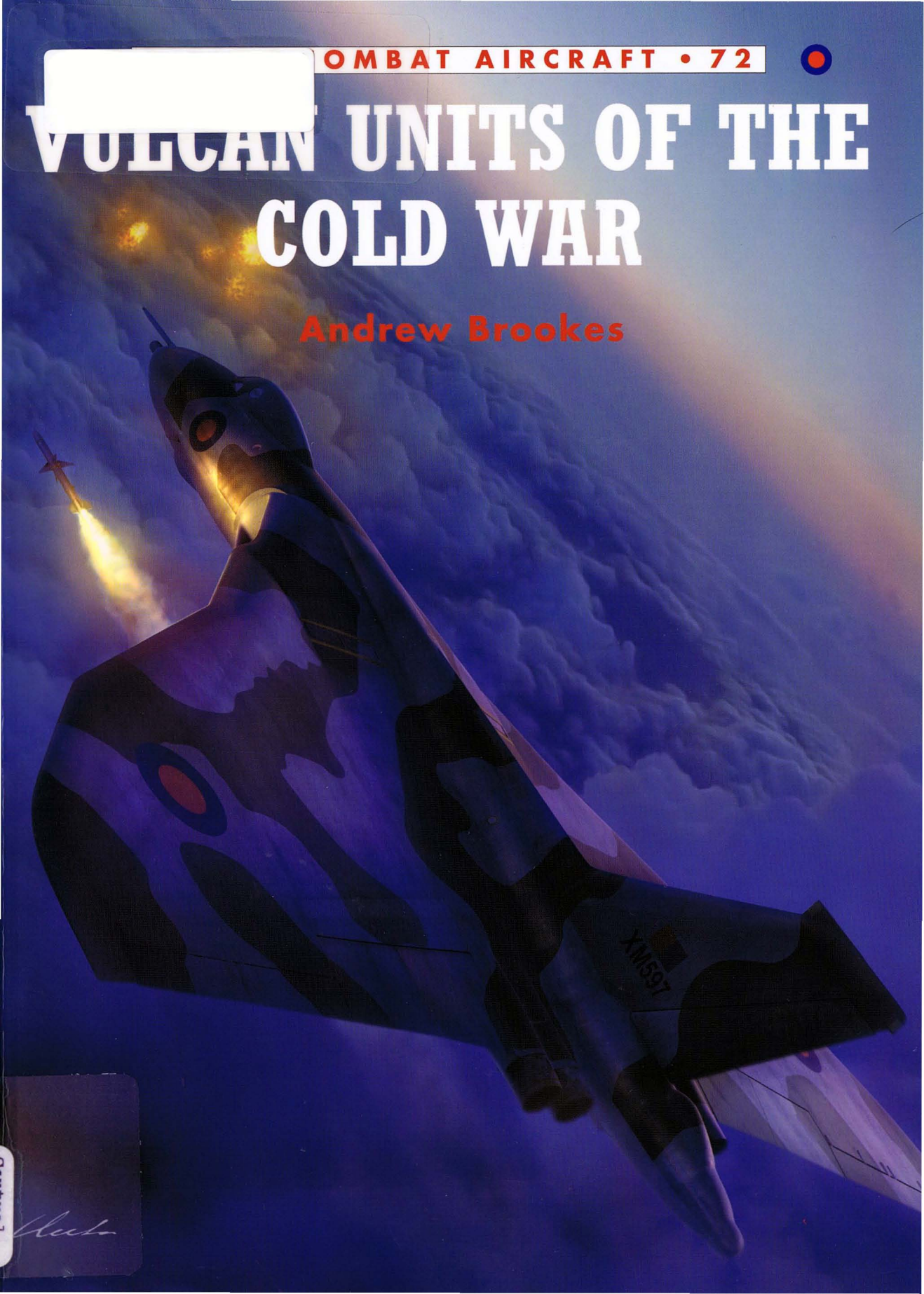
OMBAT AIRCRAFT • 72

VULCAN UNITS OF THE COLD WAR

Andrew Brookes



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OSPREY COMBAT AIRCRAFT • 72

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SERIES EDITOR: TONY HOLMES

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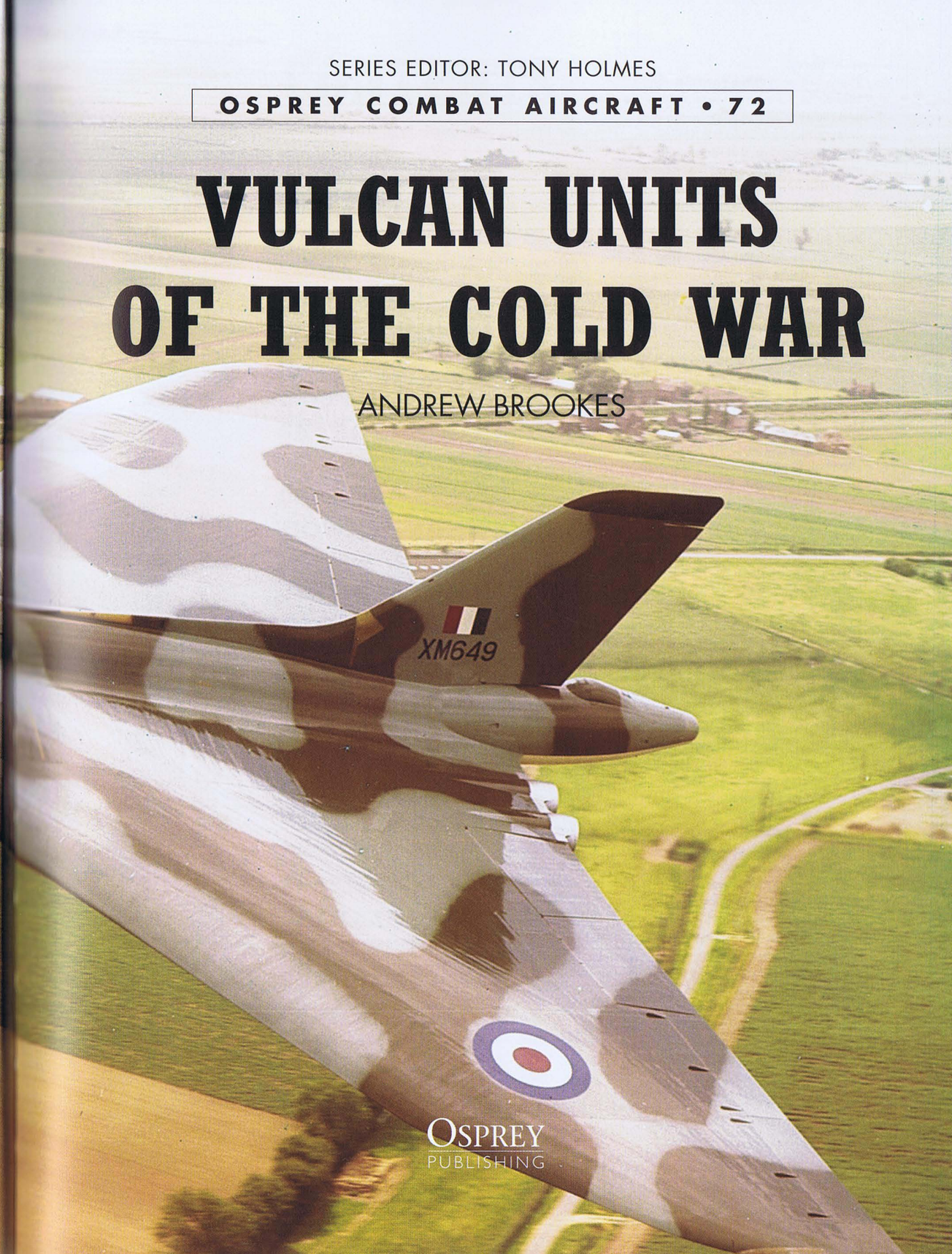

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Front Cover
The weather over the Falkland Islands on 3 June 1982 was poor, and the only offensive air action was an air strike by Vulcan B 2 XM597. Flown by Sqn Ldr Neil McDougall and his No 50 Sqn crew, 'Black Buck 6' carried four Texas Instruments AGM-45A Shrike anti-radar missiles to use against the radars around Port Stanley that were directing air raids on the Task Force, targeting Exocet attacks, warning Argentine aircraft of Sea Harrier patrols and gun-laying for AAA batteries.

McDougall approached the target from the northeast at low altitude, before popping up to 16,000 ft to begin his attack. But experience from previous 'Black Buck' raids had taught the Argentine radar operators what to expect from a Vulcan behaving in this way. 'As we got to about nine miles from Port Stanley', recalled McDougall, 'the radars started to switch off, and as we went past and out to sea again, they came on. We went round and round repeating that process for about 40 minutes. Then, on the final run before we had to go home, I decided to go into a descent towards Port Stanley airfield to tempt them into switching on the radars to have a go at us'.

McDougall eased back the four throttles and XM597 started to descend. 'We got down to about 10,000 ft, heading towards Sapper Hill, and sure enough one of their radars came on. Then the guns started firing at us. I saw flashes in the sky as four shells burst below me and to the right'.

Meanwhile, Air Electronics Officer (AEO) Flt Lt Rod Trevaskus locked on two Shrikes and launched them one after the other at the radar. As McDougall pulled the Vulcan up so as to avoid going too low, he saw an explosive flash light up the mist just above the ground. One of the missiles had impacted close to a Skyguard fire control radar, where it caused damage and killed four of the operating crew – an officer, a sergeant and two soldiers (*Cover Artwork by Gareth Hector (model supplied by MilViz)*)

For Rebecca and Edward

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VULCAN'S FORGE

As the United Kingdom still held sway over one quarter of the globe at the end of World War 2, the British government decision, taken on 8 January 1947, to develop an atomic bomb was inevitable. It would take until 1952 to detonate the first British nuclear device, and a few more years after that to perfect the first practical atom bomb, called Blue Danube.

Blue Danube had a 24ft-long bomb case, weighed 10,000 lbs and had an explosive power of up to 40 Kilotons (KT). RAF Specification B 35/46 called for a four-engined jet bomber capable of delivering Blue Danube, or a variety of conventional weapons, over a still air range of 3350 miles by day or night. Cruising speed was to be 500 knots (Mach 0.873) at continuous power to a target 1500 miles from base. The aircraft had to exceed 50,000 ft by as great a margin as possible as fuel weight reduced, yet the specification stipulated a maximum all-up-weight of 100,000 lbs because runways of the day could not cope with anything heavier.

RAF Bomber Command regarded height and speed as the means of salvation in 1946, because the higher a bomber flew the harder it would be to catch, and the faster it travelled the less time it would be exposed to detection and attack. Only a streamlined jet bomber could fly high and fast, which meant dispensing with turrets, guns and ammunition, as well as protective armour, gangways, communications and pressurised life-support facilities. Given that the war in Europe had not long been over, it was revolutionary to think about sending a heavy bomber twice as far as Berlin with no reassuring armament for protection.

Six designs were submitted to meet Specification B 35/46, the most advanced of which were the delta wing Avro Vulcan and the crescent wing Handley Page Victor. As officialdom could not decide between them, the Air Ministry ordered both, and then added the Vickers Valiant as an insurance measure.

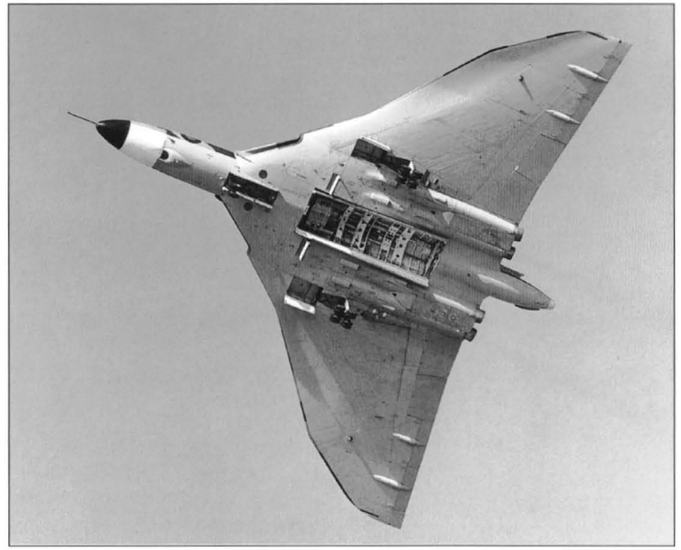
The Avro Project team in Manchester began with a conventional-tailed aircraft of 45 degrees sweepback. Swept wings produce less lift than conventional wings of equivalent size, yet the requirements of altitude demanded greater, not smaller, coefficients of lift. To compensate for this, Avro had to increase the swept span, but this resulted in a design of poorer performance that weighed 80,000-90,000 lbs too much.

So it was back to the drawing board to combine different degrees of sweep with thinner wings, lower wing loading and lower aspect ratio. However, the speed at which the

Blue Danube was the first British operational atomic bomb. The warrant officer standing on the right gives some idea of the size of the 10,000-lb weapon

bomber was expected to cruise limited the scope of these fixes, and structural weight was still so high that it meant sacrificing bomb load to an unacceptable degree. It was feared that the requirements were just too conflicting to be embodied within one airframe.

It took nearly a month to dispense with the tail altogether. Since a bomber carries its load concentrated around its centre of gravity, and as a swept wing increases longitudinal stability, all the old reasons for having a rear fuselage supporting a tail no longer applied, and it could be deleted once longitudinal controls were fitted to the wingtips. But even though this gave an immediate saving in weight and drag, the wing itself was still disproportionately large for its purpose, and much heavier than required. There was nothing left but to reduce the span.

