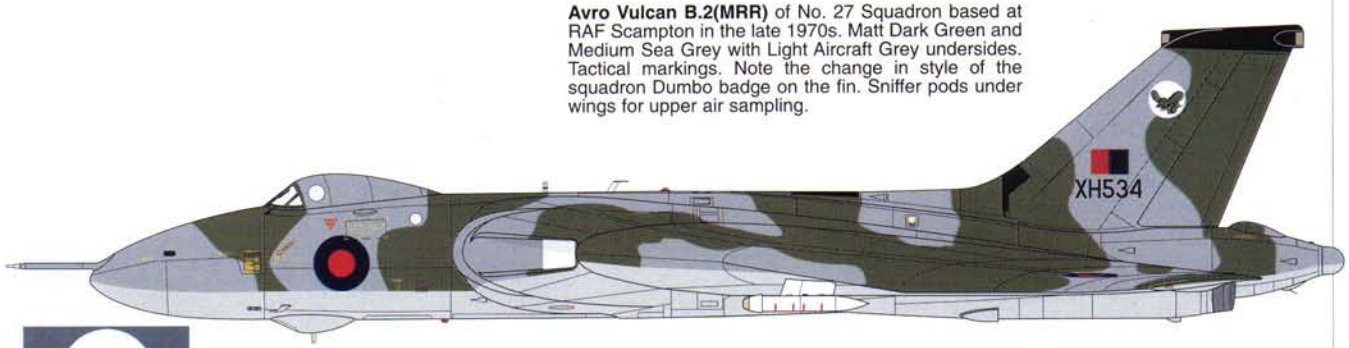
Above: The bridge over the River Humber with a view of Vulcan B.2 in close proximity. At the time this picture was taken the Vulcan force was establishing low level attack techniques. (RAF Museum) Below: Late modified Vulcan B.2 (note the fin) with crew chief still attached, about to taxy. This was taken at the Tanker Meet at RAF Fairford. White overalls were only issued to servicing crews when on display to the public. (MoD)



No. 44 Squadron and RAF Waddington Station badges on fin

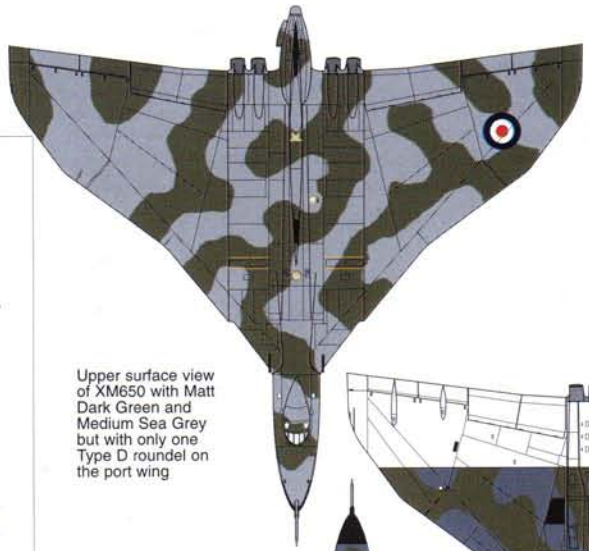
Avro Vulcan B.2 XJ784 of No. 44 Squadron based at RAF Scampton in 1978. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Tactical roundels.

Avro Vulcan B.2 XM598 of No. 50 Squadron based at RAF Waddington in the late 1970s. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Tactical roundels.

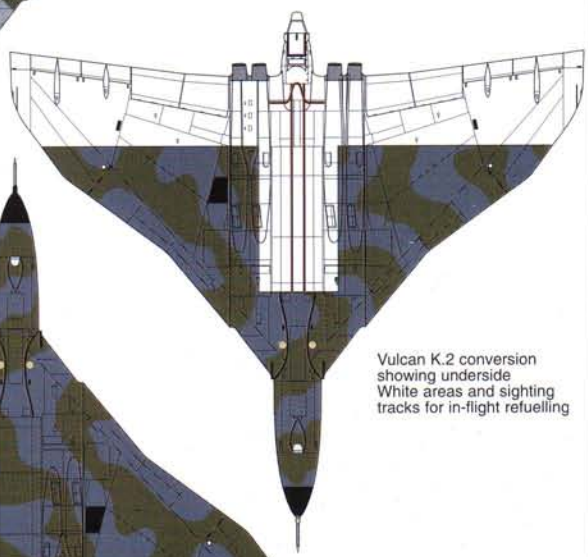


Avro Vulcan B.2(MRR) of No. 27 Squadron based at RAF Scampton in the late 1970s. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides. Tactical markings. Note the change in style of the squadron Dumbo badge on the fin. Sniffer pods under wings for upper air sampling.

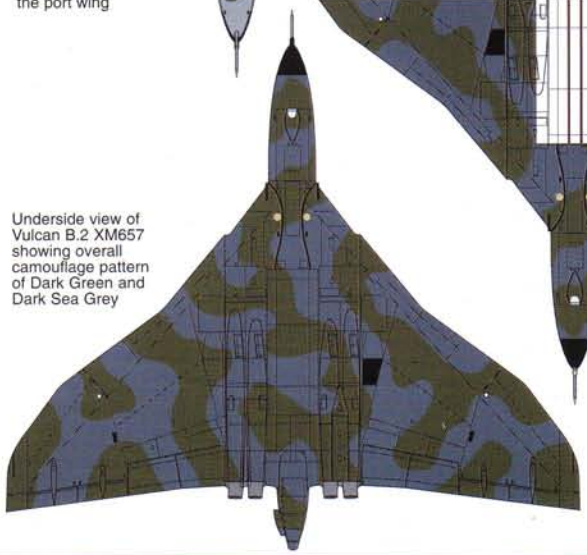
No. 27 Squadron's Dumbo badge on the fin of XH534



Upper surface view of XM650 with Matt Dark Green and Medium Sea Grey but with only one Type D roundel on the port wing



Vulcan K.2 conversion showing underside White areas and sighting tracks for in-flight refuelling



Underside view of Vulcan B.2 XM657 showing overall camouflage pattern of Dark Green and Dark Sea Grey

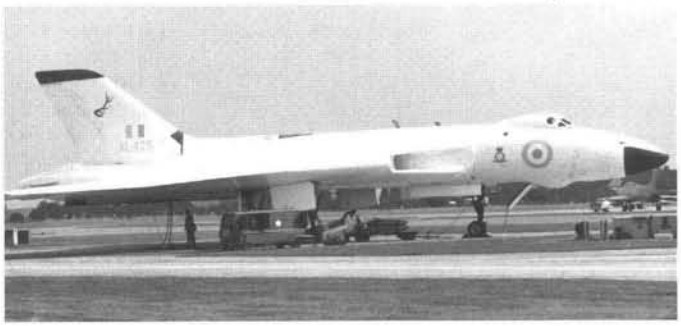
From 1966 onward the Vulcan B.1A, and the few remaining B.1s still in use, were slowly withdrawn from service, the whole process being complete by 1967.

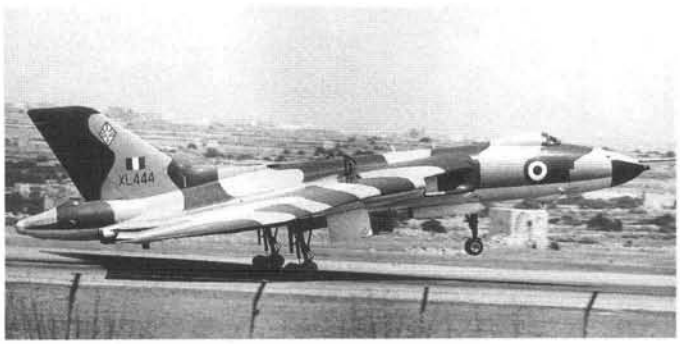
Several non-operational Vulcan B.1s remained in use as test bed aircraft. One of these was XA902 which had joined Rolls Royce in 1958 for use as an engine test bed. First flight trials involved the Conway 11 engine which in turn were followed by those for the Spey. The aircraft was finally grounded after four years useful service.

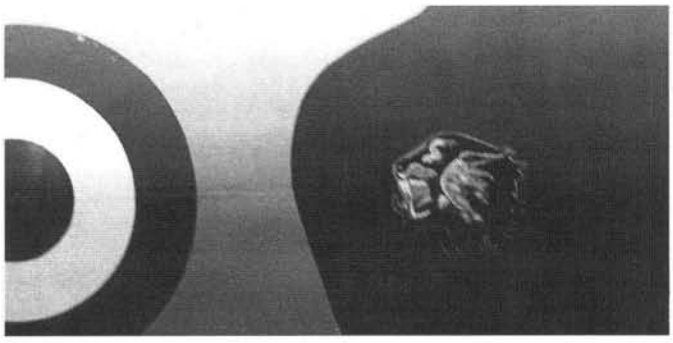
Another Vulcan B.1 used in the engine test bed role was XA894 which was based at Patchway, Bristol where it was actively involved in the Olympus 22R development programme intended for the ill-fated TSR.2. The whole installation was centred around the bomb bay where extra fuel tanks were fitted, the engine itself being contained in a mock-up of the TSR.2 fuselage nacelle. The aircraft was later destroyed on 3 December 1962 when the Olympus 22R was undergoing full reheat ground runs. The engine disintegrated and caused extensive damage to the rest of the airframe which led to its subsequent total destruction.

Possibly the best known Vulcan B.1 was XA903 which first came to notice when it was selected for the trials of the Blue Steel air-launched stand-off missile. After these trials XA903 moved to Bristol where it was







VULCAN SQUADRONS

Representative aircraft from the operational Vulcan squadrons. Tail markings took a variety of different forms during the period that the aircraft was in service and only one of each style has been shown. From top to bottom, left to right: XH555 of No. 9 Squadron. XM597 of No. 12 Squadron. XH537 of No. 27 Squadron. XJ823 of No. 35 Squadron. XM653 of No. 44 Squadron. XL386 of No. 50 Squadron. XM611 of No. 101 Squadron. XL444 of No. 617 Squadron. The last picture shows the panther's head often painted on No. 1 Group Bomber Command aircraft. All Vulcans shown are B.2s. (Pictures by Godfrey Mangion, author, APN and MAP)

modified to carry the Olympus 593 destined for eventual use in Concorde. To better understand the performance of the engine in flight it was mounted in an aerodynamic nacelle. As before, internal fuel tanks were mounted in the bomb bay, these later being replaced with tanks containing water which was connected to a spray rig mounted where the bomb aimers blister had once been. The maiden flight of XA903 in this guise was made on 9 September 1960 and test flying of the engine and its derivatives continued until July 1973.

From Bristol XA903 went to Marshalls of Cambridge where it was prepared for use in the RB.199 engine development programme. Destined as the power plant for the forthcoming Tornado this unit, was also mounted in a mock-up nacelle only this one contained a 27mm Mauser cannon and 150 rounds to test the gas ingestion upon the engine. At the completion of these trials the aircraft undertook its last flight to RAE Farnborough on 27 February 1977. Eventually it was cut up for scrap, events to preserve it having failed. The nose eventually found its way to the Wales Aircraft Museum but when this closed down it was bought by a private owner.

ULTIMATE VULCAN

The Vulcan B.2 was very similar to its predecessor in looks, however, under the skin it was a very different aircraft. First mention of the upgraded bomber appeared in 1954 when OR.330 was issued by the Air Ministry. This called for a very advanced aircraft capable of a top speed of Mach 2.5 at a height of 60,000 ft with a still air range of 3,000 miles. Further refinements resulted in Specification R.156T being issued. The

Avro Vulcan squadrons
including manufacturers, research establishments and other operating units

Vulcan B.1/B.1A(including prototypes)

No. 44 Squadron	XA896, XA901, XA904, XA905, XA906 XA907, XA910, XH476, XH477, XH480, XH499, XH501, XH503,
No. 50 Squadron	XA909, XA910, XH477, XH482, XH483, XH497, XH498, XH499, XH500, XH502, XH506
No. 83 Squadron	XA901, XA904, XA905, XA906, XA907 XA908, XA911, XH477, XH480, XH503
No. 101 Squadron	XA900, XA901, XA909, XA910, XA912, XA913, XH475, XH479, XH481, XH482, XH506, XH532
No. 617 Squadron	XH482, XH483, XH497, XH498, XH499, XH500, XH501, XH502, XH505 XH506,
230 OCU	XA895, XA896, XA897, XA898, XA900, XA901, XA902, XA910, XA911, XH504, XH505, XH532
Waddington Wing	XA905, XA906, XA909, XA911, XA912, XA913, XH475, XH476, XH478 XH479, XH480, XH481, XH482, XH483, XH498, XH500, XH501, XH502, XH503, XH504, XH505, XH506, XH532
BCDU	XA895, XH500
A&AEE	VX770, VX777, XA889, XA890, XA891, XA892, XA893, XA894, XA899 XA903, XH499
RAE/BLEU	VX777, XA890, XA891, XA899, XA903
Rolls Royce	VX770, VX777, XA889, XA891, XA894, XA896, XA902
AVRO	VX770, VX777

Vulcan B.2

No. 9 Squadron	XJ783, XJ784,XJ823, XJ824, XJ825, XL385, XL386, XL388, XL389, XL390, XM597, XM603, XM605, XM608, XM610,XM611, XM612, XM645,XM646, XM648, XM649, XM652, XM653, XM655
No. 12 Squadron	XH560, XH563, XJ780, XJ781, XJ782, XJ825, XM597, XM598, XM602, XM606, XM609, XM646, XM650, XM651, XM654
No. 27 Squadron	XH534, XH538, XH555, XH556, XH560, XH563, XJ780, XJ782, XJ823, XJ824, XJ825, XL318, XL444, XL445, XL446, XM569, XM570, XM574, XM594,
No. 35 Squadron	XH538, XH562, XJ783, XJ823, XJ825, XL321, XL359, XL360, XL361,XL392, XL426, XL444, XL445, XM595, XM597, XM599, XM600, XM604, XM607, XM647, XM652, XM654, XM656, XM657
No. 44 Squadron	XH562, XJ782, XL318, XL319, XL321, XL360, XL386, XL388, XL391, XL427 XL445, XM569, XM573, XM575, XM594, XM598, XM599, XM607, XM609, XM647, XM648, XM652, XM655
No. 50 Squadron	XH558, XH560, XH561, XH562, XJ784, XJ823 XJ825, XL321, XL387,XL426 XL445, XM571, XM594, XM597, XM599, XM605, XM608, XM650,XM651, XM652, XM657
No. 83 Squadron	XH554, XH563, XJ780, XJ781, XJ782, XJ783, XL319, XL384, XL386, XL388 XL392, XL425, XL426, XL427, XL443, XM571, XM572, XM573
No. 101 Squadron	XH562, XJ783, XJ784, XJ824, XL360,XL386, XL389, XL391, XM575, XM600, XM602, XM605, XM606, XM611, XM612, XM648, XM650, XM653, XM654, XM655, XM656
No. 617 Squadron	XJ783, XL317, XL318, XL319, XL320, XL321, XL359, XL360, XL361 XL389, XL390, XL444, XL446, XM570, XM572, XM575, XM595
230 OCU	XH534, XH537, XH538, XH554, XH555, XH556, XH558, XH559, XH560 XH561, XH562, XH563, XJ780, XJ781, XJ782, XJ784,XJ823,XJ824, XL318 XL320, XL321, XL359, XL360, XL384, XL387, XL444, XL445, XL446, XM573, XM645
Coningsby Wing	XH536, XH557, XM600, XM601, XM603, XM604, XM605, XM606, XM608, XM609, XM610, XM611, XM612, XM645,XM646, XM647, XM656
Scampton Wing	XH537, XL317, XL319, XL320, XL321, XL359, XL360, XL361, XL384 XL385, XL387, XL388, XL389, XL390,XL392, XL425, XL426, XL427, XL443, XL444, XL446, XM570, XM574, XM575, XM576, XM594, XM595, XM645
Waddington Wing	XH538, XH557, XH558, XJ781,XJ823, XL361, XL387, XL446, XM569 XM572, XM574, XM575, XM594, XM597, XM598, XM599, XM600, XM602, XM603, XM605, XM606, XM607, XM608, XM609, XM610, XM611, XM612, XM646, XM647, XM648, XM649, XM650, XM652, XM653, XM654, XM656, XM657
NEAF Wing	XH557, XH560, XJ780 XJ781, XJ783, XJ823,XJ824, XL391,XL443, XL445, XL446, XM569, XM605, XM646, XM647, XM651
A&AEE	XH534, XH535, XH536, XH539,
BCDU	XL391
AVRO	XH533
Rolls Royce	XH557

challenge was taken up by both Handley Page and Avro, the latter's proposal being known as the Type 730. In common with many projects of this period the design suggestions fell by the wayside in 1957 when the Defence White Paper of that year announced more cuts in defence expenditure.

Undetered by this near disaster for the British military aircraft industry, Avros set about the already suggested development of the Vulcan. Fortunately when the aircraft was originally designed this possibility had been thought about and consequently the proposals now put forward could make this possible. The selling of the concept to the Air Ministry and their political masters was satisfactorily achieved and the design improvements went ahead.

The first area for consideration was the wing. The overall span was increased from 99 ft to 111 ft, the maximum span possible in the available hangars of the day. Further changes were made to the leading edge where further cranking and drooping resulted in the loading remaining the same whilst the buffet threshold was increased to Mach 0.87. A revision of the flight controls dispensed with ailerons and elevators and introduced elevons instead. These comprised of four powered sections on each trailing edge whose positions were controlled by the outputs from the mixer control box. Powering each of these control surfaces was a self-contained Powered Flying Control Unit (PCFU) which allowed for redundancy should one fail. Testing of the new wing was entrusted to the original prototype VX777 which first flew in its new guise on 31 August 1957.

To match the efficiency of the new wing the Olympus engines were developed into the Mk.200 version. Test flying was undetaken using Vulcan B.1 XA891 which flew from Patchway in early 1958. This phase of its career was cut short when the aircraft was lost in a crash near Hull on 24 July 1959.

To test the electrical system needed to power the B.2 another B.1, XA893, flew with a partial installation in one wing driven by a 200 volt AC alternator. In the B.2 four of these were installed driven by the engines and were supported by an Airborne Auxiliary Power Pack (AAPP) and a Ram Air Turbine plus the obligatory 28 volt DC battery. Although much of the aircraft's systems were AC powered some of the equipment adapted from the earlier variant still required 112 volt DC which had its requirements met by Transformer Rectifier Units under the rear cabin floor. One other less obvious change was the provision of only three hydraulic pumps to drive the primary systems, that on No. 4 Engine Change Unit (ECU) being blanked off.

The culmination of all these trials and tests was the maiden flight of the first Vulcan B.2, XH533, on 19 August 1958. As this aircraft was a direct follow on from the previous B.1s on the Chadderton line it featured the slightly smaller intakes of this variant. In its original condition this, the first of the upgraded Vulcans did not have the enlarged ECM tail cone that was to have the 'Red Steer' tail warning radar at its tip. Still featured as part of the Vulcan's defensive suite

The Vulcan had a capacious bomb bay capable of carrying, in this case 14 1,000lb bombs. The aircraft belongs to No. 35 Squadron of the Near East Ear Force Wing based at Akrotiri, Cyprus when taking part in air exercises in the region. (MoD)

were the chaff dispensers although the extra option of a flare dispenser in the port wing was added.

With the advance of airborne electronic equipment and radar, the provision of ECM demanded extreme efforts be expended on its efficiency. Initially four systems all noise generation based, were developed. Consisting of eight 'cans' this valve-based technology was split 50-50 into generators and power units all cooled by a modified water glycol system developed from that fitted to the B.1A. As with the B.1A the Tail Brake Chute (TBC) for the new bomber was fitted in a compartment above the ECM 'cans'. A later addition to the ECM suite was an 'X'-Band jammer. Part was located in the tailcone whilst the transmitter can was located in the space once occupied by the rear of the Blue Steel missile. Although much of the Vulcan's defensive equipment was active in nature the era of passive detection arrived in 1973 when test flying of the ARI.18228 detector was mounted in place of the 'Blue Saga' unit in a modified fin tip fairing. Initially there was an interaction problem between the 'Red Steer' radar and the sensor array. Careful testing and eventual shielding reduced the problem to a more manageable level.

All this added equipment finally meant that the AEO was fully employed whilst his compatriots in the rear seats were finally using updated equipment that reduced their workload. Also changing was the instrument panel and its surrounds facing the pilots. More specifically the co-pilot gained a French-designed SFOM gunsight for use in the lay-down, low-level bombing role.

The ECM tail cone for the Vulcan B.2 was first fitted to XH534 in 1959. Once test fly-

Right: This airman is de-icing a 27 Sqn Vulcan on its dispersal at Scampton using a 'giraffe' portable ladder. (A.W.Hall) Below: Vulcan squadrons more often than not staged through RCAF Goose Bay, Labrador, on the way to exercises in Canada or the United States. During winter months Goose was often covered in ice and snow which made aircraft movement on the hardstanding a more difficult job than usual. (MoD)

No. 9 Squadron badge on fin

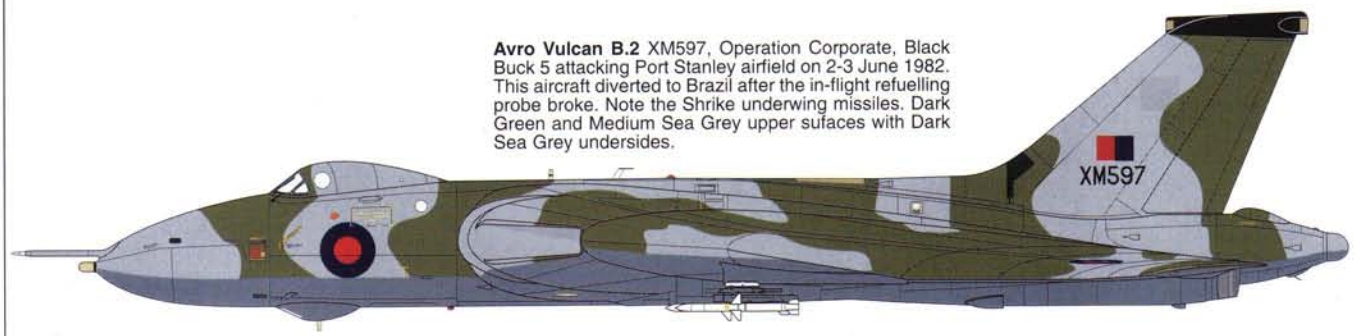
Avro Vulcan B.2 XH562 of No. 9 Squadron based at RAF Waddington in 1982. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides and tactical roundels. Camouflage extends over radome.