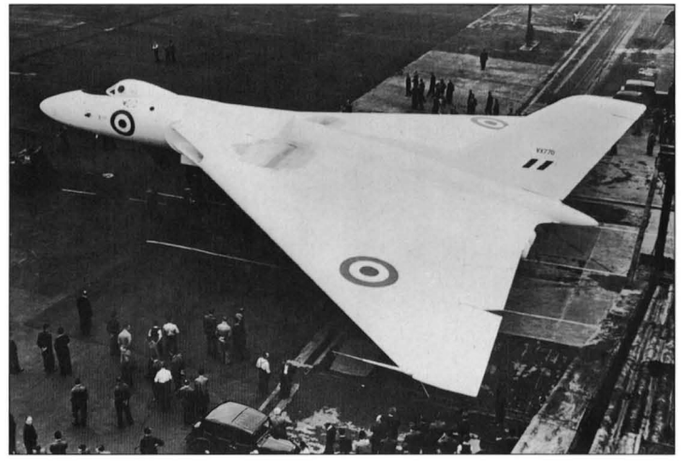


This underside view of a Vulcan B 2 clearly shows the cavernous dimensions of the aircraft's bomb-bay. Also clearly visible is the visual bomb-aiming position forward of the nosewheel leg

However, chopping pieces off the wing meant decreasing the wing area, and thereby upsetting all the carefully calculated factors of wing loading, thinness and aspect ratio. As the wings got broader and stubbier, the Project team kept the wing area constant by filling in the space between the wing trailing edge and the fuselage. By the time the span had been reduced sufficiently to get the weight within acceptable limits, while maintaining sweep and reducing tip chord to give adequate induced drag for maximum range, the gap between the short body and the wing trailing edges had been virtually filled in, forming a natural triangular planform resembling the Greek letter delta. This then was the logical evolution of the Vulcan shape. It owed nothing to the Germans or anyone else. Shortly afterwards, the maximum weight restriction was lifted on the grounds that it was cheaper to lay longer runways.

Roll-out of the first Avro 698 prototype from the factory at Woodford, near Manchester, in 1952. VX770 disintegrated when the pilot exceeded the aircraft's airframe limits during an airshow at Syerston, near Nottingham, on 20 September 1958

The first contract for two prototypes of what was then the Avro 698 was received in March 1949. By the following September the design of the big bomber should have been frozen, but wind tunnel tests had shown that the 698's fuselage was changing the pressure distribution over the wings and engine air intakes from that which had been envisaged. The solution lay in sweeping the line of peak section sharply forward over the inner portion of the uppersurface such that the wing was now thickest at the root leading edge, reducing to a minimum at the tip. Thus it came



Looking as dapper as ever, Avro chief test pilot Roly Falk boards a Vulcan at Woodford. The aircraft was so nimble and responsive to fly that Falk barrel-rolled one at the 1955 Farnborough Show

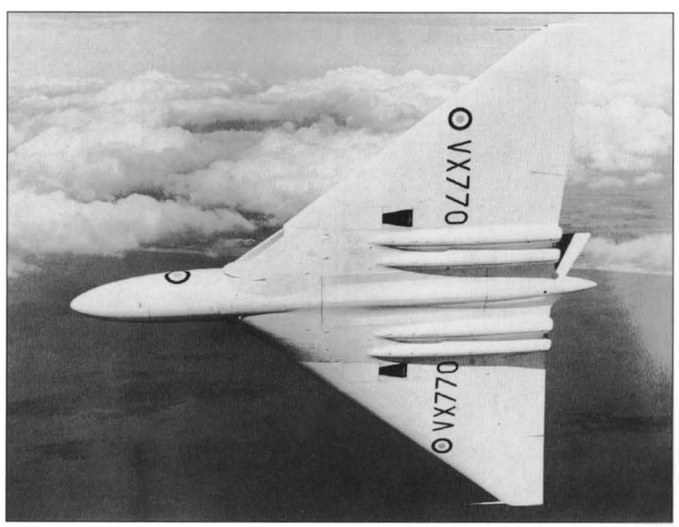
about that Avro produced the first high-speed aircraft whose wing roots were almost as thick as the 9-ft diameter fuselage to which they were connected. This provided plenty of space for future larger engines to be installed internally side-by-side.

Avro received a contract in June 1952 for 25 production models of 'the most efficient long-range bomber design in the world'. After hastening through ground running and taxiing trials, Avro test pilot Roly Falk got airborne on 30 August in all-white prototype VX770, which at the time of its first flight still had no cockpit pressurisation or wing fuel system. VX770 went on to appear at the Farnborough airshow just days later, giving rise in the mind of *The Aeroplane* correspondent at least 'to eerie sensations, and a feeling that it was extra-terrestrial, manned by species hitherto unknown to man'!

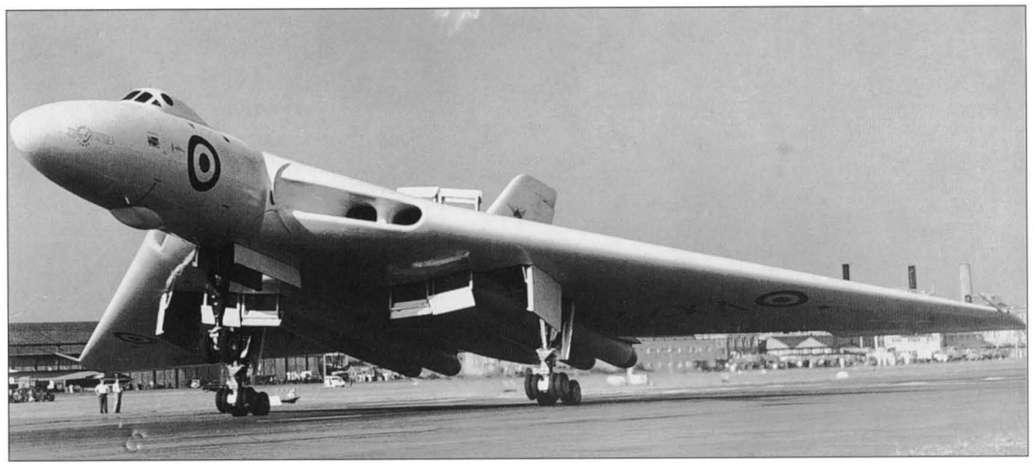
Flight magazine subsequently came up with all sorts of alliterative names such as 'Avenger', 'Apollo' and 'Assegai' (after the Gloster Javelin), before finally recommending Avro Albion. However, the Chief of Air Staff stated that his preference was for a V-class of bombers based on their wing shapes. By October the Air Council had decided to christen the Avro 698 'Vulcan' after the Roman god of fire and destruction. Vulcan was not a new name in aeronautics, as it had been used for a Vickers transport in the 1920s, and it did not meet with universal approval. 'I never liked the name', said Avro's technical director. 'After it was announced I went to look it up in a mythology book, and the definition of Vulcan was "misshapen god of war thrown out of heaven"'.

The Vulcan's crew was housed in a single pressure cabin, and the flight deck was very cosy. The two pilots sat up top looking out through what can best be described as a letterbox with bars. One pilot could fly the Vulcan, but the RAF believed that the days of letting a brand new pilot loose on an expensive bomber had died with the Lancaster, and they needed the co-pilot's seat to both train captains of the future and to cope if the first pilot was disabled.

Down from the pilots, behind a blackout curtain to stop the sun shining on all the dials and screens, sat the Nav Radar, Nav Plotter and Air Electronics Officer (AEO) in line abreast. Their seating was likened to sitting backwards in a coal cellar at midnight. There was little room to move around, and the only place to lie down was the visual bomb-aiming position in the nose. There was no toilet – only individual pee-tubes – and if you flew non-stop to Australia, you had to wear nappies. In-flight rations were sandwiches, chocolate and orange squash. There were, however, soup heaters, but it took 90 minutes to heat up a tin of Crosse and Blackwell, and you had to remember to puncture the tin first or soup went all over the cabin.



VX770 showing off its pure delta shape to maximum effect in 1952. The gaps show where the undercarriage fairings blew off during the prototype's first flight. Avro had forgotten about the flexibility of the wing structure, which tore the fairings off like tissue



The second Vulcan prototype, VX777, lands at Farnborough in September 1953. The over- and underwing airbrakes look crude, but they were very effective. The lower airbrakes were soon halved in number to prevent pitching down when extended at high speed

The intention throughout was to power the Vulcan by 11,000-lb thrust Bristol Olympus turbojets, but this engine had only reached the ground-testing stage by 1952. Consequently, Avro chose the 6500-lb Rolls-Royce Avon as an interim engine, and so it was not until late 1954 that Olympus 101s were finally installed. The Olympus prototype confirmed that when 'g' was applied at high level and high speed, a mild high-frequency buffet resulted.

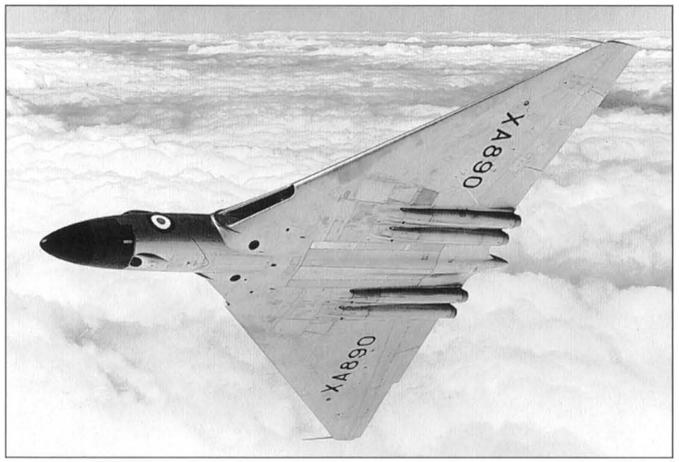
Buffeting occurs when the airflow separates from the uppersurfaces of the outer wing, and at its worst, buffeting could lead to failure of the outer wing structure.

Of more immediate concern to Vulcan designers was the fact that buffeting cut down range, did little for accuracy on a bombing run and allowed little margin for evasive manoeuvre before the stall. The answer was to put a kink in the straight delta leading edge, which increased the incidence of buffet threshold by about 20 per cent.

It was an old joke that Avro aircraft were built by simple folk for even simpler folk to fly, and the real reason why they had a winner was the fundamental simplicity of the bomber. This was exemplified by the Vulcan's over- and underwing airbrakes, which motored out courtesy of nothing more sophisticated that enlarged bicycle chains!

Known affectionately as the 'Flat-iron', the Vulcan entered service eight-and-half years after receipt of the Instruction to Proceed, as against nine years for the Boeing B-52. A single Vulcan B 1 cost around £750,000, and for this the RAF received a bomber consisting of 167,063 separate parts (excluding engines), 410,300 nuts, bolts, washers and rivets, enough metal sheeting to cover 1 1/2 football

Delta show-stopper. Roly Falk leads in VX777 with Olympus 100 engines while Sqn Ldr J B Wales flies the Sapphire-engined VX770 in line astern. Four Avro 707s – small scale deltas designed to prove the aerodynamics of the real thing – complete the delta formation



XA890 – the second Vulcan B 1 – was painted silver overall and retained its 'straight' wing throughout its long test career, which finally ended on the fire dump at Boscombe Down in 1973

pitches, 9362 ft of tubing, 2½ miles of rolled sections and 14 miles of electrical cabling. When it had all been put together to make the first production Vulcan, XA889 was delivered to Boscombe Down for acceptance trials in spring 1956. Initial Release for operational use came on 29 May. The RAF received its first Vulcan B 1 in July 1956.

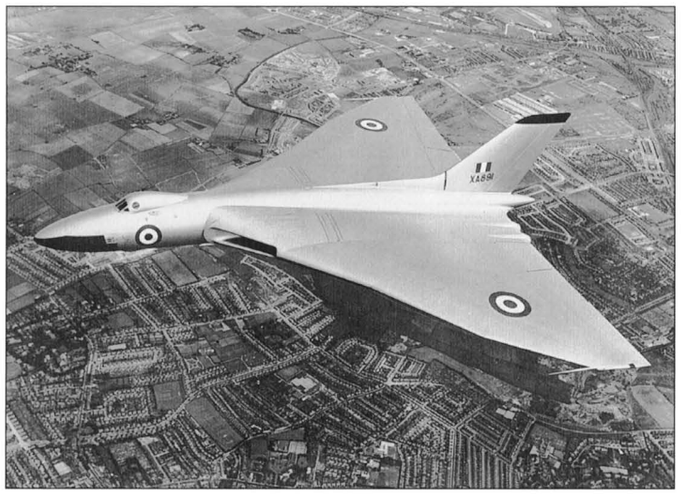
No 230 Operational Conversion Unit (OCU) at Waddington completed Vulcan service trials in December 1956, prior to officially commencing the training of crews on type from 22 February 1957. The first course went on to form 'A' Flight of No 83 Sqn at Waddington, the second course completed the unit's complement and the third course formed 'A' Flight of No 101 Sqn at Finningley on 15 October 1957, and so on.

Forty-five production Vulcan B 1s were built, and these were followed by 89 Vulcan B 2s. The latter had a bigger wing area of 3965 sq ft – by comparison, the Rockwell B-1B's wing area is 1950 sq ft – and by spring 1958 a development Vulcan had been fitted with 16,000-lb Olympus BO 16 engines, which were later designated the 200 series. The B 2's more efficient use of greater engine power extended Bomber Command's target coverage by 25 per cent, and paved the way for the first pre-production B 2 (XH533) to reach 61,500 ft on 4 March 1959. Nothing vindicated the larger delta wing more forcibly than the following succinct entry under Airframe Limitations in the Vulcan B 2 Aircrew Manual;

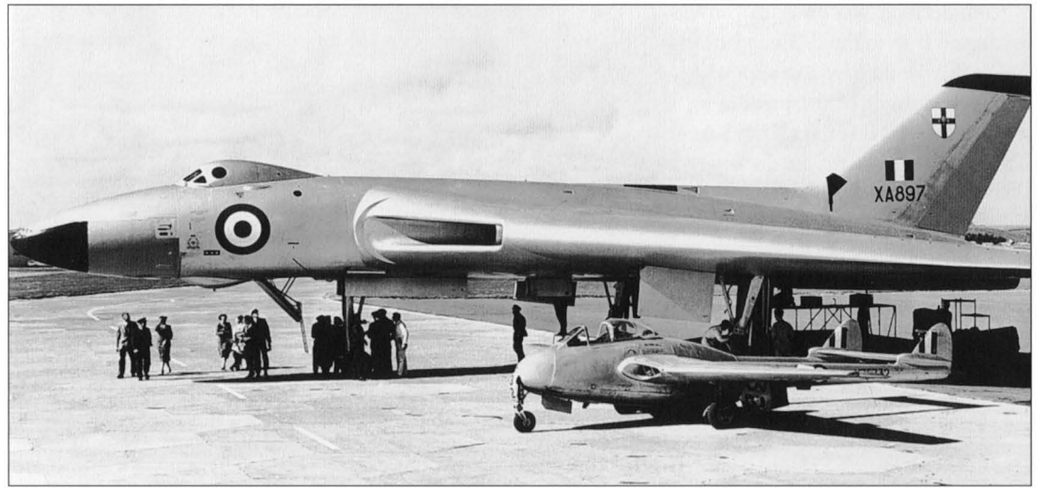
'There is no height restriction on the aircraft because of airframe limitations.'

The first Vulcan B 2s were powered by Olympus 201 engines, now rated at 17,000-lb thrust, set behind enlarged air intakes and in front of toed-out jet pipes. The larger intakes had been fitted in preparation for the day when the BO 121 (300 series) turbojets would be ready, but the engines could only be squeezed in by compressing the electrics. It was therefore propitious that Avro had decided to fit a less bulky constant-frequency AC electrical system into second-generation Vulcans in place of the old DC equipment.

XA891 – the third Vulcan B 1 – was also painted silver overall and featured the new double glass-fibre/Hycar sandwich nose cone housing the H2S radar scanner. XA891 also sported the new kinked leading edge that increased outer wing area and thereby reduced the onset of buffeting



The introduction of a constant-frequency AC system sounds mundane, but it is impossible to over-estimate its implications for Vulcan crews. The main AC system



XA897, with the City of Lincoln crest on its fin, at Ohakea, New Zealand, in September 1956 after establishing a point-to-point record between Hobart and Christchurch of 634 mph. A diminutive Vampire of No 75 Sqn RNZAF sits alongside. XA897 was the first Vulcan to make an overseas flight, but it would crash in poor weather at London (Heathrow) airport upon its return to the UK on 1 October, killing all the rear crew

was not only much more reliable, it also meant that more effective back-up facilities could be built into the aircraft. For a start, the main Vulcan electrical system was divided into two halves so that even if two alternators on one side failed, the two on the other side could carry all the loads. If all four alternators failed at height – most likely because a nuclear blast blew back on all four engines – the pilots would pull a handle that lowered a Plessey ram air turbine (RAT) into the airstream below the port engine intake. This wind-driven alternator would provide power for the flying controls until the bomber descended to less rarefied levels, where the AEO could start the Rover gas turbine Airborne Auxiliary Power Plant, positioned outboard of No 4 engine, to take over all the essential services until the main alternators could be brought back on line.

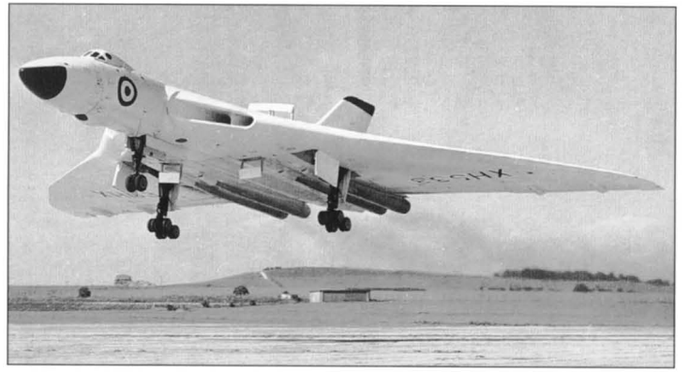
AC would also meet the needs of additional services such as electronic countermeasures and stand-off missiles that were then in the offing.

The Vulcan carried 9400 gallons of fuel in 14 separate pressurised tanks, five in each wing and four in the fuselage. A simple system, based on an electric motor driving a few cams that switched pumps from full to half speed cyclically, kept the fuel centre of gravity constant throughout flight. Along the B 2's wing trailing edge were eight full-span elevons – two very large inboard and two small honeycomb-filled ones outboard on each side – which were great for holding the bomber up on its hind legs for aerodynamic braking after touchdown.

The Vulcan B 2 also had a strengthened undercarriage and shortened nosewheel leg.

The B 2 production line was established before the B 1 orders were completed, so the last B 1 (XH532) was delivered some seven months after the first pre-production B 2 (XH533) had taken to the air for the first time on 19 August 1958. Production B 2s should have followed in quick succession, but then Avro was suddenly asked to fit a range of large electronic countermeasures (ECM) equipment into the aircraft as well. This necessitated a new Vulcan B 2 tail which, although only 34 inches longer than that fitted to the B 1, was much bulkier and 'knobblier', and as large as a Folland Gnat fighter so as to be able to accommodate all that lay therein.

Consideration was given to converting all B 1s to the B 2 standard, but as this would have cost approximately two-thirds of the price of a new B 2, only 28 B 1s (plus XA895 as a trials airframe) were given the same bulged and extended rear fuselage – these aircraft were designated Vulcan B 1As. Each basic Vulcan B 2 cost in excess of £1 million at 1960 prices, and the first was delivered to No 230 OCU at Waddington on 1 July 1960.



XH533 was the first production Vulcan B 2, and it is seen here undergoing acceptance trials at Boscombe Down

As more B 2s entered service, the first 20 aircraft from the September 1954 B 1 contract and eight of the best from the original 1952 order were individually withdrawn from the frontline to be converted into B 1As. The first conversion was completed by Armstrong Whitworth in August 1960, whereupon XH505 was redelivered to No 617 Sqn. Although the B 1A incorporated the Mk 2 ECM jamming kit and tail cone, it was impossible to modify its electrical system from DC to AC, so the ECM equipment had to draw its power from an additional engine-driven alternator. The bulk of the B 1As were modified in 1962, and conversion ended on 6 March 1963 when the last one was returned to Waddington.

There were three B 1 squadrons in existence by the beginning of 1960 – No 83 Sqn at Waddington, No 617 Sqn at Scampton and No 101 Sqn at Finningley. Once Vulcan B 2s started entering service, there was much shuffling of units and aircraft until by the beginning of 1962 all the B 1s and B 1As were concentrated within three squadrons at Waddington.

The first of these was No 44 Sqn, re-forming on 10 August 1960 by the simple expedient of taking over No 83 Sqn's eight B 1s and personnel – it received its first B 1A in January 1961. In June 1961, No 44 Sqn was joined by No 101 Sqn, which moved its aircraft over to Waddington from Finningley while No 230 OCU moved in the opposite direction. Finally, No 50 Sqn became the last B 1/1A unit, re-forming on 1 August 1961 with aircraft that had come from No 617 Sqn.

Vulcan sartorial chic 1957. This No 83 Sqn crew consisted of, from left to right, Donald Howard (captain), John Pack (co-pilot), Roy Hansard (Nav Plotter), 'Slim' Pocock (Nav Radar) and Jock Wilson (AEO)

The first Vulcan B 2s went to those squadrons that had just handed over their B 1s and B 1As. Scampton was the first B 2 station, accommodating No 83 Sqn, which received its first B 2 in December 1960, followed by No 27 Sqn on 1 April 1961 and No 617 Sqn that September. As more aircraft came off the production line, Nos 9, 12 and 35 Sqns were formed at Coningsby on 1 March, 1 July and 1 November 1962, respectively, to complete the Vulcan force.

WAY UP HIGH

A down-rated Blue Danube was dropped on Maralinga, in South Australia, on 11 October 1956. After Blue Danube came second-generation bomb Red Beard, which went into production in 1959. Once the US tested its first thermonuclear device in October 1952, followed by the USSR in August 1953, the British had to follow suit.

On 6 April 1955, the UK Chiefs of Staff laid down the first priority to develop a weapon with a yield of about 1 Megaton (MT). Britain's first thermonuclear bomb, a Green Granite warhead in a Blue Danube casing, was dropped from a Valiant on Christmas Island, in the Pacific, on 17 May 1957. These Operation *Grapple* trials, which lasted until September 1958, provided the warheads for the Yellow Sun family of thermonuclear bombs – Yellow Sun Mk 1 had a 0.5 MT yield and Yellow Sun Mk 2 a 1 MT warhead. Weighing around 3000 lbs less than Blue Danube, Yellow Sun Mk 2 was the only serious free-fall British megaton bomb.

Vulcan B 1/1As carried Blue Danube and then Yellow Sun Mks 1 and 2 from 1960, while Vulcan B 2s only carried Yellow Sun 2s.

RAF nuclear weapons were kept in Special Storage Areas (SSAs) on main base airfields. Maintenance was undertaken in highly guarded depots at Barnham, near Thetford, and Faldingworth, north of Lincoln. Faldingworth dealt in the main with the mighty Yellow Sun.

One of the *Grapple* series of thermonuclear explosions during the Christmas Island tests, staged in 1957-58

The RAF strategic nuclear bomber force came of age with the appointment of Air Marshal (AM) Sir Harry Broadhurst as Commander-in-Chief (CinC) Bomber Command in 1956. His command was divided into No 1 Group, with its HQ at Bawtry Hall, near Doncaster, responsible for Vulcan bases in Yorkshire and Lincolnshire, and No 3 Group at Mildenhall, which looked after the Victors' and Valiants' Midlands and East Anglian airfields. No 1 Group was given to AVM Augustus 'Gus' Walker, the ex-England stand-off and famous World War 2 one-armed bomber leader.

A Yellow Sun 2 megaton bomb is kept under wraps and securely guarded at Waddington in 1965

Throughout its life, the Vulcan was part of the Medium Bomber Force (MBF), reflecting the bombers' range when set against the truly intercontinental USAF B-52. The MBF was concentrated on ten Class 1 airfields, with dispersal in tension to 26 other airfields in the UK. But dispersal on its own would not suffice for long. Low-trajectory nuclear-tipped medium-range missiles that appeared in Czechoslovakia after 1958 could hit the UK within four minutes of launch.

The 1958 Defence White Paper revealed that measures were being taken to raise the MBF's 'state of readiness, so as to reduce to the minimum the time needed for take-off'. Concrete hardstandings known as Operational Readiness Platforms (ORPs) were placed at the end of the runway on main bases, and money found to put ORPs for two/four jets on all but six dispersal sites. Once 'quick start' facilities were added, all the V-bomber crews had to do was roll forward and 'scramble' in succession.

OPERATIONAL EFFECTIVENESS

Talks in early 1957 between the RAF Chief of Air Staff and his USAF opposite number resulted in the targeting plans of US Strategic Air Command (SAC) and RAF Bomber Command being closely dovetailed. Consequently, Bomber Command had the advantage of knowing that its progress in a war would be facilitated by US missiles, but it was not just a one-sided arrangement. 'Some of our targets', recalled one AEO, 'looked as if they were clearing the way for someone else', and in the words of former Deputy Chief of Air Staff, AM Sir Geoffrey Tuttle, 'we taught the Americans a hell of a lot. We had to face many of the problems first – we were nearer to the USSR and we were threatened long before they were, so we had the incentive to survive much sooner than they did'.

Under the Single Integrated Operational Plan (SIOP), total US/RAF strategic air forces were deemed sufficient to cover all Soviet targets, including airfields and air defence. Bomber Command's contribution was given as 92 aircraft by October 1958, increasing to 108 by June 1959. Some 106 targets were allocated to Bomber Command as follows;

– 69 cities, which were centres of government or of other military significance.

– 17 long-range air force airfields, which constituted part of the Soviet nuclear threat.

– 20 elements of the Soviet *PVO-Strany* air defence system.

As Vulcans and Victors arrived in service, the Valiants were assigned to the Supreme Allied Commander Europe (SACEUR) in 1961 as a Tactical Bomber Force. Several Valiants were placed on 15-minute readiness in case of a surprise attack, and on 1 January 1962 this Quick Reaction Alert (QRA) concept was extended to the whole MBF. From now on there would be two jets on every main base armed with nuclear weapons and ready for take off 24 hours a day, 365 days a year.