Avro Vulcan B.2 XM569 of No. 50 Squadron based at RAF Waddington in 1982. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides and tactical roundels.

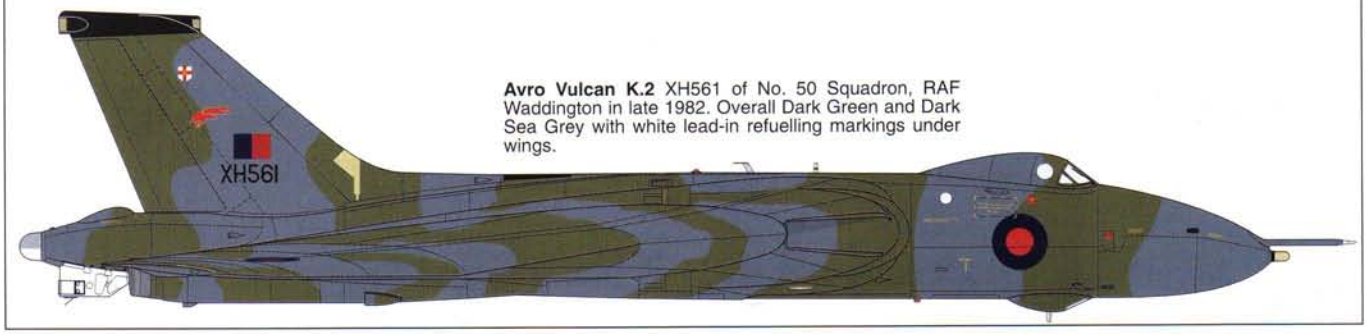
Avro Vulcan B.2 XM573 of No. 44 Squadron based at RAF Waddington in 1982. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides and tactical roundels.

Avro Vulcan K.2 XM571. Development aircraft, ex-No. 101 Squadron, June 1982. Matt Dark Green and Medium Sea Grey with Light Aircraft Grey undersides and tactical roundels. Retained No. 101 Squadron badge on fin during trials.

Avro Vulcan B.2 XM597, Operation Corporate, Black Buck 5 attacking Port Stanley airfield on 2-3 June 1982. This aircraft diverted to Brazil after the in-flight refuelling probe broke. Note the Shrike underwing missiles. Dark Green and Medium Sea Grey upper sufaces with Dark Sea Grey undersides.



Avro Vulcan K.2 XH561 of No. 50 Squadron, RAF Waddington in late 1982. Overall Dark Green and Dark Sea Grey with white lead-in refuelling markings under wings.



When No. 27 Squadron's Vulcan B.2(MRRs) took over the maritime reconnaissance role from the Victors of No.543 Squadron they also inherited another task, that of upper air sampling. Seen in June 1977 at Luqa, Malta, this aircraft has two pods under the wings for this purpose. For much of the time they checked on fallout from nuclear test explosions. (Godfrey Mangion)

ing had been completed and Controller (Aircraft) clearance granted the new bomber began to enter service in 1960. First recipient was No. 83 Squadron which was later joined by both the newly reformed Nos. 27 and 617 Squadrons by now all based at RAF Scampton. With all the Vulcan B.1s and B.1As concentrtated at Waddington production contracts allowed the formation of another 'V' Bomber Wing. This was established at RAF Coningsby and consisted of Nos. 9 and 12 Squadrons.

During this time the Vulcan force flew many exercises in conjunction with Strategic Air Command. Apart from long range flights these consisted of weapons handling which for the Vulcans meant the 'Blue Danube' bomb, and similar American nuclear weapons, as well as conventional iron bombs. But there was a new weapon on the horizon this being the British stand off missile, Blue Steel.

BLUE STEEL

Intelligence gathering flights had revealed that Soviet air defences had been growing stronger as the Cold War developed. It soon became obvious that sending bombers over at any altitiude for free fall missions would be nothing short of suicidal. From this came the realisation that a form of stand-off weapon would be required. Although the theory of such a weapon was well known, the reality would be something different.

Thus it was that a combined task force from Avro and the Royal Aircraft Establishment began work to create such a weapon. Intended from the outset as a missile to clear present and future Soviet air defences, the first ideas of a weapon of this nature resulted in two free fall aerodynamic test vehicles in 1955.

Full development contracts were issued by the Ministry of Supply in 1956 and involved a multi-company organisation that was led by Avro with Armstrong Whitworth responsible for the propulsion system. Navigation was to be the responsibility of Elliot Bros who were charged with developing the inertial navigation system. Development of the power supply turbines became the responsibility of de Havilland Dynamics missile division. Enough of an advance in design had been achieved by 1957 to allow the formation of a joint trials team.

The two aerodynamic trials vehicles built to two-thirds scale began launch trials from a modified Vickers Valiant over the Aberporth ranges in North Wales. Further examples were built, these containing a rudimentary flight control system. The final addition to the trials missiles were solid fuel rocket motors which allowed them to perform as intended. Even so their flight time was short as it was necessary to self-destruct

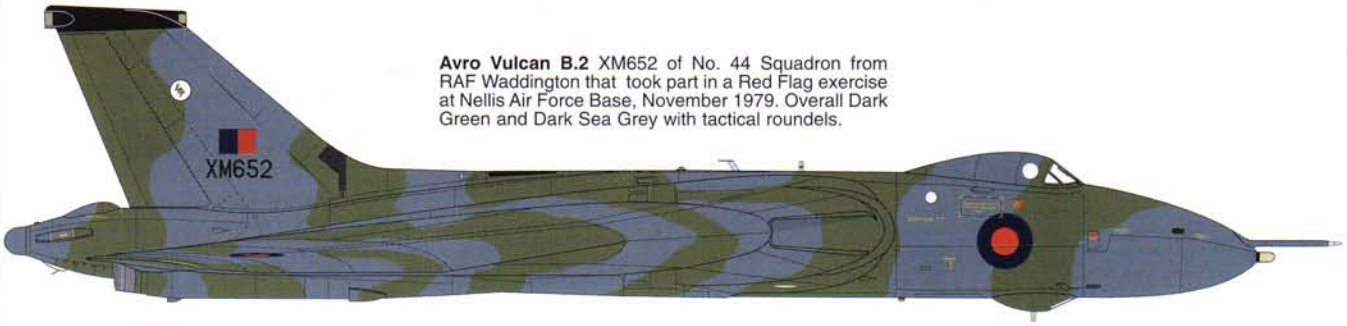
No. 27 Squadron changed roles from a purely bomber to a maritime reconnaissance unit tasked with, amongst other things, surveillance of North Sea oil and gas rigs. Vulcan B.2(MRR) XH534 is shown overflying one of the gas rigs off the East Anglian coast. (MoD)

them after a few minutes flight for safety reasons.

Vulcan B.1 XA903, represented the intended carrier aircraft. The next development stage was to build Full Scale Development (FSD) missiles fitted with as many of the intended systems as possible. Originally it was intended that these would be built using the intended production material, stainless steel, but problems with working the metal meant that the first few weapons would utilise aluminium in their construction.

Drops of the Full Scale Development specimens began over the Aberporth ranges in 1958 with trials under full power being carried out at Woomera, Australia, during the following year. The carrier for many of these flights was Vulcan XA903. Numerous

Above: Complete with two Skybolt training rounds Vulcan B.2 XH537 is fitted with camera pods on the wingtips. The heat exchangers on the centre engine doors are painted black to help with camera tracking of the aircraft and missiles. (Avro Heritage/ BBA Collection) Below: This Skybolt training round is reckoned to be the only one left in existence. It is now reported to be in the RAF Museum at Hendon. (Mel James)



Avro Vulcan B.2 XM652 of No. 44 Squadron from RAF Waddington that took part in a Red Flag exercise at Nellis Air Force Base, November 1979. Overall Dark Green and Dark Sea Grey with tactical roundels.

No. 1 Group panther's head badge on nose

Avro Vulcan B.2 XM605 of No. 1 Group Strike Command that took part in the 'Giant Voice' bombing competition in 1982. Matt Dark Green and Dark Sea Grey overall with tactical roundels. No. 1 Group badge and Union Jack on fin.

The celebrated Vulcan B.2, XM607, was one of the stalwarts of the Black Buck raids over the Falklands. It is seen here parked at Wideawake airfield complete with an ALQ-101 ECM pod under the starboard wing. Since retirement it has been the gate guard at RAF Waddington. (Mel James)

Avro Vulcan ground instructional airframes

B.1/B.1A		
XA892	7746M	Halton
XA898	7856M	Halton
XA899	7812M	Cosford
XA900	7896M	Cosford
XA901	7897M	Cranwell
XA904	7738M	Waddington
XA905	7857M	Newton
XA910	7995M	Waddington
XH475	7996M	Waddington
XH478	(MC)8047M	Akrotiri
XH479	7974M	Halton
XH498	7993M	Waddington
XH500	7994M	Not known
B.2/B.2A		
XL317	8725M	Akrotiri
XL384	8585M/8670M	Scampton

questions concerning the missile's performance and behaviour were answered during the trials although one would arise that would remain as a problem throughout the service life of Blue Steel. This was the interface between the missile and the carrier aircraft. It often meant that up to half a dozen weapons would have to be offered up to an aircraft before finding a match that would fit.

Further FSD weapons powered by the Armstrong Whitworth Stentor rocket motor were later added to the development programme. These differed from the earlier version in that they were, as intended, built from stainless steel, the problems in manufacture having been overcome. Close to production standard inertial navigation platforms were also installed and were found to be very accurate, so much so that at times the aircrews confirmed their on board basic navigation systems by the navigator checking with those of the missile.

The arrival of Blue Steel in Australia saw another aircraft being allocated to the trials programme. This was Vulcan B.2, XH539, which began its new duties as a test aircraft in 1961.

One aspect that could easily be overlooked in a programme of this nature was the ground equipment needed to support it. For Blue Steel this entailed the design and manufacture of a dedicated tranporter vehicle but here again a difficulty emerged as, apart from the Vulcan, Blue Steel was intended to equip the Victor squadrons of the time and the two aircraft were of different heights as far as loading the missile into the bomb bay was concerned. To add to any difficulties in actually producing a workable, efficient missile the design teams now had to concentrate on producing a vehicle with a common set of aircraft interfaces for the airborne disconnection of hydraulic, cooling, heating and electrical power supplies. All connections had to be of the face-to-face variety thus removing the potential problems caused by pin interconnect hang-ups.

Parked up on Wideawake airfield are Vulcan B.2s XM607 and XM598 awaiting their next mission. The satellite dish on the hill top is American. (Mel James)

Preserved Vulcans and gate guardians

XA893	Cosford Aerospace Museum
XA903 (nose)	Sidcup
XH558	Bruntingthorpe
XH560 (nose)	Rayleigh. The Cockpit Collection
XH537 (nose)	Bruntingthorpe
XH563 (nose)	Banchory
XJ823	Solway Aviation Museum, Carlisle
XJ824	Imperial War Museum, Duxford
XL318	RAF Museum, Hendon
XL319	North East Aviation Museum, Sunderland
XL360	Midland Aircraft Museum, Coventry
XL361	Goose Bay
XL391	Blackpool Airport
XL426	Southend Airport (Vulcan Restoration Trust)
XM569 (nose)	Gloucestershire Aviation Collection
XM573	Offutt Air Force Base
XM575	East Midlands Airport
XM594	Newark Air Museum
XM597	Museum of Flight, East Fortune, Scotland
XM598	Cosford Aerospace Museum
XM602	Woodford Avro Heritage
XM603	Woodford Avro Heritage
XM605	Castle Air Force Base Museum
XM606	Barksdale Air Force Base
XM607	RAF Waddington
XM612	Norwich Museum
XM655	Wellesbourne Mountford

Above: Seen undergoing pre-fitment preparation is an ALQ-101 ECM pod. Such a unit was required as the inernal fit in the Vulcan was tuned to the Soviet radar systems. Below: Heading for its parking slot on the Ascension Island airfield is XM598 complete with a different variation of deflector vanes on the nose. (Mel James)

Alongside the operational live weapons that were built for the 'V' Force were a series of training rounds. These were weapon shells that were built without fuel propellant, engines and warheads but retained the full navigation set-up that allowed crews to practise mock attacks all the way to the launch point.

Service entry of Blue Steel began at RAF Scampton with No. 617 Squadron during 1962. To accommodate the missile each carrier Vulcan had its conventional bomb doors removed and replaced by a set of fairings to fit the weapon. Inside the bomb bay were installed the various packs to provide the required services for the missile. Originally it was expected that a Blue Steel armed Vulcan could be quickly re-configured for the conventional role but as time passed and more modifications were embodied, the prospect of re-roling became almost impossible. It was not until Blue Steel was withdrawn from use that a sense of commonality returned within the Vulcan fleet.

Once No. 617 Squadron had been declared operational it was the turn of Nos. 27 and 83 Squadrons to receive their modified aircraft coming on-line as part of NATO's deterent in 1963. With Blue Steel in service the operational methods used by the 'V' Force also changed. Never able to sustain the routines exercised by their colleagues in Strategic Air Command in its round-the-clock airborne alert, Bomber Command settled for the Quick Reaction Alert standby. These hard standings were built on the bomber's home bases but other airfields, including even London (Heathrow) airport, had a QRA facility which would have been used in dispersing the vital deterent should this have become necessary. In some cases these came equipped with crew accommodation with crews rotating on a set period of alert duty. With crews ready for immediate action the four-minute warning system was introduced in which a force of four Vulcans or Victors could be launched immediately Soviet ICBMs were detected coming over the horizon.

This manner of operation remained Britain's primary strike deterent until the Royal Navy's nuclear-missile-armed submarines took over the role on 30 June 1969.

NUCLEAR ALTERNATIVES

Although Blue Steel was a success it was seen from the outset as being an interim weapon for the 'V' Force. Interest had already been aroused by an American project to place an Air-Launched Ballistic Missile (ALBM) under the wings of a B-52 Stratofortress to replace the GAM-77 Hound Dog. Designated the XGM-87A Skybolt, this project was led by the Douglas Aircraft Corporation. British involvement began in 1969 after discussions between the Prime Minister Harold Macmillan and the incum-

On the occasion of its roll out the now preserved Vulcan K.2, XH558 still wears the gloss finish it aquired whilst in service with No. 27 Squadron. The tanker basket can be seen under the rear fuselage with the drogue stowed inside the box. (Avro Heritage/BBA Collection)

bent US President Dwight D. Eisenhower.

Post-Camp David talks a deal was struck to provide 100 Skybolt missiles for the Vulcan force. To reinforce Avro's lead in the UK some of the Vulcans being built at Chadderton were fitted with wing strengthening and hard points for the new weapon. Another change that took place from the 40th airframe was the substitution of Olympus 301 series engines rated at 20,000 lbs st in place of the earlier Olympus 201 power plants. Trials of the new engines were undertaken using Vulcan B.2 XH557, which also sported Olympus 22R engines destined for the TSR.2 in the number one and four positions. After three years the test-bed aircraft was returned to service standard and was issued back to a squadron.

Missile trials were undertaken using Vulcan B.2s XH537 and XH538. Before the involvement of these aircraft XH563 had already visited the Douglas factory at Santa Monica for electrical compatibility checks.

Although most of the technology in Skybolt would be of American origin, the warhead would be of British design and manufacture thus retaining a measure of independence for Bomber Command. In late 1961 XH537 began test flying from Woodford with a pair of aerodynamic dummies under the wings. To simulate operating conditions as closely as possible all sorties were flown at a height of 45,000 ft and at a speed of Mach 0.84. To reinforce the flying development side of the project a joint trials team was established at Eglin AFB during 1962 to act as a liaison.

Initially the trials were a success as drops of dummy weapons behaved mostly as planned. However, the development of the operational version was running into difficulties. Both the propulsion and navigational systems were exhibiting tendencies to malfunction allied to which the entire programme was suffering from severe cost overruns. From a USAF perspective the more stable, but less flexible silo-launched Minuteman, was about to enter service and the US Navy was about to commission its fleet of Polaris submarines. Against this backdrop it was hardly surprising that the Americans became intent on cancelling the whole of the Skybolt project.

During 1963 at a meeting in the Bahamas, the Skybolt project was put under the spotlight in spite of the announcement that the missile had made its first successful launch and recovery.

With the disappointment of its cancellation British aircraft designers made further attempts to extend the life of the Vulcan as a front line nuclear deterent. Revamped wing and multiple pylon-mounted missiles were just one idea that reached the drawing board stage. It is also recalled that the aircraft of the Waddington Wing, acting as stand-off weapon lanchers, carried out a project to use Folland Gnat trainers mounted under the wings of a Vulcan to simulate the missiles that might be launched against sea targets during Exercise Northern Wedding.

CHANGING ROLE

By the time Blue Steel had been retired all of the Vulcan force were destined for a change of role. Green and grey camouflage was

When the Vulcan K.2 was created it was neccesary to split the HDU apart to get it to fit. Even so enough protruded into the airflow which required a 'dogbox' surround for protection. The white painted undersides were an indication to receiver aircraft where their position was in relation to the drogue. (Avro Heritage/ BBA Collection)

Gently does it as one part of the hose drogue unit is lifted into the rear fuselage of Vulcan XH560 which still carries the pods associated with its earlier role of B.2(MRR). (Avro Heritage/ BBA Collection)

applied to all upper surfaces of the aircraft as by then the Vulcan's role was destined to be low-level attack. Once the Royal Navy, with its Polaris missiles, had assumed the main deterent role the entire Vulcan force was assigned the task of conventional attack with nuclear strike as a secondary option.

Under these circumstances the retirement of the remaining Vulcan B.1 fleet from front line service was inevitable. Many were moved to technical training or fire training duties thus leaving the Vulcan B.2 as the sole equipment in use. At the same time the last Vulcan B.2, XM657 for the RAF left the Chadderton production line in December 1964.

As the primary bomber in RAF service the Vulcan B.2 underwent a series of modifications. The first of these was Terrain Following Radar (TRF) which was mounted in a small pod on the extreme nose. The initial installation was flown in 1966 on XM606, the remaining aircraft being rapidly equipped soon afterwards with this boon to low-level flying. Improvements to the ECM suite saw the addition of an X-Band jamming system. Test flying of a partial single head system was test flown on XL388 and on Vulcan B.1A, XA907 of the Bomber Command Development Unit (BCDU).

Organisational changes were also afoot of which the greatest was the creation of RAF Strike Command on 30 April 1968 by the combination of Fighter and Bomber Commands. Thus the Vulcan and Victor tanker fleet came under the control of No. 1 (Bomber) Group which has its headquarters at Bawtry.

Above: Turbulence and heavy aircraft trials were carried out using Vulcan XH560 as the tanker with XL426 acting as the receiver, note the red photographic marks on the wing leading edge of the latter. Below: This rear on shot of XM571 reveals quite clearly the distinctive turn down and toe out of the jet pipe end caps. This was more noticable on the Olympus 201 powered aircraft as the caps were longer and more slender whilst those of the more powerful Olympus 301 were more squat in nature. (Avro Heritage/BBA Collection)

Part of the ground crew's job was to check the hose drogue unit after each sortie in case of damage. These three airmen have the hose almost fully extended to carry out the check.

Further organisational changes were more of a unit nature with No. 35 Squadron moving to RAF Akrotiri, Cyprus in January 1969 being followed by No. 9 Squadron in February.

The disappearance of Blue Steel also saw the end of the need for the Quick Reaction Alert requirement and the Vulcan force stood down to a lower level of unmanned availability called 'Edith Standby' whereby the more conventional role and use of iron bombs returned as the standard offensive equiment albeit that a new free fall nuclear weapon known as the WE-177 was issued which had a limited guidance system for precision strikes.

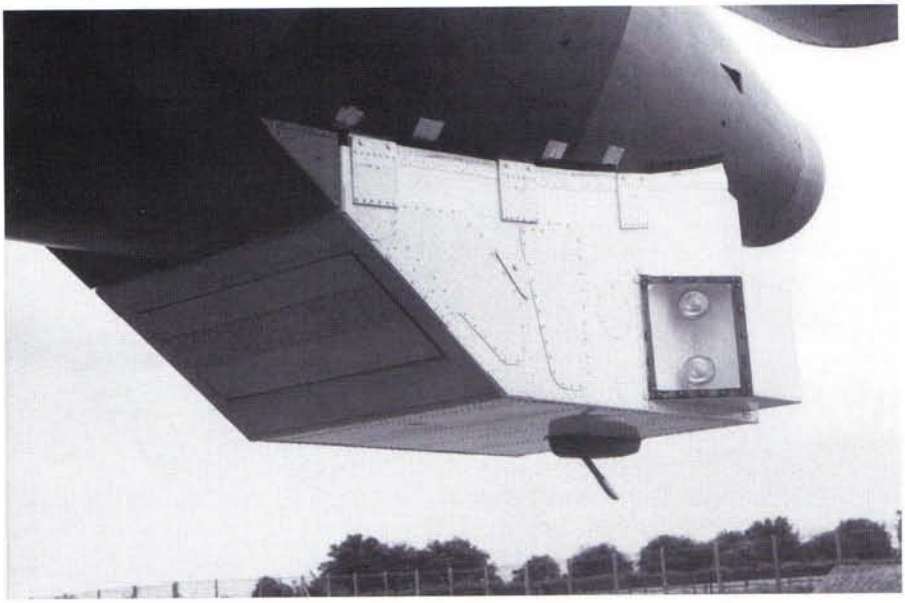
During the 1970s the Vulcan fleet was centred upon Nos. 9 and 35 Squadrons in Cyprus whilst RAF Scampton was the base for Nos. 27 and 617 Squadrons plus the Operational Conversion Unit. RAF Waddington housed Nos. 44, 50 and 101 Squadrons. Changes in the UK were few thereafter although No. 27 Squadron disbanded leaving only two Vulcan squadrons at Scampton.