No 101 Sqn Vulcan B 1s XA909, XH475 and XH476 formate for the camera. From the arrival of XA901 on 4 April 1957, all production Vulcans were finished in an overall gloss white paint produced by Cellon – the same paint as was used on Concorde – which was reflective to protect against nuclear flash

The nearest the Vulcan force ever came to nuclear Armageddon was during the Cuban missile crisis in October 1962. Based on a no-notice alert and readiness exercise held over 20-21 September 1962, Bomber Command could muster approximately 120 weapons-carrying V-bombers capable of generation.

B 1 XA896 was one of the first Vulcans delivered to No 230 OCU. Seen here soon after it had been repainted in white, the bomber joined the ranks of No 83 Sqn in June 1960. It later served with No 44 Sqn, prior to returning to the OCU. XA896 was transferred to the Ministry of Aviation in June 1964 for trials with the BS100 vectored-thrust engine intended for fitment in the Hawker P 1154. However, the fighter was cancelled in February 1965 prior to XA896 being modified, and the Vulcan was scrapped at Hucknall a short while later

In 1962, both President John F Kennedy and Prime Minister Harold Macmillan had read a history book which showed that World War 1 had come about in 1914 through misperception and misunderstanding, and both are claimed to have been influenced by this account. That said, Kennedy and Macmillan adopted very different approaches to nuclear readiness. Macmillan was adamant that no actions should be taken that could be misunderstood by Moscow, while Kennedy put SAC on the unprecedented alert state of Defense Readiness Condition 2.

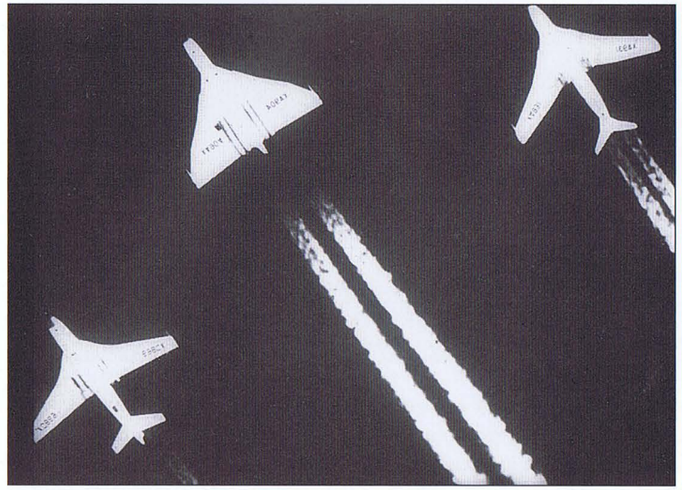
Macmillan supported the mobilisation of US forces for an invasion of Cuba as an appropriate instrument of 'coercive diplomacy'. However, on 27 October, when Macmillan met his Chief of the Air Staff, Air Chief Marshal (ACM) Sir Thomas Pike, he made it clear that overt preparations should be avoided. Bomber Command was, therefore, not dispersed.

Nor were the ten V-bombers overseas recalled. However, on 27 October RAF Bomber Command was moved to Alert Condition 3 – the precautionary pre-dispersal state of preparedness. Two days later the number of V-bombers on QRA was doubled. There has been speculation that AM Sir Kenneth 'Bing' Cross, CinC Bomber Command, exceeded his authority in authorising these measures. The archival record shows that AM Cross acted within his authority, although there is some doubt that Macmillan was aware of bomber readiness on QRA.

Bomber Command was stood down from Alert Condition 3 on 5 November and QRA reverted to normal. But if the Vulcans had been despatched, how would they have gone about their business? Eventually, the international situation would have become so strained that High Wycombe would have been told to disperse the V-force in groups of four. There, the quartets would have stayed at increasing states of readiness.

Each jet was connected to reality by an umbilical telescramble link to the Bomber Controller at High Wycombe, and on the command from the War Room in London he would have been instructed by his CinC to order the V-force to start engines and then to 'Scramble'. On airfields from northern Scotland to Cornwall, 16 engines would have started simultaneously. Throttles would be opened and four bombers would take off in quick succession until, long before four minutes had passed, there would be nothing left to show where they had been save some turbulent and darkened air and the pungent smell of burnt aviation fuel.

Radio silence would be maintained to prevent detection. The crew of a V-bomber needed no chatter to go about its business. Fuses could blow,



The V-bomber family showing their distinctive planforms on high. They are, from left to right, the Vickers Valiant, the delta-winged Avro Vulcan and the crescent-winged Handley Page Victor

equipment go on the blink, even engines fail – it would have made no difference, as staccato responses and practised hands would have sorted it all out. The systems were so duplicated as to carry on regardless, and the Nav Plotter could work by 'astro' from the unjammable and infallible heavens if need be. Years of toil and training with simulated equipment failures had been endured in preparation for this moment, and there would have been nowhere else to go but forward so long as the wings remained attached and two engines worked.

The advantage of the manned bomber over the missile is that the former could be launched to make a potential aggressor withdraw from the brink, whereas there is no way of bringing back a missile. V-bombers would have met timing points and specific positions in order to comply with the coordinated raid plan.

The routes were planned to fly out to a 100-mile arc based on Flamborough Head, then tracks would fly to a straight line position known as the Go/No Go Line. No Vulcans were allowed to cross this Line without the crew receiving a valid coded message. If no message came, there was no assuming that Whitehall had been obliterated – the V-force turned back. On the other hand, once the Go message had been received, there was no mechanism for recalling the dogs after they had been unleashed.

The Vulcans would have flown dense parallel tracks toward a few chosen penetration points, each around four to five miles wide, in as short a period as possible. The MBF would have entered the Soviet Union anywhere in loose cells of six at speeds up to Mach 0.93. By now the Vulcan B 2s would have gently 'cruise-climbed' upwards, as less fuel was used and weight reduced when flying above 50,000 ft.

However, the higher an aircraft goes, the earlier the ground radar can detect it, so carefully preplanned routes were essential. As Soviet radars could detect a Vulcan 200 miles away, some would have flown a longer and more circuitous route than might otherwise have been necessary. Eventually, though, the bombers would have to run the gauntlet of the opposing air defences. Western intelligence tried to predict the points where the defences might be weakest, but those targets worth attacking would also be those best protected, and this was where ECM came in.

The Vulcan had an impressive ECM suite comprising powerful jammers, a radar warning receiver, a tail warning radar, infrared flares and oodles of chaff. This kit provided a reasonable degree of situational awareness, and the crew could avoid or evade the ground or air defences by jamming their control and warning radars with noise.

Noise jamming was a 'brute force' expedient in that it relied on 'outshouting', rather than deceiving, the opposition. 'The argument back then', said Alfred Price, an AEO on Vulcans during the Cuban crisis, as well as being an expert on electronic warfare, 'was that if you are short of

money, go to jam out the ground control. The Soviets could point their fighters straight at the high flier if they'd got good radar control from the ground to put them there, but if they hadn't got it, the interception of a 50,000 ft Mach 0.93 bomber became a bit of a lottery'.

You had to stand under the Vulcan's tail to appreciate the size of the ECM power units and transmitter cans, which weighed several thousand pounds and were each the size of a domestic dustbin. They drew a lot of electrical power in transmit mode, although the biggest single consumer of power was the Vapour Cycle Cooling Pack (VCCP). Located towards the rear of the tail compartment, it circulated a water-glycol mixture around the ECM cans.

The VCCP drew 8-10 kW in normal running, but a massive 40 kW on start-up. Being blessed with an improved AC electrical system built around four engine-driven 40 KvA alternators, power was no longer a problem with the B 2, but heat dissipation was – hence the VCCP.

The AEO, who was responsible for the Vulcan's electrical system and handled a great deal of communications – particularly long-range HF radio traffic – looked after the jammers. In his 'office', the EW controls were in front of him on the bulkhead, with a schematic of the electrical system, and its controls, to his right on the port side wall of the cabin.

Two Blue Divers, which had notched aerials at the wing tips, operated in the metric frequency range and were intended to jam Soviet early warning radars. They radiated plenty of power, and it was said that during an air defence exercise in 1960, just as the nation was settling down to watch the soap opera of the day, a group of Vulcans switched on their Blue Divers and wiped out all the television signals! True or false, the story reflects the jamming output that could be achieved.

Red Shrimp antennas were normally located on the flat plates between the starboard engines, although later Vulcans had them between Nos 1 and 2 engines as well. The three Red Shrimps, each of which operated in two modulation modes between 2.5 GHz and 3 GHz, were intended to jam gun-laying radars controlling 57 mm and 76 mm AAA and the Low Blow radar acquisition element of the SA-3 SAM. On some aircraft there was also a lower frequency L-Band version, with its own blade antenna on the mounting plate between the starboard jet pipes.

Avro flight crew, led by Jimmy Harrison (second from right, who succeeded Roly Falk as chief test pilot in January 1959), wearing partial pressure clothing designed for Vulcan test flights well above 50,000 ft

A Vulcan AEO, with his hand on the Nav Plotter's seat. The Vulcan EW controls and displays are mounted in front of the AEO. The Red Steer Mk 2 tail warning radar is the rectangular orange display at eye level immediately in front on the AEO. This system scanned immediately behind the Vulcan in search of fighters or missiles. The radar warning receiver is the small circular display to the right of the Red Steer. The AEO could also see behind the aircraft via a periscope set into his desk (*Andy Leitch*)

The impressive jamming capability of the B 2 had been optimised for high-level attack against the USSR in the late 1950s and early 1960s. In a coordinated attack over a broad front with 100 V-bombers jamming on full power to provide mutually reinforcing protection, the Blue Divers would have denied the Soviets early warning and the Red Shrimps negated their SAMs and AAA.

Soviet fighters of the time used only four VHF channels for their radio communications, and the B 2's Green Palm, with its antenna at the top of the fin emitting a deafening noise that sounded like a cross between a continental police siren and the bagpipes – was tuned to jam them. There was a good chance, therefore, that the AEO could prevent a Soviet fighter from ever receiving enough instructions to attain radar or visual contact.

B 1As and B 2s were also provided with a Blue Saga radar warning receiver. This was a first generation passive warning receiver that relied on four sets of stub antennas mounted 'quadrangularly' on the uppersurface of the nose and the lower tail. Blue Saga received signals in the bands 2.5 GHz to 12 GHz. Its display comprised two orange lights, one for S-Band and one for C/X-Bands, which illuminated when a signal reached a pre-determined pulse repetition frequency (PRF) threshold or pulse width. The AEO monitored the PRF audio tone in his headset and switched between the four sets of antennae to determine the quadrant from which the signal was being received. This was a 'mandraulic' device, and it was slow by modern standards. However, with practice, AEOs became adept at detecting, identifying and taking action against threat signals.

The V-bomber H2S radar had a modification called Fishpool which, under certain circumstances, could detect fighters around and below, so the Nav Radar could sometimes see them climbing. He would tell the crew, and the AEO could take over the running commentary as the fighter swept in behind and into the ken of his backward-looking tail warning radar. The latter evolved from the Green Willow Airborne Intercept (AI) radar developed as a back up for the English Electric Lightning.

A team at Telecommunications Research Establishment Malvern recognised that with minimal re-design, Green Willow could be adapted to meet a requirement issued in 1956 for a V-bomber tail warning radar. The system was christened Red Steer after Malvern liaison officer Jerry Steer, and in trials in 1958 it demonstrated a 75 per cent certainty of detecting a Hunter making a 'straight tail-on' approach at ten nautical miles, rising to 100 per cent certainty of detection at eight nautical miles.

Even if an fighter pilot got into a tail position, bundles of chaff (tinfoil strips that produced echoes equal in magnitude to those of an aircraft) might confuse him if he was relying on his airborne radar. The Vulcan carried 4000 packets of chaff, and the latter was pre-cut to various lengths to give wideband frequency coverage. They were stored within the wing just aft of the main undercarriage legs in what were inevitably known as 'window boxes', two per side. Chaff was dispensed through apertures in the underside of the wing that looked like letterboxes.

If crews dropped chaff on a training flight, they were supposed to lower the undercarriage to create turbulence across these apertures to suck out any strips stuck inside. The Auxiliary Power Unit (APU) was in the right wing behind the main undercarriage leg, and if it was fired up before the stray chaff had been cleared, it could badly damage the Rover gas turbine.

A close-up of the new Vulcan B 2 tail cone as fitted to XL385 (whose tail features a No 9 Sqn bat insignia). The tail cone was full of ECM 'cans', and the scoop was for cooling air to keep all these systems operable

Later on, crews were provided with 192 Magnesium Teflon Viton compound flares, which allegedly had a sufficient infrared signature to seduce a missile away from the jet pipes. A two-inch metal pin was ejected when the flares were fired, so in peacetime Vulcan AEOs could only dispense them over the sea. Nevertheless, as AEO Rod Powell recalled, 'they did light up the sky! I can assure you that it was spectacular!'

The main Soviet radar-guided air-to-air missile of the time had to be launched when its fighter's wings were virtually level, otherwise the weapon fell out of the directing beam. 'One must not exaggerate the advantages of these new rocket weapons', wrote Soviet missile expert General Pokrovsky. 'The more automatic any procedure becomes, the easier it is for the enemy to jam that procedure. These missiles can be used only when precise advance knowledge of all the conditions of the combat situation is present. Manoeuvre can easily fool such automatic weapons'. However, a Vulcan turning to avoid a fighter (and it could out-turn all of them above 50,000 ft) was being prevented from flying towards its target.

Vulcan ECM was largely an extension of World War 2 barrage jamming, albeit with greater intensity. There was little sophistication involved. The ECM kit did not respond with specific reactions to counter individual threats in the way that modern systems do. Crews relied on brute force, and lots of it – jammers were switched on at a particular point on the outbound track and left to radiate on a pre-set range of frequencies, regardless of whether or not there was an actual threat to be countered.

Through all the white noise, the Vulcans would try to sneak past undetected. And they would have gone in behind the Thors and other ballistic missiles, which if they did not hit air defence centres would certainly have played havoc with telephone lines and fragile aerial arrays when they exploded. As Sir Harry Broadhurst observed in France in 1940, all the sophistication in an aerial defence system goes to the wall when lines of communication are down and everyone goes underground.

Despite all the prophets of doom, the SAM did not make the bomber obsolete overnight. Vulcan crews knew where most of the SA-2 sites were located, they could hear the SAM radars looking for them and, consequently, they could detour around them. But by 1962 there were too many sites in existence to avoid them all, so the AEO would try to barrage jam the missile radar and feed it false chaff targets while the pilot weaved around track to prevent the missile-control computers from ever having enough steady and reliable information on which to base a launch.

Straight and level bombing runs from as high as possible were designated as Type 2 attacks by the RAF. Once Frances Gary Powers' U-2 was downed by an SA-2 on 1 May 1960, the V-force changed to a Type 2A high-level evasive bomb run. Some 40 miles from the target, the bomber would pull 1.5g through 45 degrees. Wings would be levelled for 15 seconds, before the pilot induced a 90-degree turn in the opposite direction. Wings would be levelled again for 30 seconds, and then the manoeuvre was repeated. The next steady leg was 15 seconds before the jet was rolled onto its attack heading about 15 miles from the target. The SA-2 system needed 60 seconds of uninterrupted lock-on to make good, and all the Type 2A jinking was designed to thwart that objective.

The trained men at the SA-2 site would have been more difficult to fool than a machine, and the barrage of three missiles they fired would have

increased their chances of overcoming jamming. However, an SA-2 system needed a good 60 seconds from initial acquisition to the end of the engagement, and continuously effective jamming for any 15-second period within that time would probably be enough to avoid destruction.

In addition, despite the demarcation between missile and fighter zones, some Soviet fighters would have hung on to their bombers as they entered SAM radar cover, thus complicating the issue for SA-2 controllers.

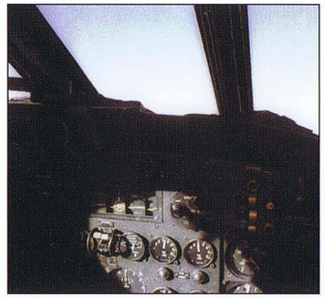
Nevertheless, SAMs would have taken a toll of the V-force, especially as the groups of aircraft would by now have split up to go towards their respective targets. Once through the coastal SAM screen and out into the hinterland, the Vulcan force would disperse, although some notional corridors were used. Jets would enter and exit the corridors at pre-briefed times in the mission so as to suggest to the enemy that at least two Vulcans were flying in a particular direction towards a particular target.

The Nav Radar could often see his aiming point from 160 miles away, and the usual procedure was to home to an easily identifiable Initial Point 60 miles from weapon release, where navigation and bombing computers could be updated accurately. At 40 miles to weapon release, the Nav Radar would change over to his larger bombing scale and place the target under his aiming markers by means of his 'joystick'. If the target response was weak or impossible to identify, the bombing run could still be pressed home, provided there was an identifiable reference point close by. The coordinate distances of the target from the reference point could be set on 'offset' dials and the jet automatically homed to the correct release point.

Once the target or 'offsets' were in, computers did the rest down to feeding steering information into the autopilot. But at this most crucial part of the mission most men would have bombed manually, if only to take their minds off other things.

At this stage in the operation, a mixture of efficiency and high tension would have reigned. Outside, the fighters might have been temporarily shaken off, but the warning receivers would have been chattering frantically as they picked up a crescendo of radar signals. The windscreen blinds would have been down, but the occasional flash of light might have crept in underneath from an exploding bomb or missile. It would have been claustrophobic in the cockpit – muttered instructions, shrieked warnings and spurious alarms, blanketed by sheer fear. Nevertheless the Navigation and Bombing System was a marvellous piece of kit that even opened the bomb-bay doors automatically just before the point where it computed that the bomb should be dropped. As the weapon left the jet, the pilot would have racked his Vulcan round into the escape manoeuvre and beaten a retreat.

Where did the crews go from there? 'Your best bet, young man', said one squadron leader to an inquiring mind, 'is to keep on flying east, come down somewhere deep in the country and settle down with a nice, warm Mongolian woman'. On a more serious note, crews were expected to try to get home. They were given return routes, and although the problems of coordinating the returning jets back through outbound waves of SAC bombers and into Western airspace without being shot down were not insuperable, no one postulated how many of them would get back. And there was never any intention of sending the remnants back over the USSR on the morrow. The best hope for survival lay in closing down two engines to conserve whatever fuel was still lapping the bottom of the tanks and heading for the RAF's Mediterranean bases.



This photograph clearly reveals the limited view outside the Vulcan B 2 cockpit – this photograph was taken during a high-level cruise. The handle top left released the RAT (ram air turbine), while below that are the engine fire extinguisher buttons. Visible in the sunlight (clockwise spiral from top left) are the flying control position indicators, compass switches, No 4 JPT indicator (400 deg C), the co-pilot's ASI (245 knots), Mk 29/30 altimeter (FL430), Nos 4 and 3 RPM gauges (at 85 per cent), TACAN indicator, brake parachute switches, autopilot trim indicator, No 3 JPT and Nos 3 and 4 fuel-flow 'dolls eyes'. In the gloom, the machmeter reads M86 and the artificial horizon shows level unbanked flight ***(Andy Leitch)***

A line-up of newly delivered No 83 Sqn Vulcan B 2s at Scampton in late 1960

On the basis of this generalised summary of V-force high-level tactics, a goodly proportion of the Vulcan force would have got through. There is a valid pointer to the Vulcan's chances in 1962, and that is Exercise *Skyshield* against the formidible air defences of North America.

In 1951, the USAF contracted with the Massachusetts Institute of Technology to work on what Secretary of the Air Force T K Finletter described as the 'Manhattan Project of air defence'. Its conclusions in the summer of 1952 recommended the construction of an early warning radar line across northern Canada to give three to six hours' warning of approaching enemy bombers, an integrated and fully automatic communications system, and improved fighters and SAMs for interception.

This culminated in the merger of the US and Canadian air defence systems within the North American Air Defence Command (NORAD) on 12 May 1958. Coordinated from Colorado Springs, in the Rocky Mountains, the Americans and Canadians had every right to be proud of NORAD, and to prove its effectiveness they decided to mount a massive air defence exercise in October 1961 that was to be fully realistic, and to which Bomber Command was invited. High Wycombe was more than happy to oblige, especially as it gave the RAF an opportunity to test the new Vulcan B 2 under virtually operational conditions.

Nos 27 and 83 Sqns sent four jets each, with aircraft from the latter unit being sent to Lossiemouth to attack from the north, while No 27 Sqn went to Kindley AFB, in Bermuda, to penetrate from the south. On 14 October both groups set off. The northerly wave began with USAF B-47s going in at low level from 500 ft upwards, jamming out the ground radars. Behind them came B-52s at 35,000 ft to 42,000 ft, supported by B-57s, while finally at 56,000 ft came No 83 Sqn's B 2s in stream. ECM proved so effective that only the first Vulcan heard an F-101 Voodoo lock-on. Although many fighters were scrambled, they concentrated on the B-52s so that by the time the B 2s came in the interceptors did not have enough fuel left to climb to 56,000 ft for another battle. The RAF bombers penetrated unscathed to land at Stephenville, Newfoundland.

The southern wave also came in 'using all jamming equipment and passive defence systems'. The No 27 Sqn jets penetrated on a broad front, but as they approached 50 miles from the coast, when the fighters were unleashed, the southernmost Vulcan turned and flew north behind the jamming screen provided by its compatriots. Thus, while the F-102 Delta Daggers concentrated on the three lead aircraft, the fourth jet crept round to the north and sneaked through to land at Plattsburgh AFB, New York.

Skyshield obviously had its limitations in that the only way to see how a Vulcan would have coped against a MiG-21 was to send one against it, but B 2s at height were no sitting ducks, even when the opposition knew they were coming. This exercise proved that a few resourceful crews could hold their own against the world's most sophisticated air defence system.

Left
The Nav Radar's position on the left hand side of the rear crew section looking aft. He is peering into the nine-inch circular radar display. Various scales could be displayed on the screen, and by moving the timebase origin away from its centre with a small joy stick in front of the screen – known as the '626' – the Nav Radar could look out to a range of approximately 180 nautical miles when at an altitude of 40,000 ft. The scales had an accurate electronic marker system that provided accurate fixes to determine aircraft position for en route navigation or bombing runs. An R88 camera is mounted on top of the display to record radar information (*Andy Leitch*)

SKYBOLT AND BLUE STEEL

Even as the first Vulcan B 1s were entering service, the Blue Steel stand-off weapon was quietly taking shape at Woodford in Avro's Weapons Research Division. The Blue Steel story started in 1954 when a small group of Farnborough armament men, led by Hugh Francis, Superintendent of the Royal Aircraft Establishment's Armament Development Division, visited Woodford with a brief to produce a short-range lay-down bomb that could be directed or dropped in free fall. This work grew into Specification 1132, dated 3 September 1954, and eventually led to Avro being awarded a development contract in March 1956 for a 'propelled controlled missile' suitable for the V-bombers.

There were to be three other main contractors – Bristol Siddeley for the propulsion motors, Elliott (under RAE design authority) for the inertial navigation and de Havilland Engines for the power supply turbines. Among other achievements, the Christmas Island *Grapple* tests provided the Red Snow warhead for the Avro Blue Steel.

Across the Atlantic, the US was working on a triad of ballistic missiles as a sure way of delivering nuclear ordnance. The land-based Minuteman was too vulnerable to pre-emptive attack on a small island like Britain, but the submarine-launched Polaris or air-launched Skybolt missiles were seen as more practical ways of maintaining the UK deterrent capability.

Skybolt, with its range of 1000 miles, was to be the first air-launched ballistic missile (ALBM). Ground-launched ballistic missiles are vulnerable to anti-missile defences in that their trajectories are predictable, but Skybolt promised all the advantages of a ballistic missile in terms of speed, accuracy and range, while retaining the tactical flexibility of the aircraft. Soviet early warning stations could watch a missile silo in Montana or East Anglia night and day, but they could never keep a permanent eye on 500 million cubic miles of sky. Skybolt's direction of approach was as infinitely variable as the meanderings of the aircraft that carried it.

At one time the RAF hoped to build a Skybolt of its own. After experimenting with Blue Steel Mk 1 variants such as the 1B with high-speed fuel, the 1C with external boosters, the 1D with externally mounted tanks, the 1E using hydrazine fuel and the 1S with external drop tanks, it became clear that the basic Blue Steel could not be stretched any further.

Consequently, Specification 1159 was issued in its place for what was to be known as Blue Steel Mk 2. It had the same forebody as the Mk 1, but was to be powered by four 19-in Bristol Siddeley ramjets at the wingtips and twin solid-fuel booster rockets on top of the main body. The inertial guidance was to be replaced by a rear-mounted Doppler radome, and the missile was intended to cover up to 1000 miles at Mach 3.8-4.0 after it had left the bomber. Yet this too proved to be a very difficult specification

to meet, especially when it came to missile guidance, and after £825,000 had been spent, Blue Steel Mk 2 was cancelled in December 1959.

Having lost Blue Steel Mk 2, the RAF pressed for Skybolt in preference to Polaris, and the Air Board did not encounter much opposition. 'I was greatly influenced by the fact that we in Britain already had a bomber force', wrote Prime Minister Harold Macmillan, and as the Mk 2 V-bombers were just about to enter service, it made sound financial sense to utilise them fully. Skybolt also preserved the essential deterrent mobility on which the Prime Minister's advisers were insistent, and Bomber Command liked the ALBM because it could be launched from outside the fighter and SAM defences being erected around Soviet targets, thereby extending the useful life of the V-force well into the 1970s.

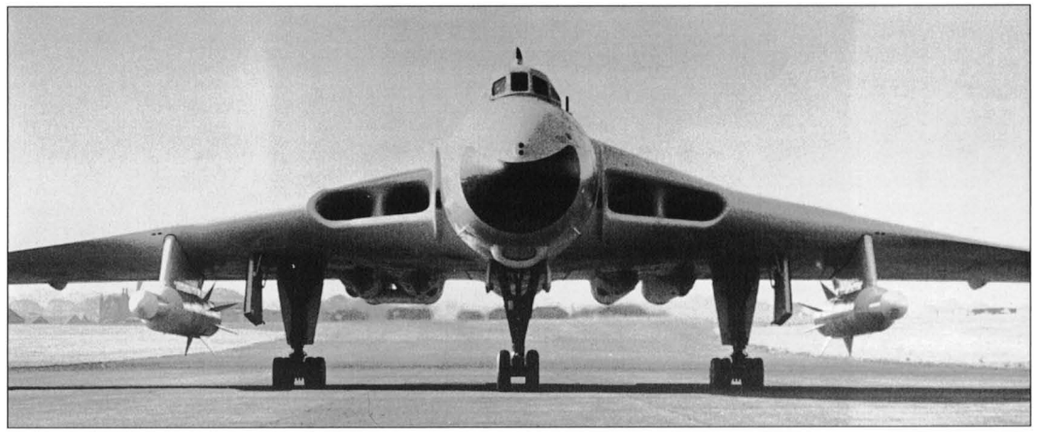
During a visit to President Dwight D Eisenhower's retreat at Camp David in March 1960, Macmillan secured a valuable exchange of notes about Skybolt and Polaris, and the Prime Minister returned to London with an undertaking in principle to allow Britain to buy, or be given, Skybolt in 1965. In exchange the US Navy was granted nuclear submarine facilities in Scotland. In May 1960, Defence Minister Harold Watkinson and US Secretary of Defense Thomas Gates concluded the arrangements whereby Britain would initially purchase up to 100 Skybolts.