But further changes, locational this time, were forced upon the two squadrons at Akrotiri when in 1974 civil war broke out between the Greek and Turkish communities in Cyprus. Vulcans of the Near East Air Force Wing were flown back to the UK with No. 9 Squadron going to Waddington and No. 35 Squadron being re-housed at Scampton. The decision to disband No. 27 Squadron was also reversed in 1973 when it was reformed to operate a small number of Vulcans converted as B.2(MRR)s for standard reconnaissance duties replacing the Victor SR.2s of No. 543 Squadron which were required for conversion to the increasingly important tanker role.

The end of the decade saw the Vulcan equipping eight squadrons and the OCU although a smaller, more potent replacement aircraft was about to enter service. This was the Panavia Tornado which, as the GR.1 version rolled off the Warton production line, began to replace the Vulcan in RAF service.

The first to go was 230 Operational Conversion Unit in 1981 being quickly followed by No. 617 Squadron. Scampton's other two squadrons, Nos. 27 and 35 Squadrons, disbanded the following year.

At Waddington No. 9 Squadron was in the



Seen from in front the hose drogue unit fairing also featured lights to illuminate the underneath guidance markings. Also underneath the box is the tail bumper which would warn the pilots via warning lights if their angle of attack was to high on landing. (Mel James)

throes of disbanding when an event many thousands of miles away in the South Atlantic would change the final chapter of the Vulcan story. With the Argentinian invasion of the Falkland Islands, the Vulcan was about to go to war.

THE VULCAN GOES TO WAR

Events in the South Atlantic were precipitated by the attack made on the islands of South Georgia. This was followed by the full scale invasion of the Falklands by Argentina which began on 1 April 1982. From the Argentinian point of view this was a good distraction from problems at home where inflation was running rampant and human rights abuse was normal. In England many suspected that the Foreign Office was already aware of Argentinian plans but were told to play the situation in low key for domestic political reasons. For whatever reasons the local forces under the direction of the Governor, Rex Hunt, surrendered in order to protect the local civilian population and avoid further casualities amongst the small Royal Marine detachment.

The reaction of the British government was to announce that the islands would be retaken by force if necessary. Rhetoric was one thing but logistics of how this could be achieved was another. In part it was solved by the selection of the little known, volcanic, Ascension Island in mid-Atlantic which had a very convenient airfield at Wideawake nominally administered by the Americans to replenish their satellite tracking base there. It had a reasonably long runway and the necessary infrastructure to support operations further south and could be used as a staging post for bombing, transport and maritime reconnaissance missions. Much of the tactical airborne and land operations would have to be the responsibility of the Royal Navy's task force.

Strategic bombing of enemy forces at that distance could only be undertaken by one aircraft, namely the Vulcan. Halting the disbandment of the remaining squadrons was immediate and the planners sought ways whereby the Vulcan force could be used to carry out this task. The irony of the situation was such that only a few months previously a delegation from the Argentinian Air Force had inspected many of the surviving Vulcans as part of a possible purchase agreement.

Although fully capable of carrying many of the weapons in the RAF's inventory the Vulcan had one deficiency that of range for such distant operations when based on Ascension Island. Even with a full 98 per cent of main tankage plus 16,000lbs in the cylindrical bomb bay fuel tanks it was felt that there was not enough leeway to allow for diversionary requirements. Also this fuel arrangement would reduce the Vulcan's weapons load to a third of its potential maximum and was seen as an inefficient use of the resource. As a result steps were immediately taken to restore the Vulcan's in-flight refuelling system which had been dormant for many years. In fact its use had been more of an aid to taxying and as a reference point for the SFOM gunsight. Restoration work required the replacement of all system seals plus work to repair the system compensation bellows which had shown a propensity to leak.

The answer was that the Victor tanker force would be heavily commited to refuelling any Vulcan involved in an attack on Argentinian forces. But further ideas were

Avro Vulcan technical specifications

Power Plants

Prototype VX770
Four 6,500 lbs.st RR Avon RA3
Four 8,000 lbs.st AW Sapphire
Four 15,000 lbs.st RR Conway R.Co.7

Prototype VX777
Four 9,750 lbs.st Olympus 100

Vulcan B.1/B.1A
Four 11,000 lbs.st Olympus 101
Four 12,000 lbs.st Olympus 102
Four 13,500 lbs.st Olympus 104
XA903
Four 17,250 lbs.st RR Conway R.Co.11
XA891
Four 16,000 lbs.st Olympus 200

Vulcan B.2
Four 17,000 lbs.st Olympus 201
Four 20,000 lbs.st Olympus 301
XH533
Four 16,000 lbs.st Olympus 200

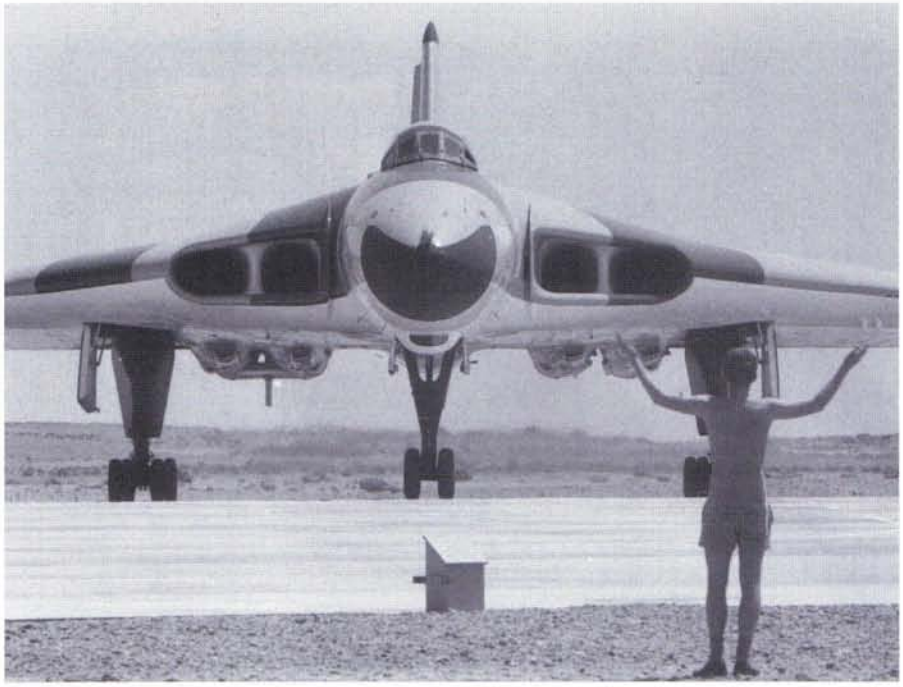
Performance (all values are nominal depending on loading)
Vulcan B.1 Height 55,000 ft Speed 607 mph Max Speed 625 mph Ceiling 55,000ft
Range 3,000 miles
Vulcan B.2 Height 60,000 ft Speed 620 mph Max Speed 645 mph Ceiling 60,000ft
Range 4,600 miles

Operating weights (all weights dependent upon modification state, fuel load, weapons load)
Vulcan B.1 170,000 lbs Vulcan B.2 250,000 lbs Vulcan K.2 266,000 lbs

Dimensions
Span 99ft 5ins (B.1/B.1A) 111ft (B.2) Length 97ft 1ins (B.1) 99ft 11 ins (B.1A/B.2)
105ft 6 ins (with probe) Height (average) 26ft 6ins (B.1/B.1A) 27ft 1ins (B.2)
Wing Area 3,554 sq.ft (B.1/B.1A) 3,964 sq.ft (B.2)

Armament
21x 1,000 lbs iron bombs, 1x Blue Danube, 2 x USAF weapons, 1 x WE.177 weapon.
1x Blue Steel 2 or 4 AGM-45 Shrike, Martel air to surface missile.

Shadow of things to come. A Vulcan K.2 of No. 50 Squadron refuelling a Tornado GR.1 during the latter's introduction into service. The Vulcan tankers did a very necessary job before the arrival of the VC-10 K.2/3s later in the decade. (MoD)



Wearing the first camouflage scheme of grey and green with gloss white undersurfaces this Near East Air Force Vulcan is about to be directed by the waiting marshaller. The only highlights to relieve the finish was the black of the radome and fintip. (John Nickolls)

tried out on redundant XL387 that was awaiting scraping at RAF St. Athan as an aid to reducing the workload of the Victor K.2s. Using a variety of fuel tanks from other aircraft, many of which had long been out of service, ground trials were carried out to see which, if any, were compatible.

The chosen mounting point was just outside of the main undercarriage doors and connection to the main fuel system would have been by a series of unsightly pipes fixed to the wing de-fuelling points. The overload tank that was chosen as the most suitable was the large ferry tank once fitted to the Hunter FGA.9. It was also intended, had hostilities lasted that long, to reinstate to flying status many of the Vulcans that had been set aside for scrapping. In many ways this was fortunate as the Falklands war was over before the programme could be fully implemented.

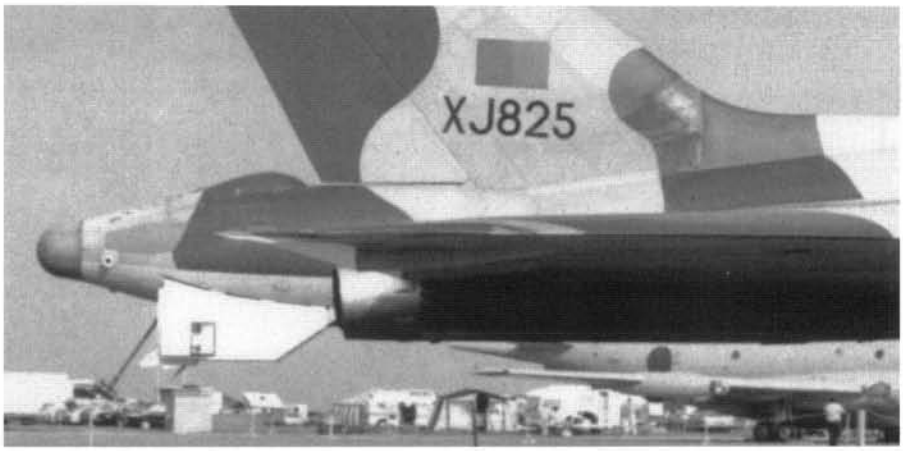
To extend the weapons capabilities of the Vulcan, trials were carried out using a variety of missiles and bombs. The most important of these was the use of the Martel missile for Suppression of Enemy Air Defences (SEAD) operations. In order to carry such a weapon, external pylons would be required and as aircraft from the 40th B.2 had included wing strengthening points for the aborted Skybolt missiles, these were the locations chosen to mount the pylons. As no such pylons were currently available locally manufactured items from Waddington's station workshops were created for the task. Made from a length of steel joist with standard weapon shackles attached, the design was later improved by the use of aerodynamic fairings and quickly cleared for service.