Fifteen American firms had tendered for the ALBM when it was first mooted, and Douglas had been awarded the design study contract in May 1959. The following February, the company received an order for research and development, with Aerojet-General being made responsible for the Mach 9 two-stage solid-fuel propulsion system, General Electric for the re-entry vehicle and the Nortronics Division of Northrop for the miniaturised stellar-monitored inertial guidance system, consisting of an astro-inertial system and star-tracker tied together by a ballistic missile computer. Thus endowed, the 38ft-long AGM-87A Skybolt, weighing 11,302 lbs, was expected to navigate 1000+ miles with pinpoint accuracy.

The first ALBM was due to be ready for mating with a B-52H carrier in USAF service by early 1964 after a high-priority programme running to $400 million in development costs.

Avro, as designer and builder of Blue Steel, was made associate contractor and manager for Skybolt in Britain. Standing high off the ground, Vulcan B 2s would initially carry two Skybolts, with the prospect

XH537 with dummy Skybolts underneath. This aircraft first flew with the dummy weapons in place in November 1961, and made the first trial drop the following month



of aircraft carrying four or six ALBMs to follow. B 2s already built, or on the production line, were to be converted in batches, while new airframes from the 40th jet onwards were to leave the factory with internal wing strengthening and Skybolt attachment points outboard of the undercarriage. They also boasted four Olympus 301s, each capable of 20,000 lbs thrust, squeezed into the wings to carry the extra weight of the ALBM.

In January 1961, a No 83 Sqn jet visited the Douglas plant at Santa Monica, California, for electrical compatibility tests, and in July AEI was awarded the main UK contract for the equipment to mate Skybolt to the Vulcan. As it turned out, the Vulcan and Skybolt mated 'beautifully' with no interference, whereas the Americans had to spend $10 million to achieve electrical compatibility between the ALBM and the B-52.

Scientists at Aldermaston simultaneously set to work to design a British thermonuclear warhead to fit in the missile nose cone. By November, XH537 was flying from Woodford on aerodynamic trials with two dummy Skybolts, while XH538 carried out drop tests over the West Freugh range in Scotland beginning on 9 December 1961. Thereafter, Avro conducted an intensive development programme in conjunction with Douglas, culminating in the despatch of 200 RAF personnel under the command of Wg Cdr Charles Ness to Elgin AFB, in Florida, to act as the British Joint Trials Force for advanced Skybolt testing with a B 2.

Having opted for a weapon as formidable as Skybolt, the Air Staff realised that this now increased the likelihood of a pre-emptive strike on British bomber airfields. So, in 1961, the RAF closely examined the SAC practice of 'Continuous Airborne Alert' to see if it was feasible to keep Skybolt-equipped aircraft airborne around the clock.

On 19 December 1961, Avro gave a special presentation on the Vulcan Phase 6 to the Air Staff. Olympus 301 engines had stretched the Vulcan B 2 to its structural limits, so the Phase 6, which was to be fitted with up-rated Olympus 23s, was given an extended wing, with the leading edge straightened, and an enlarged fin. This Phase 6 Vulcan, weighing over 350,000 lbs with six Skybolts, had an extra 10 ft 9 in inserted in the nose so that the cabin could accommodate a crew of six seated in pairs behind each other, all with ejection seats, and a bunk at the rear for off duty crew.

This relatively palatial accommodation was designed to give Bomber Command a continuous airborne alert potential along the lines of SAC,

XH537 undertakes one of the Skybolt aerodynamic trials flights in 1962. Unfortunately, Skybolt was only one third the size of Polaris, and it was relatively small for a strategic ballistic missile. Due to the weapon's modest dimensions, engineers from Northrop's Nortronics Division found it very difficult to produce a miniaturised guidance system of sufficient accuracy to fit inside the Skybolt's nose cone

and Avro postulated that if Bomber Command launched an aircraft every two hours, with some staying airborne for twelve hours with two Skybolts, some for ten hours with four, and some for seven hours with six, 84 Skybolts could be deployed around the clock using the Vulcan B 2s already in service, plus 48 Phase 6 aircraft, at an annual operating cost of something over £55 million. As an added inducement, Avro offered a conventional version of the Phase 6, which could carry 38 1000-lb bombs – ten in the bomb-bay and fourteen under each wing in large pods.

Unfortunately, all Avro's grand designs came to nothing when Skybolt was scrapped. Originally, it had been ordered along with Minuteman and Polaris to fill the supposed 'missile gap' between the USA and USSR, but when Secretary of Defense Robert McNamara came into office he found that Skybolt did not come within his definition of a cost-effective programme. It was no easy matter to launch a ballistic missile from a platform travelling at 500 mph at 40,000 ft, not to mention guiding it for 1000 miles from then on, and in January 1962 President John F Kennedy happened to wonder aloud at a luncheon with Julian Amery, then Minister of Aviation, whether Skybolt would ever succeed.

As late as April 1962, Defence Minister Peter Thorneycroft assured the Commons that he had no evidence of any unforeseen setback, even though on the first launch on 19 April the second-stage rocket failed to ignite. There was no ignition in the first stage on 29 June, but on 10 July, after a meeting of the Cabinet Defence Committee, agreement was reached on the number of Skybolts required and the number of warheads to be built in Britain. The US government accepted the British order.

On 13 September 1962, the third Skybolt test missile had to be destroyed when it veered off course, and this probably persuaded McNamara to cancel the whole thing. The programme had already cost $500 million, and it promised to absorb five times that amount before it was complete, so there was no chance of Skybolt entering service either at anything like its original price or within the laid-down timescale. Moreover, in comparison with Minuteman and Polaris, Skybolt had the lowest accuracy, reliability and yield. The first Polaris firing from a submerged submarine had taken place on 20 July 1960, and the USS *George Washington* (SSBN-598) was at sea with its 16 missiles by year end.

The Cuban crisis preoccupied the US government throughout October 1962, so it was not until 7 November that McNamara finally recommended the cancellation of Skybolt to the President. The British Ambassador was told the following day, and McNamara offered to go to London to discuss the matter. By the time he got there, Skybolt had been test-fired five times and failed on all five occasions. To the Americans, the cancellation was essentially a technical matter – it was, said President Kennedy, 'in a sense, the kind of engineering that is beyond us' – but to the British it was a matter of life or death to their 'independent deterrent'.

Macmillan and Kennedy met to discuss Skybolt at Nassau, in the Bahamas, on 19 December. Harold Macmillan dwelt at length on the agreement made with Eisenhower at Camp David in 1960, and on the fact that the UK, having kept its side of the bargain and granted the US Navy facilities at Holy Loch, expected the US government to fulfil its obligation in return. To Macmillan, the cancellation of Skybolt appeared to be 'a method of forcing Britain out of an independent nuclear

capacity'. President Kennedy was staggered by all of this, for he had never realised how many British hopes had been pinned on Skybolt. 'He (Macmillan) should have warned me of the dangers to him', Kennedy later said. 'We would have come up with a solution before publicity'.

US officials were warning Whitehall throughout 1962 not to put all their eggs in one basket. The trouble was, as one British official remarked sadly, 'there was no other egg and no other basket'. The President assured the Prime Minster at Nassau that Skybolt had not been abandoned for political reasons, and to prove his sincerity, he even offered to pay half of all future Skybolt development costs if Britain would meet the rest.

This was a generous offer, and it put the onus back on Macmillan, as to have refused on grounds of cost alone would have exposed Britain to the charge of wanting an independent deterrent only at the expense of the US taxpayer. Unfortunately the President had damned Skybolt in a television interview prior to leaving for Nassau, and the British were no longer interested in the lady now that her honour had been impugned in public.

The President was so impressed by Macmillan's eloquence that he offered Hound Dog as an alternative. A stand-off bomb designed to extend the lethal range of the B-52G, the first production model had been launched by SAC on 1 March 1960. It was more versatile than Blue Steel in that it could be interconnected with the parent bomber to boost the take-off thrust, and Hound Dog's inertial guidance system was monitored by star trackers to help it transport a 4 MT weapon over twice the distance of Blue Steel, but otherwise it was no great advance.

Secretary of State Dean Rusk was reported as wishing that Hound Dog had been christened Skybolt B, to which McNamara replied that Rusk would have been great in the automobile business! There was no disguising the fact that the air-breathing Hound Dog was not in the same league as the ballistic Skybolt, so the President had to offer Polaris instead.

The Skybolt experience cost Britain £27 million, made up of 'modifications to the Vulcan, support and training'. But, more importantly, the whole business highlighted the extent of the dependency Britain had entered into, and that she was now firmly tied to the American order of priorities, rather than to her own. It would have been better if the British government had admitted this publicly so as to pre-empt all the hysteria about 'clutching at straws' at Nassau, for the upshot was only to denigrate the Vulcan force long before it had reached the end of its credibility. Ironically, three days before Christmas 1962, just after the Nassau Conference, the sixth Skybolt was launched, and it worked perfectly.

BLUE STEEL

Scampton was nominated as the first Blue Steel base, and in order to get the missile into service as quickly as possible, Sir Harry Broadhurst was asked to join Avro and take over the project when he retired from the RAF. Broadhurst and Avro succeeded in their brief, as No 617 Sqn had attained an emergency operational capability at Scampton by September 1962. This feat was achieved through a variety of measures, ranging from pressurising Bomber Command into releasing some of its precious Mk 2 V-bombers for trials work to convincing the Air Ministry that a year's financial allocation for the forerunner of the VTOL Harrier should go to Blue Steel because the Kestrel was then progressing slowly.

A Blue Steel missile is carefully loaded into the modified bomb-bay of a No 617 Sqn Vulcan B 2

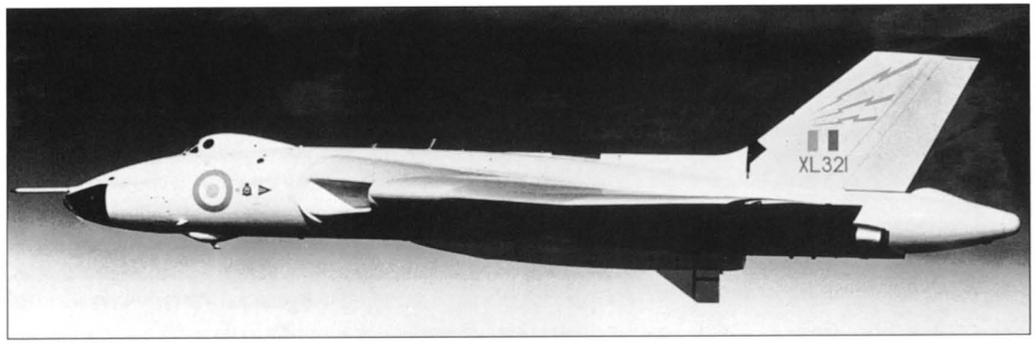
Fifty-seven Blue Steels were bought, including four for proof firings. The missile was officially accepted into service that December, and No 617 Sqn had become fully operational by February 1963. Modifications 198 and 199 put a crank in the front bomb-bay spar of the Vulcan B 2 and a cut-out in the rear spar to accommodate the missile, and the bomb doors were replaced by new fairings to fit round it. The first Vulcan to have all this built in was the 26th B 2 to leave the factory, although the systems modification to carry Blue Steel was undertaken at Scampton. A trolley containing all the new components would be brought out to a particular aircraft, and a few days later it would go away again with all the old bomb-bay bits on it.

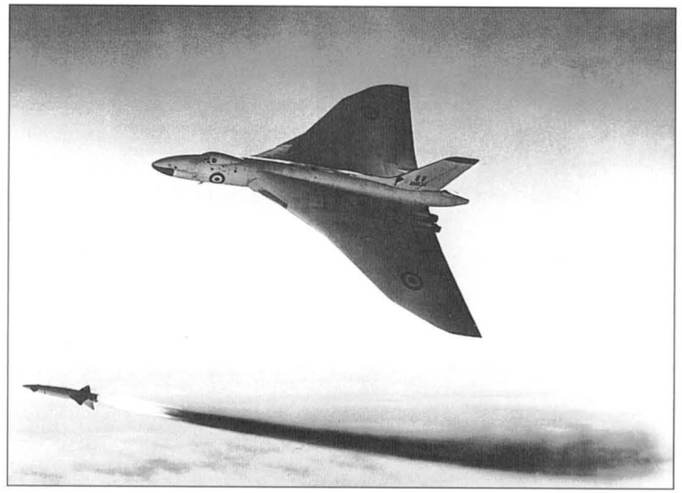
Apart from XH539, which acted as the trials aircraft, 26 Vulcan B 2s were equipped to carry the Blue Steel missile (XL317-321, XL359-361, XL392, XL425-427, XL443-446, XM569-576 and XM594-595). They were confined to the Scampton Wing, with eight modified aircraft being assigned to Nos 27, 83 and 617 Sqns, and two kept as spares.