The first Vulcan to be fitted was XM597 which carried out firing tests of Martels over the Aberporth ranges during 4 and 5 May 1982. Although these were successful the Martel was never used in anger mounted on a Vulcan as the limited number available were all allocated to the Nimrod fleet. In their place the United States offered the AGM-45 Shrike anti-radar missile.

With the preparations to extend the Vulcan's capabilities going to plan it became time to select which aircraft would be used operationally. From the remaining aircraft in service ten were chosen all of which had the wing mount points, but more importantly had the wiring looms still in place. Several, it was discovered, had been built without the cable looms whilst others had the looms

Vulcan B.2 XM575 reveals the pattern of the camouflage applied to the undersurfaces. Before this only one other Vulcan had worn an undersurface finish. This was yet another No. 44 Squadron machine that was painted sand and brown underneath. The engines of this aircraft were also modified to eliminate the distinctive smoke signature. Both changes were intended to improve the bomber's chances during Red Flag. (MoD)

Right: Vulcan B.2(MRR) XH560 is seen fitted with its underwing pods converted from redundant Sea Vixen fuel tanks. Not long after this the aircraft flew to Bitteswell for conversion to K.2 tanker standard. Another picture on page 26. Below right: When the six Vulcans required for tanker duties had been converted they were assigned to No. 50 Squadron at Waddington. Besides the more obvious modifications it was felt advisable to instal a fuel dump pipe for emergency use, this can clearly be seen close to the Red Steer tail warning radar. (C P Russell Smith)



removed during major servicing.

From the ten aircraft selected six were chosen as the strike force. Crews were selected from those that had as recently as February taken part in Red Flag exercises in the United States. Two came from No. 44 Squadron whilst one each were provided by Nos. 50 and 101 Squadrons. The last crew came from the recently disbanded No. 9 Squadron. During the selection process the numbers of aircraft thought suitable was further reduced to five although a sixth one did remain available in case any of the others malfuntioned at the last minute.

Inevitably a code name had to be selected and whilst the crews were preparing and the aircraft thoroughly serviced the whole exercise became known as Operation Corporate. Preparations concentrated on flight refuelling and weapons delivery. As far as the former was concerned the crews were unfamiliar with the skills required so their training was undertaken by instructors from the Victor tanker force. To achieve an air-to-air-refuelling qualification the Vulcan pilots were given an intensive four day course in April which normally took two weeks to complete.

As far as the aircraft were concerned even more modifications were considered necessary. The most important amongst these was the installation of a Carousel inertial navigation platform borrowed from the British Airways Boeing 747 fleet in order to improve pin point accuracy over the distances involved. The first Vulcan to be fitted was XM597 quickly followed by the other five. Improvements to the ECM system were also undertaken as although the Vulcan was adequately equipped in that area it was geared towards the suppression of Soviet-based radar systems. As the Argentinian forces had mainly western defence radar, changes had to be made to control and selector boxes and adjustments to the cabling to allow a Westinghouse AN/ALQ-101 jamming pod to be installed on the starboard pylon.

With their training complete and the undersurfaces of the aircraft repainted in dark sea grey, the first two crews and Vulcans XM598 and XM607 were prepared for their journey south. Both left Waddington on 29 April for Wideawake airfield with XM598 flying as an airborne spare. With two successful air-to-air refuellings from Victor tankers on the way the

When centralised servicing was introduced and the Vulcan force aircraft lost their squadron identities many had the squadron badges of Wing units painted on the nose entrance door. This aircraft at Scampton shows the fin insignia of Nos. 27, 83 and 617 Squadrons in addition to the Wing crest. (MoD)

Vulcan cockpit interor. Right: The changes to the pilot's cockpit panel suggested by Roly Falk are clearly seen here. The most prominent is the fighter type control column which helped the pilots throw the aircraft about during combat manouveres. (Damien Burke) Centre: This view over the AEO's shoulder inside XM648 reveals the amount of equipment facing the rear crew. The switch cover by the AEO's left knee when operated would withdraw the entrance door locks thus enabling the crew to egress more easily. (Mel James) Bottom: Although complicated this area was the province of the Nav Rad and Nav Plotter. On the far left of the picture is the indicator screen for the H2S system. (Damien Burke)

two Vulcans reached Ascension Island later that day.

BLACK BUCK RAIDS

After the obligatory rest period the crews prepared for their first mission code named 'Black Buck'. The first mission was launched during the night of 30 April-1 May with XM598 acting as the primary and XM607 acting as the airborne spare. As it happened this was all to the good as the Captain's direct vision window failed to seal properly which caused an unacceptable loss of pressurisation and XM607 took over the lead on the long flight to the target. After eleven in-flight refuellings the Vulcan began to climb to 10,000 ft to achieve the optimum height required to carry out its intended diagonal bomb run across the only airfield on the Falklands at Stanley. With the bomb release set to auto release all 21 bombs cleared the aircraft successfully. The crew were somewhat surprised that the bomb run and the approaches to the target were virtually unchallenged although a Skyguard radar did paint the aircraft before it was jammed.

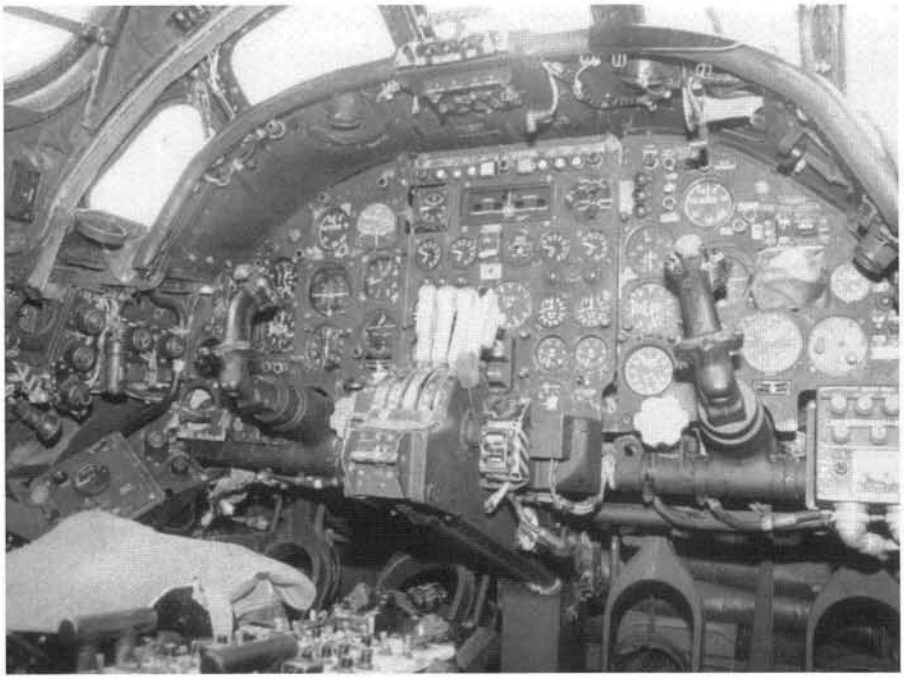
The raid sent two important messages to the occupying Argentinian forces. It proved that heavy bombers were perfectly capable of making attacks on the Falklands, or indeed other targets in Latin America, and now that any hope of a diplomatic solution was over they could expect that British seaborne forces were on their way.

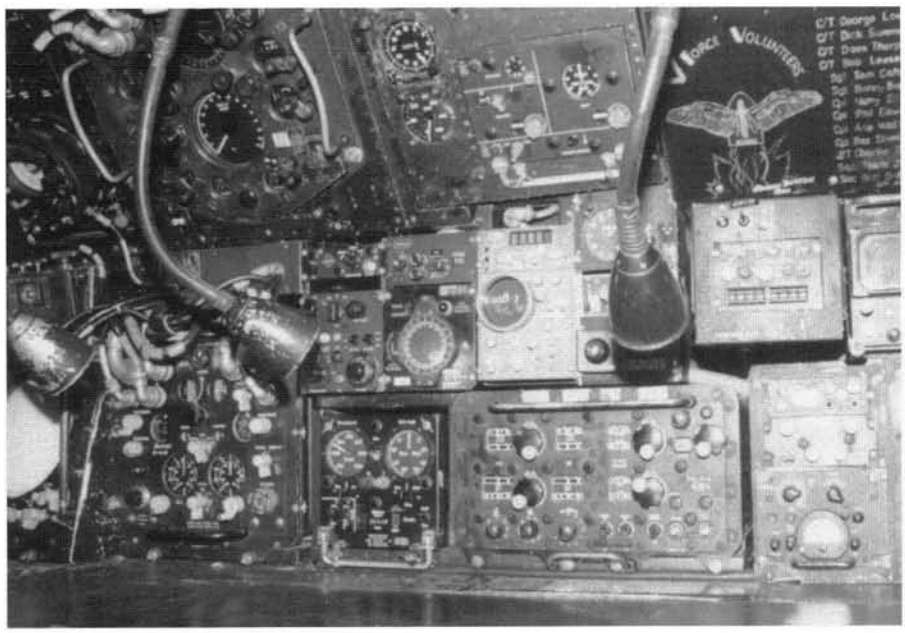
As if to reinforce this message Black Buck 2 was launched on 3 May with XM607 acting as the primary aircraft. Once again the target was the airfield at Stanley and once again the raid went almost unchallenged, the Vulcan returning safely to Ascension. A third mission, Black Buck 3, was planned for 16 May but in the event it was cancelled and the two Vulcans returned home to Lincolnshire.

A change of emphasis was required for the next batch of missions. These were intended to act in the SEAD role to prepare the way for tactical strikes by Harriers from the aircraft carrier accompanying the British expeditionary force. Two of the Black Buck aircraft, XM597 and XM598, were prepared for the mission at Waddington. The Shrike missile load was mounted as a pair on the port pylon only, the starboard side being kept for the ECM pod.

Deployment of the two aircraft began on 26 May with the first mission, Black Buck 4, being launched on the 28th. XM597 was the primary aircraft but had to abort as it was unable to reach the target area as the Hose

Continued on page 40

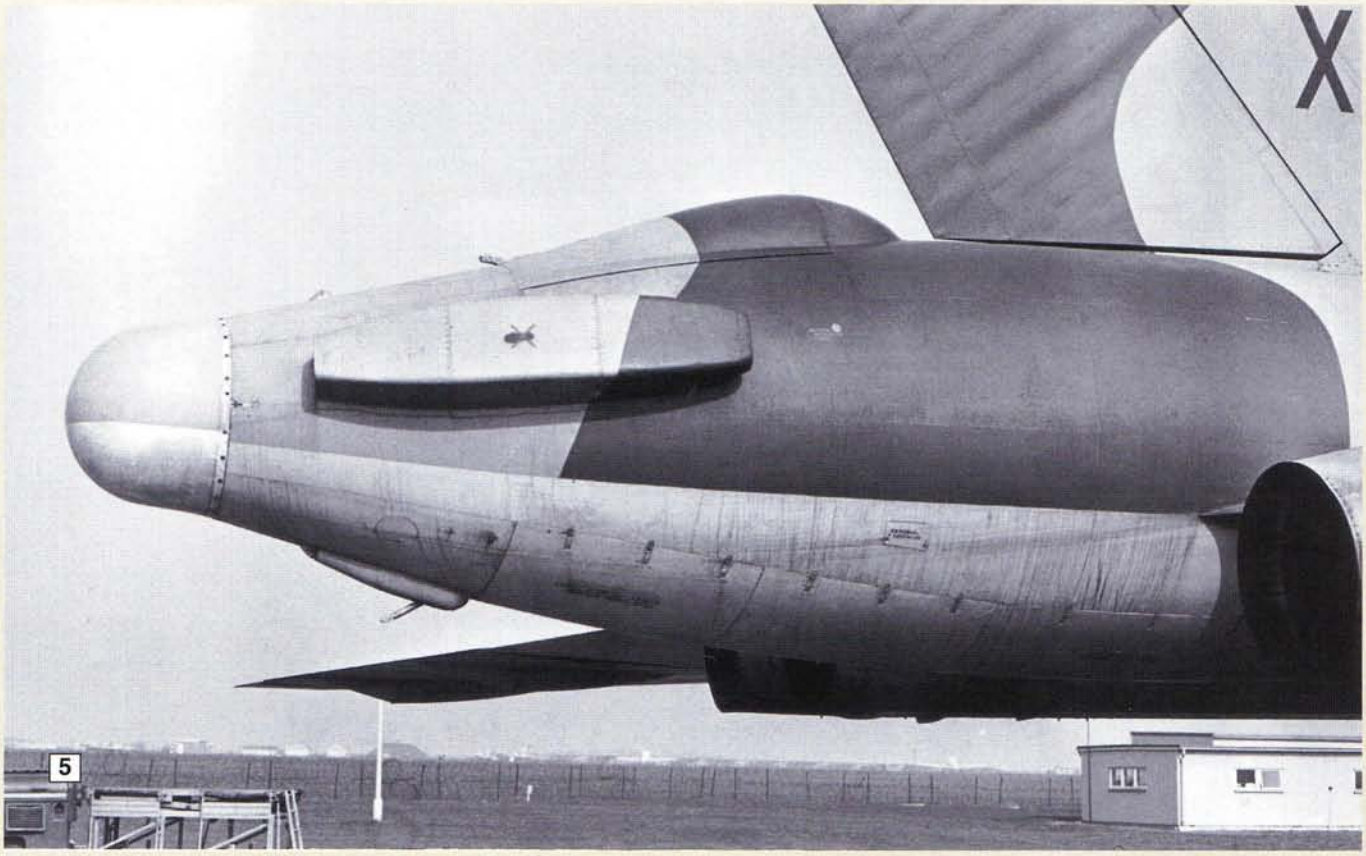




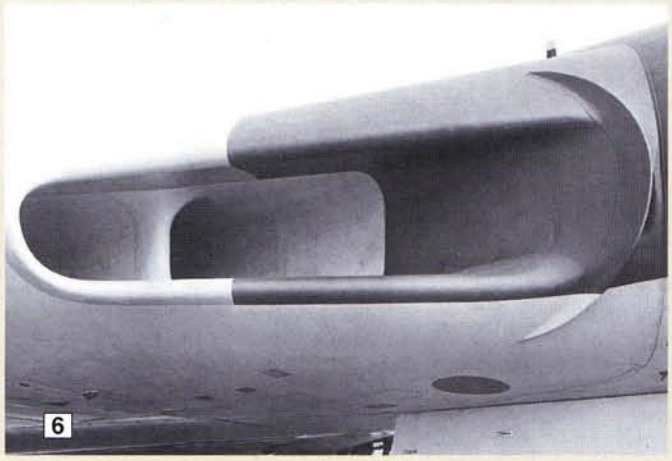
1. Vulcan crew entrance was forward of the nose wheel. The nosewheel leg is for the most part cast as a single component. All three undercarriage leg components were painted black. 2. Fin tip of No. 617 Squadron Vulcan showing the electronic countermeasures aerials that were fitted later in the aircraft's operational career. 3. The starboard main undercarriage leg on Scampton Vulcan XL359. Both main and nose wheel tyres on Vulcans were the same small size, two on the nose and eight each on the main legs. A large oleo strut behind the main leg absorbed the impact of landing. 4. Port side engine intake and part of the dorsal line showing various communications aerials.

Vulcan in detail

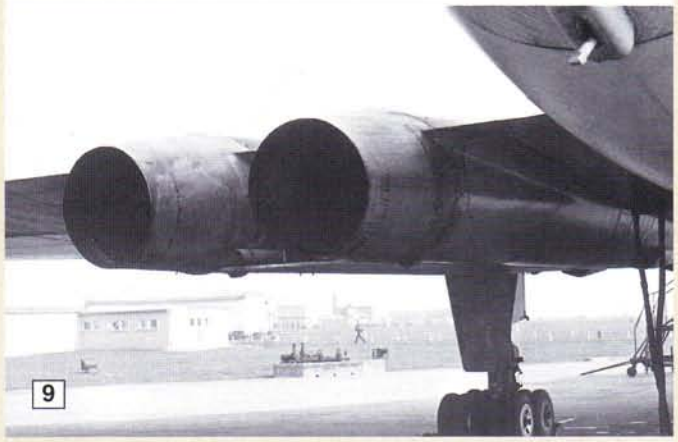
Photographs by Alan W.Hall and Kev Darling of Scampton Wing Vulcans

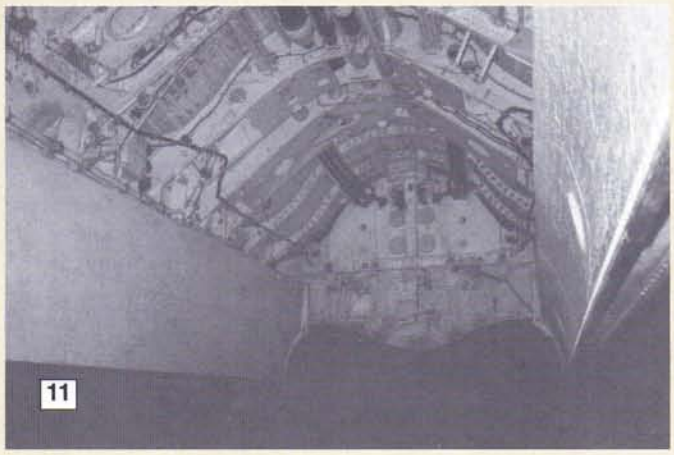


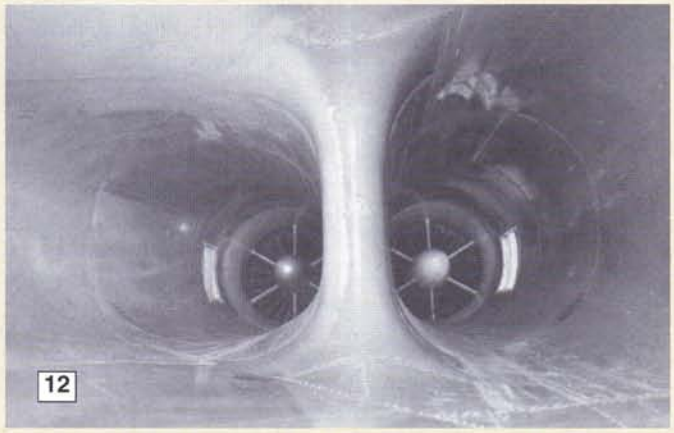
5. Because the ECM equipment housed in the Vulcan's tail used a lot of power and was prone to overheating a Vapour Cycle Cooling Pack was fitted on the side. On top was the tail brake chute housing. 6. Starboard side intakes for the Olympus engines on XL360. A large splitter plate directed air into each engine housed within the wing. Note that the camouflage colours have hard outlines.



7. Another view of the Vulcan's crew entrance in front of the nose wheel assembly. Suspended from inside the undercarriage bay are the headphones used by the crew chief during start up and before taxy clearance. 8. Another view of the main undercarriage leg. Note the size of the main wheel door.







9. This view of the Vulcan's jet orifices clearly shows the way in which each was canted outboard. The positioning of the engine above and below the wing is also shown. 10. There are plenty of pictures available of the Vulcan's air brakes from the front but very few showing the rear side construction. Both upper and lower surfaces are the same although in this case the lower one is partially obscured by the undercarriage door. 11. The rear of the bomb bay mirrored the front in some respects thus a cutout in the spar exists for Blue Steel. The more visible pipework is that required for the bomb bay fire suppression system. The fuel gallery for the bay tanks is just visible above the doors. The tanks could be fitted in the following combinations from the front: drum plus drum, saddle plus saddle and drum and saddle. The extra tank for the K.2 coupled up to points already built into the system. 12. A view familiar to anyone carrying out engine and intake integrity checks. To reduce the risk of Foreign Object Damage (FOD) the number of removable panels was kept to a minimum. In each intake were two panels held in place by numerous fasteners that allowed access to the airbrake guides. 13. Pictures of Vulcans being serviced at night are always impressive. This was probably taken on an exercise in the United States as the ground equipment is certainly not RAF standard. (MoD)

Vulcan 7812M had once been XA899 of RAE Bedford BLEU with whom it made the first four engined automatic landing. After retirement it was transfered to RAF Cosford for instructional use. (Ray Deacon)

Continued from page 36

Drogue Unit (HDU) on the lead tanker failed. A fifth raid was launched on 30 May using XM597 again and this time it was successful. Only one radar locked-on and was fired upon with a Shrike, however, it missed and a second was launched but this lost the lock completely and crashed some distance from the target.

Further radar hunting was the premise for the last Suppression of Enemy Air Defences (SEAD) Black Buck sortie which took place on 2 June. In order to entice the enemy radar operators to switch on, the crew lined XM597 up on the Stanley runway and began an approach as if to make a landing. The ruse worked and Stanley fire control radar came on line against which the Vulcan launched both missiles completely destroying the target.

Having completed its task successfully the Vulcan turned for home. On line and on track the Victor tanker was waiting but then disaster struck. The tip of the refuelling probe broke during the hook-up and no fuel could be taken on board.

After rapid calculations it was seen that the nearest diversion airfield was Rio de Janeiro in Brazil so the crew promptly changed course for the mainland. Part of the diversion plan involved climbing to 40,000 ft, the Vulcan's optimum cruising height, in an effort to extend the range. The aircraft still had two Shrikes on board and to avoid problems these were jettisoned. The first cleared the aircraft but the second hung up. Also ditched at the same time were many of the classified documents which was achieved by opening the crew door and throwing them out.

As soon as the Vulcan approached Brazilian airspace air traffic controllers began to query the unidentified blip on their radar screens. The Vulcan crew were understandably evasive about their origins as hurried diplomatic efforts were made to allow the aircraft to land. These were eventually accepted and the Vulcan landed safely at the airport after a straight in approach complete with Brazilian fighter escort. Immediately impounded by the local authorities the Vulcan was later released. By this time the Shrike missiles had been removed and a new refuelling probe fitted. Part of the negotiated release of the aircraft was that the Vulcan should return to the UK and take no further part in the conflict which it did on 13 June.