The Blue Steel inertial guidance system was integrated with the navigation equipment of the parent aircraft, and the former was so accurate that the missile navigated the aircraft on the outbound leg while the Nav Radar periodically fed in H2S fixes to realign it. The inertial navigator suffered from a gyro wander rate of up to one degree per hour, so just before release point, the Nav Radar took a final Release Point Fix. This updated the missile flight rules computer with the exact aircraft position, the direction in which it was heading, airspeed, altitude, acceleration and attitude data, as well as the relative position of the target.

The captain then operated a switch to unfold the bottom stabilising fin, and the missile was released from 50,000 ft. For four seconds it fell freely for about 300 ft to clear the aircraft, and then the Stentor liquid-fuelled rocket motor fired. Two seconds later, the missile controls unlocked and it accelerated up to its pre-set height.

No 617 Sqn's Vulcan B 2 XL321 carries a Blue Steel missile during a training flight soon after the unit had achieved emergency operational capability at Scampton in September 1962. Enjoying two decades of frontline service, XL321 ended its days with the RAF Fire Fighting and Safety School at Catterick





Blue Steel powers off on its way while the launch Vulcan turns to beat a retreat

The Stentor was an inexpensive engine, and its main combustion chamber produced 16,000 lbs of thrust. This was supplemented by a secondary chamber which added an extra 4000 lbs of thrust, and the pair together were capable of sending the missile up vertically to 110,000 ft. However, such heights were not conducive to range, so the main combustion chamber drove the missile up to 70,000 ft, where it levelled off. The main chamber then cut out and the secondary took over, this being enough in the rarefied air to sustain a speed of Mach 2.5.

The missile hurtled along under the control of the flight rules computer, which calculated every change of velocity and direction from ultra-sensitive acceleration measurements made from within the missile. In simple terms, the missile knew its distance out and its distance from the target, and it tried to fly the most direct route in between. Directional control of the missile was on the 'twist and steer' principle, by which each turn was begun by rolling with the inboard ailerons on the rear-mounted delta wing and then maintained by increasing lift on the small delta-shaped foreplanes. The inertial navigator was forever looking for a particular dive angle to the target, and when it got there after approximately four minutes on a 100-mile flight, down the missile went at Mach 1.5-1.8 to penetrate the defences.

Blue Steel was an excellent stand-off weapon in that it required no signals from outside to go about its business, it could not be jammed or diverted by countermeasures, and its profile could be infinitely varied from short distances at very high speed to a range of 200 miles with a descent speed of Mach 0.8-0.9. On trials in Australia using a distinctive well in the desert as an aiming point, the missile regularly landed within 100 yards of the target, and it was estimated that a Blue Steel released over London could have hit Manchester with its megaton Red Snow warhead to within 700 yards of the designated aim point.

Blue Steel's relatively short range would eventually tell against it, but in the beginning its main drawbacks came on the ground. The Stentor engine was fuelled by High Test Peroxide (HTP) and kerosene, and the former was lethal stuff. Unless strictly controlled, and handled at all times in airtight containers with surgical standards of cleanliness, it 'decomposed' of its own accord. 'Decomposition' was a violent eruption, as the peroxide gave off oxygen at a fantastic rate, which is why it was used to power the Stentor. At high altitudes above the atmosphere, kerosene needs oxygen to burn or it dies out like a candle in a closed box. HTP enabled the kerosene to burn with immense heat anywhere at any time. Every Blue Steel jet had positioned beside it a large water tank into which a man had to dive if HTP leaked onto him, or he would burst into flames.

Blue Steel was also temperamental. Large sums of money were spent on special air-conditioned workshops with heated floors so that the missiles could be cosseted while they were serviced and stored, yet on many occasions it proved impossible to mate a missile with a bomber. In effect, the ground tradesmen had to fit two sophisticated aircraft together, and that was extremely difficult. The hydraulics, for instance, which were used to power the control surfaces and to drive the alternator that provided the missile's electrics, were located half in the aircraft and half in the weapon. The missile was electrically connected to its carrier by three lanyard-operated disconnectors, each with 157 contacts. To ensure that all these released simultaneously when the weapon fell away, the 471 connections were not pins but buttons that touched. Thus, if something vital did not touch properly the missile would not work.

Unfortunately, it took 2.5 hours to arm the missile and load it before compatibility checks could be carried out, and if anything was then found to be wrong with either aircraft or missile, or more infuriatingly if a serviceable missile still would not mate with a serviceable jet, the missile had to go back through the laborious chain of safety checks and warhead unloading before rectification work could be carried out. Nonetheless most of the irritations were eventually sorted out and aircrews and groundcrews alike learned to live with the missile's idiosyncrasies. 'Out of the last ten shots at Woomera', said AM Sir Kenneth Cross in 1963, 'nine have been completely successful. The Blue Steel can stand comparison with any other missile system being developed anywhere in the world'.

Although the greatest numerical strength of the V-force was 159 bombers (50 Valiants, 70 Vulcans and 39 Victors) in June 1964, the greatest offensive power was achieved later that year when all the Blue Steel units were operational. Only enough missiles were ordered to equip the Wittering Victor and Scampton Vulcan wings, the intention being to fit the remainder of the B 2 force with Skybolt, and to let the Valiants and B 1/1A V-bombers see out the rest of their useful lives as they stood.

The Coningsby Vulcans on Nos 9, 12 and 35 Sqns were to have received Skybolt first, but when the missile was cancelled the wing became fully operational at the beginning of 1964 in the free-fall role.

By the time Polaris took over the UK deterrent in 1969, Blue Steel was coming to the end of its operational usefulness because of its short range. The weapon was also very man-power intensive to maintain. No 83 Sqn lost its missiles first when it disbanded on 29 August 1969. The unit's aircraft were then returned to Hawker Siddeley for removal of the Blue Steel fittings and replacement of the bomb-bay doors, before being returned to Scampton so that No 27 Sqn could revert completely to the free-fall role by 1 January 1970. This individual conversion of jets took time, which explains why No 617 Sqn only flew its last Blue Steel sortie on 21 December 1970, before completing the transition to free-fall in the New Year.

A Vulcan captain, in pressure jerkin for high level flight, before descending for low-level release, signs for his aircraft and missile in the Form 700. The range of a Blue Steel Vulcan was 1500 miles high-low-high and 2000 miles at high level, but this was increased by the fitment of saddle-shaped bomb-bay tanks which fitted around the missile

DOWN IN THE WEEDS

For nearly three years, Bomber Command's plans had rested on Skybolt. There had been a proposal to fit extra ram-air turbines to Skybolt Vulcans to power more jammers, and ideas were floated to produce a new jammer that could cope with a variety of beam widths, but the Treasury refused to fund such enhancements for a force that was never supposed to penetrate enemy defences. It was too late after the Skybolt hiatus to catch up, especially once it was decided that the life of the V-force need only be stretched out until Polaris submarines entered service.

Avro also proposed a Vulcan with three Gnat fighters slung underneath it after Skybolt cancellation. The Gnats were to have been released over enemy territory to provide fighter escort cover, and they were expected to land 'in friendly territory' or return to the Vulcan mother ship to replenish their tanks by means of a specially installed flight-refuelling probe. It was barking mad. The quickest and cheapest way to keep the Vulcans credible was to send them in at low level beneath the cover of all the new radars, missiles and aircraft that were proliferating throughout the USSR.

Air Staff plans for continuance of the V-bombers' strategic nuclear deterrence were outlined in a paper put before the Air Council on 14 March 1963 by the Vice Chief of Air Staff (VCAS), AM Sir Wallace Kyle. Describing the defences facing the V-force, VCAS said that they had become increasingly effective against high-flying aircraft, and by 1966-67 they were expected to include a system against high-level cruise missiles.

On the other hand, Intelligence had indicated that the Soviets were having no greater success than the Americans or the British in developing effective low-level defences other than a possible SAM key point defence system, which would provide the only serious opposition to Vulcans operating in a low-level role. VCAS affirmed, therefore, that low-level attack was the only method offering a reasonable chance of penetration. The V-bombers would fly out at high level, descend while still outside early-warning radar cover and go to their targets at low level. Bomber Command trials had shown that there was little difficulty in locating targets while at such levels, given the appropriate navigation equipment.

Ministers agreed that high priority should be given to increasing the warhead yield of the lay-down bomb being designed for the TSR 2 and Buccaneer. The resultant high-yield weapon should be available for V-force use by mid-1966. Additionally, the Ministry of Defence (MoD) instructed the Ministry of Aviation to see if Blue Steels could be modified for low-level launch – if this could be done within the next few years, it would 'clearly increase the striking power of the V-force'.

Until the lay-down bomb and/or low-level Blue Steel became available, VCAS believed that the V-force would have the best chance of penetrating to its targets by operating as follows;

(a) Mk 1 bombers would fly a high-low-high profile and be armed with Yellow Sun Mk 2. A Vulcan was to climb, in the target area, to 20,000 ft before release, which made it vulnerable to SAM defences. Consequently, Yellow Sun Mk 2 was modified for low-level release from 1963.

(b) Initially, the Mk 2 jet, which would include an element with free-fall bombs as well as Blue Steel, would operate at high level against fringe targets. However, it was proposed, as soon as possible, to operate Mk 2 aircraft with free-fall bombs in the low-level role. Blue Steel Vulcans would operate at low-level as soon as the missile had low-level capability.

VCAS described the other parameters for the Vulcan force of the 1960s, including low-level training routes in Germany or in the UK. From the beginning of 1966, the number of dispersal airfields was reduced. Waddington's free-fall B 1As and B 2s had two near dispersals (Finningley and Marham) and six distant ones. Scampton's Blue Steel Vulcan B 2s had two near dispersals (Coningsby and Bedford) and three distant ones, and Cottesmore's free-fall Vulcan B 2s used two near dispersals (Honington and Leconfield) and six distant ones.

V-bombers were to be given additional navigation and electronic equipment, including Green Satin (a self-contained navigation aid, giving continuous information on track, groundspeed and distance flown), radar altimeters and an ECM fit to counter continuous-wave (CW) radar – 'the only effective radar for SAM systems and fighters operating against low-flying aircraft'. CinC Bomber Command (AM Sir Kenneth Cross) said that these improvements would not be necessary until 1965. After that, the lay-down bomb and low-level operations would give a good chance of making successful attacks. It would be an advantage if the in-service date of the lay-down bomb could be brought forward, and low-level Blue Steel would be a valuable alternative weapon.

When asked by Secretary of State for Air Hugh Fraser whether Skybolt cancellation, and the need to employ low-level tactics, was having any effect on morale, the CinC said that to date there had been no morale problem. As a member of the V-force put it, 'Skybolt or no Skybolt, we'd have had to get down among the weeds anyway'.

Modifications were initiated to enable the V-bombers 'to withstand flights at high speed/low-level, and to the navigation/attack systems to permit low-level penetration and weapon delivery'. The War Office opposed the proposal to provide Blue Steel with a low-level launch capability on the grounds of weapon system vulnerability, but by October 1963 approval had been given to modify Blue Steel for low-level launch.

The cost of modifications was put at £20m to give the missile a low-level trajectory, or about £3m to give it a low-level launch and an 'up and over' trajectory. The Minister was told that the programme to modify Blue Steel for low-level launch 'is a relatively cheap one. It will cost only £3.5m in development. The production costs will be about £7000 per missile, with £0.4m for modification to the test equipment'. Hugh Fraser was told in a letter from the new CinC Bomber Command (AM Sir John Grandy) that the first low-level trials weapon had been successfully launched at Woomera, in South Australia, on the morning of 19 November 1963 from a Vulcan flying at 300 knots at 2000 ft.

Vulcan B 2s, especially those strengthened to carry Skybolt, were such sturdy aircraft that they took the transition down to low level in their

XM572 of the Scampton Wing undertakes a low level training flight complete with a Blue Steel in its bomb-bay in the mid-1960s. Serving with Nos 83, 35 and 9 Sqns, the bomber was eventually sold to the Bird Group for scrapping on 30 November 1982

stride. V-force low-level Standard Operating Procedures, dated 3 May 1964, had the Vulcans flying a 2H pop-up attack. The bomber was navigated to a precise point – in the case of the Vulcan B 2, it was to within 18,350 yards of the target – before rotation through 15 degrees. Yellow Sun 2 was released as the aircraft passed 10,500 ft in the climb. Then it was time for a maximum rate turn to get as far away as possible before Yellow Sun lit up the sky after about 103 seconds.

In October 1964 it was announced that 'The Blue Steel Force now has both a high-level and a low-level capability'. Missile modification was not extensive, the main difference being that the two combustion chambers now fired together. Release range, however, was reduced to 25-50 nautical miles at low level instead of 200 nautical miles up high, and when it was at release point the Vulcan had to climb sufficiently to give the missile room to fall away before it fired. The Blue Steel then zoomed to 17,000 ft, at which point the Stentor cut out, leaving the missile to hurtle down and detonate within a theoretical accuracy of 300 yards.

During 1966-67, a post-acceptance launch programme for Blue Steel – codenamed Operation *Fresno* – consisted of two launches each from Victors and Vulcans. The first launch from a Vulcan (XL390) took place on 31 May 1967, when the missile was released 47 miles from the target and the impact error was 1065 yards. Three firings were made from this Scampton Wing Vulcan, the last by a No 617 Sqn crew on 7 July 1967. This third low-level Blue Steel firing flew as planned for a distance of 35 miles, with an impact error of 515 yards.