A final Black Buck bombing mission, the seventh, was made by XM607 as the primary aircraft. Leaving Ascension on 11 June the aircraft bombed Stanley airfield without resistance before it returned to Wideawake. On 14 June Vulcans XM598 and XM607 returned to Waddington, the day of the Argentinian surrender. For the crews and aircraft of Waddington, their part in the Falkands war was over.

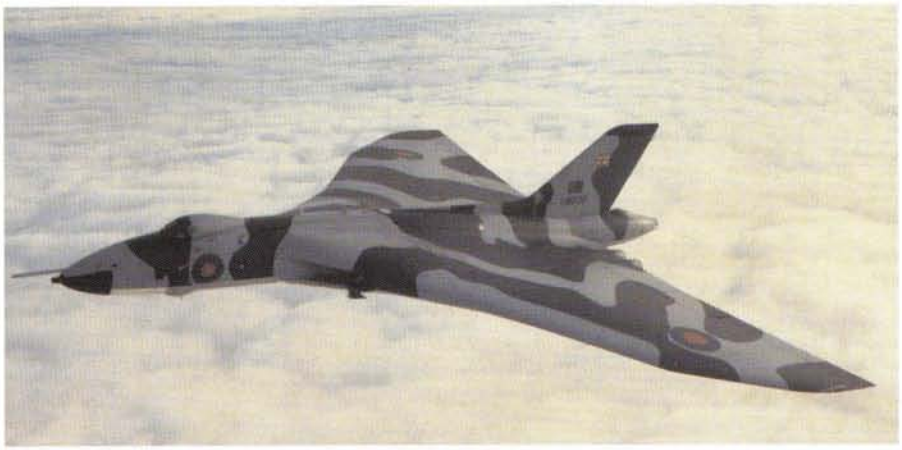
FINAL MODIFICATIONS

The refuelling missions of the Falklands war in support of both Vulcan and Nimrod sorties had placed an incredible strain on the Victor tanker fleet. To overcome this deficiency in the long term, the RAF had contracted for a number of ex-civil VC-10 airliners to be converted at BAe Filton, Bristol, to the tanker configuration. As the conversion process and subsequent trials would take a long tme, it was felt that a short term substitute was required. To overcome this six Vulcans were sent to Woodford for conversion into tanker aircraft. The Vulcan's main fuel system was capable of carrying 72,400 lbs of fuel with a further 16,000 lbs in bomb bay tanks. To extend the tanker role another 8,000 lb bomb bay tank was installed and coupled into the galleries using the already installed connections.

To dispense the fuel a Hose Drogue Unit (HDU) was placed in the ECM tail cone although to get it to fit it had to be split into two. Even so a certain amount of the machinery still protruded below into the airflow. To protect the HDU an aluminium and wooden 'dog box' was added underneath it together with a tail bumper arm to protect against over rotation and excessive flaring on landing

The first flight of a Vulcan K.2 was made by XH561 on 18 June. Between August and September of 1982 all six of the conversions were delivered to No. 50 Squadron at Waddington where they operated alongside four standard bombers retained for the training role. On 31 March 1984 No. 50 Squadron finally relinquished its aircraft as the HDUs were required by the VC-10 tankers. During their active service they had flown some 3,000 hours in support of a wide variety of aircraft. With this, the last Vulcan squadron to disband, the career of this fine aircraft had finally ended.

Known as 'sick-o-sick' by members of the Waddington Wing XM606 is high above the clouds. It is wearing the badges associated with Giant Voice, the SAC bombing competition normally held at Barksdale AFB. This is the matt finish that began to replace the eartlier gloss scheme in 1974-5. (Avro Heritage/ BBA Collection)

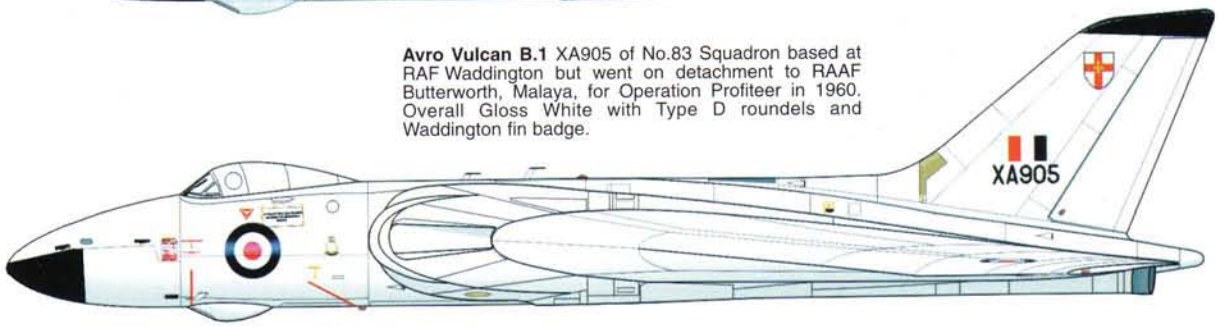


Avro Vulcan kits, decals and accessories

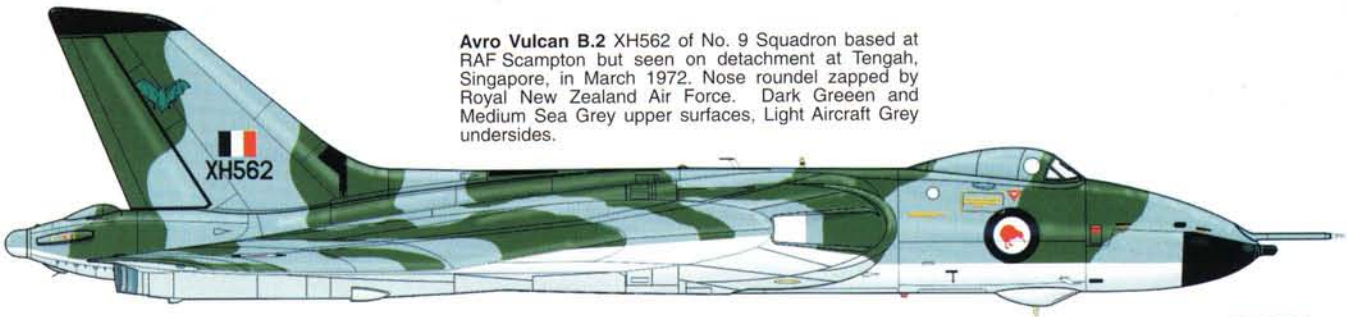
Scale	Type	Manufacturer	Reference	Remarks
1:144	Vulcan B.2	Welsh Models	WHPJW29	Vacuform with metal parts
1:72	Vulcan B.2	Airfix	AX09002	Complete kit
1:72	Vulcan	Rareplanes	-	Early vacuform kit
1:72	Vulcan	PPAeroparts	PPAL720	Early vacuform kit
1:72	Vulcan B.2	Airwaves	AES72090	Black Buck conversion
1:72	Vulcan K.2	Airwaves	AES72091	Tanker conversion
1:72	Vulcan B.2	DB Productions	DB2015	Now from Flightpath
1:72	Vulcan B.1	DB Productions	DB2031	Conversion kit. From Flightpath
1:72	Vulcan	Flightpath	FHP72056	Resin conversion
1:72	Vulcan	Flightpath	FHP72052	Brass etched detail set
1:72	Vulcan	Modeldecal	MD070	Decals
1:72	Vulcan	Modeldecal	MD071	Decals
1:48	Vulcan B.2	Aeroclub	ABVA19	Complete multimedia kit

Avro Vulcan B.1 XA890 retained by Avros for trials purposes but demonstrated at the SBAC Farnborough show in September 1955. Overall Aluminium with Type D roundels.

Avro Vulcan B.1 XA905 of No.83 Squadron based at RAF Waddington but went on detachment to RAAF Butterworth, Malaya, for Operation Profiteer in 1960. Overall Gloss White with Type D roundels and Waddington fin badge.

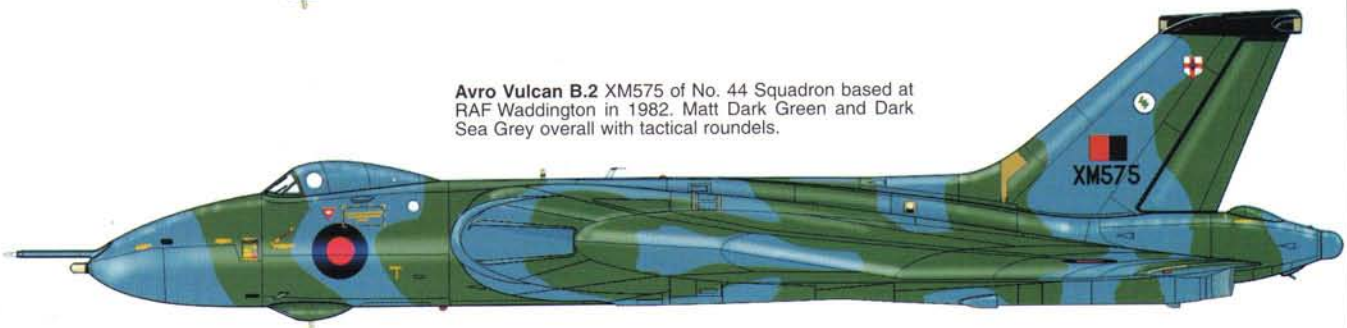


Avro Vulcan B.2 XH562 of No. 9 Squadron based at RAF Scampton but seen on detachment at Tengah, Singapore, in March 1972. Nose roundel zapped by Royal New Zealand Air Force. Dark Greeen and Medium Sea Grey upper surfaces, Light Aircraft Grey undersides.



Avro Vulcan B.2 XM605 of No. 101 Squadron, based at RAF Waddington in 1981. Matt Dark Gren and Medium Sea Grey with Light Aircraft Grey undersides and tactical roundels.

Avro Vulcan B.2 XM575 of No. 44 Squadron based at RAF Waddington in 1982. Matt Dark Green and Dark Sea Grey overall with tactical roundels.



Avro Vulcan B.2 XM607 Flew Black Buck 1 during Operation Corporate's first bombing of Stanley airfield in the Falklands on 1 May 1982. Matt Dark Green and Medium Sea Grey upper surfaces with Dark Sea Grey undersides and tactical roundels.

Above: Although showing the fin badge of No. 44 Squadron, Vulcan XM575 had flown for many years as part of No. 101 Squadron. The colour scheme and markings were from the final period of the Vulcan's operational life. Centre: Four of the Waddington Wing's Vulcan B.2s in formation, an opportunity for which did not often happen. The upper surface camouflage demarcations stand out with clarity. Compare this picture with the similar type of formation on page 6 taken at the beginning of the Vulcan's operational career. Below: For many years XM655 was a stalwart of the Waddington Bomber Wing before passing to No. 101 Squadron with whom it stayed for several years. Upon retirement however it was wearing the tail badge of its last operator, No. 50 Squadron. (Damien Burke)

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