The last British free-fall nuclear bomb was the WE177. The product of a Joint Naval/Air Staff Requirement, WE177 replaced Yellow Sun, Red Beard and, finally, Blue Steel from 1966 onwards. As a WE177 fell away, its tail parachute opened, delaying impact and detonation long enough for a variety of RAF and Royal Navy aircraft to make their getaway. Produced in three versions, and capable of air-, ground- or underwater burst, the most powerful yield was on the 950-lb WE177B (B stood for the Big one!) for use by the Vulcan. WE177 was to remain in RAF service with Vulcans and then Tornados until 1998.

ALERT POSTURE

The most likely form of a Soviet attack on Britain after 1960 would have been a counter-force missile strike aimed at neutralising the V-force during the opening phase of a large Soviet-American nuclear exchange. Unlike SAC, which enjoyed 30 minutes (*text continues on page 43*)

COLOUR PLATES

1
Vulcan B 1 XA901 of No 101 Sqn, RAF Waddington, 1962

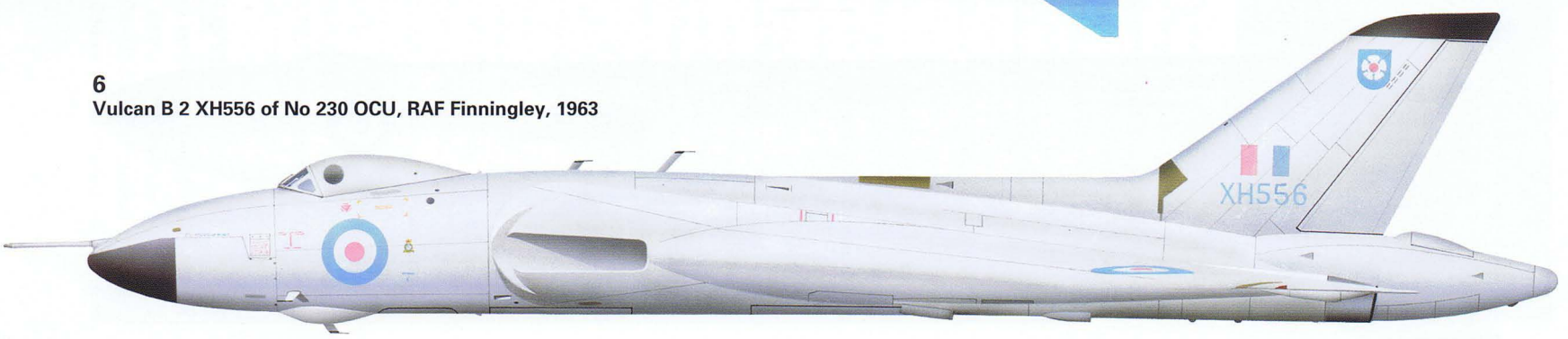
2
Vulcan B 1 XA895 of the Bomber Command Development Unit, RAF Finningley, 1962

3
Vulcan B 1A XA910 of the Waddington Wing, RAF Waddington, September 1964

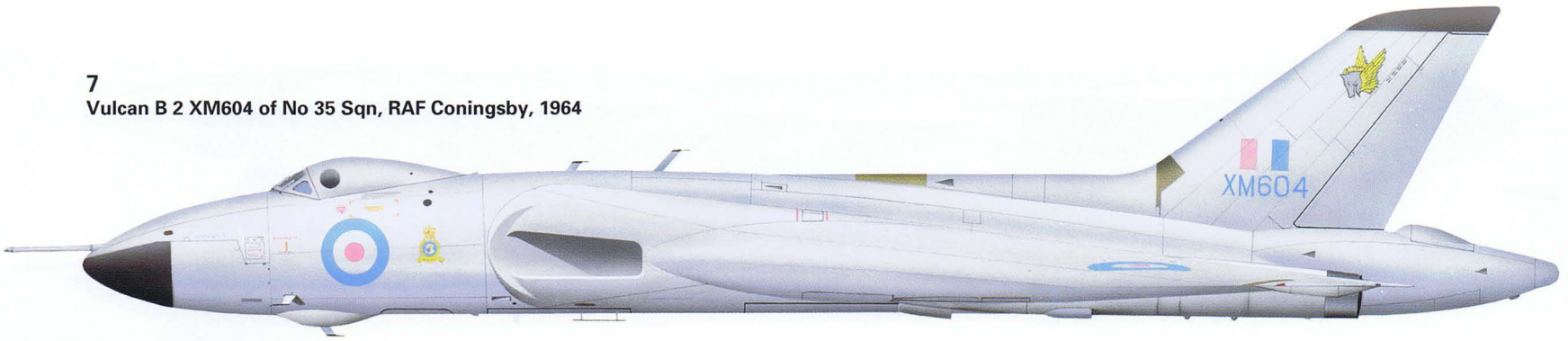
4
Vulcan B 2BS XL427 of No 83 Sqn, RAF Scampton, 1963

5
Vulcan B 2BS XL317 of No 617 Sqn, RAF Scampton, 1963

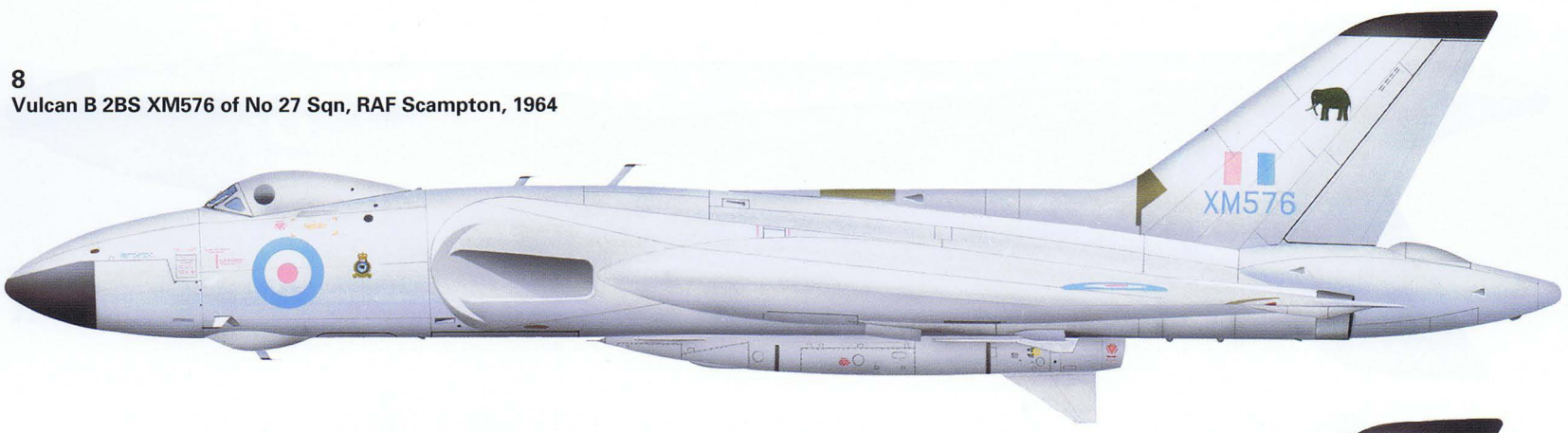
6
Vulcan B 2 XH556 of No 230 OCU, RAF Finningley, 1963



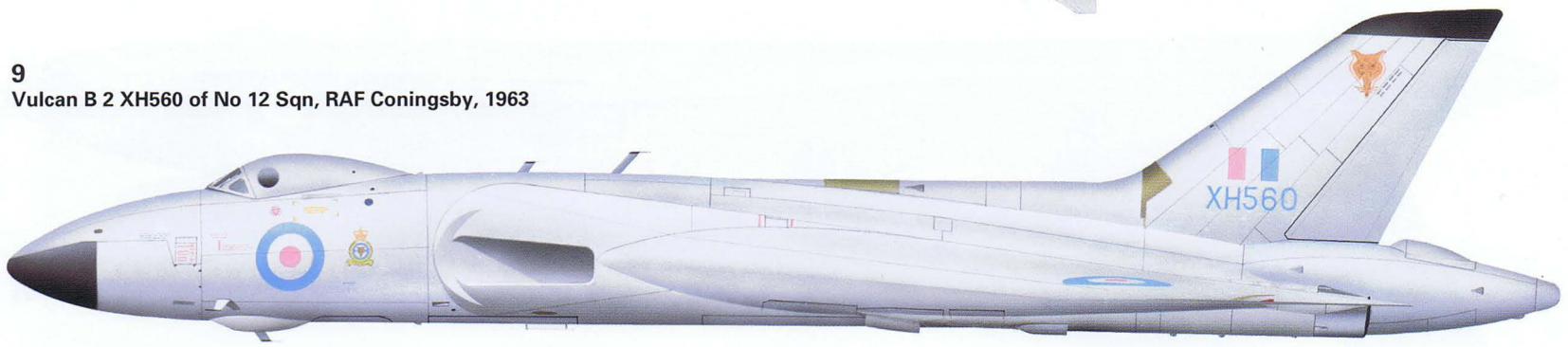
7
Vulcan B 2 XM604 of No 35 Sqn, RAF Coningsby, 1964



8
Vulcan B 2BS XM576 of No 27 Sqn, RAF Scampton, 1964



9
Vulcan B 2 XH560 of No 12 Sqn, RAF Coningsby, 1963



10
Vulcan B 1A XH506 of the Waddington Wing, RAF Waddington, September 1967

11
Vulcan B 2BS XM610 of No 44 'Rhodesia' Sqn, RAF Scampton, January 1969

12
Vulcan B 2 XM595 of No 27 Sqn, RAF Scampton, 1970

13
Vulcan B 2 XM574 of No 617 Sqn, RAF Scampton, June 1970

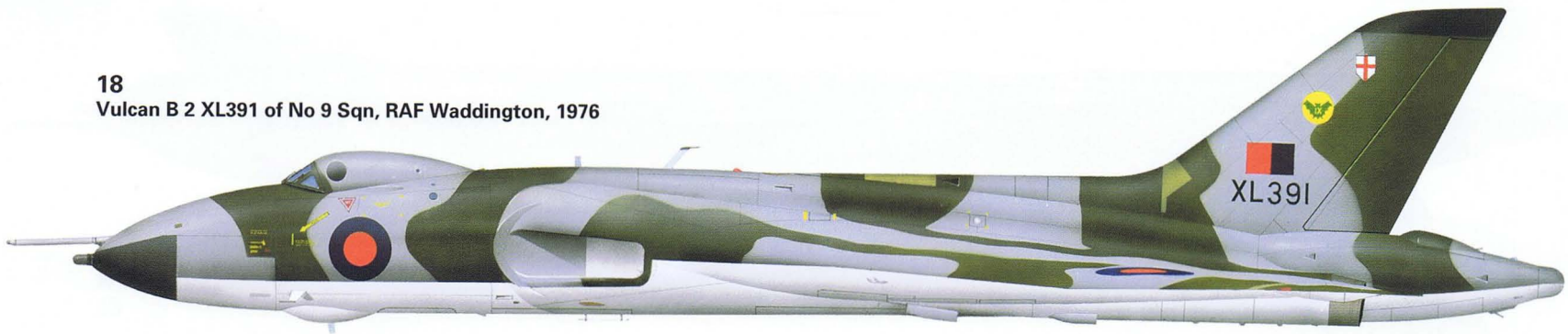
14
Vulcan B 2 XM602 of No 1 Group, 'Giant Voice 1971', McCoy AFB, Florida, 1971

15
Vulcan B 2 XL446 of the NEAF Bomber Wing, RAF Akrotiri, March 1973

16
Vulcan B 2 XJ783 of No 35 Sqn, RAF Scampton, September 1975

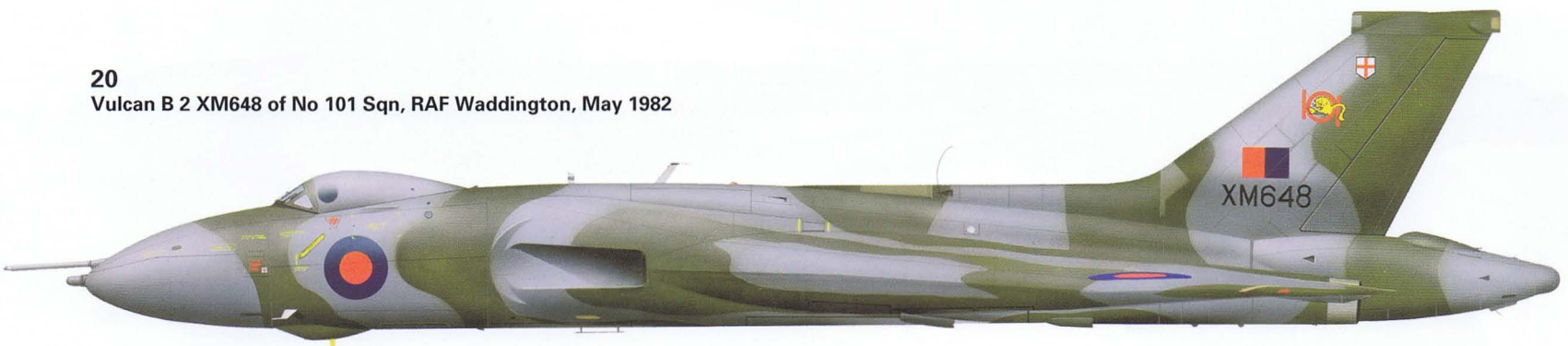
17
Vulcan B 2 XL444 of No 617 Sqn, RAF Scampton, mid-1970s

18
Vulcan B 2 XL391 of No 9 Sqn, RAF Waddington, 1976



19
Vulcan B 2 XL445 of No 230 OCU, RAF Scampton, October 1980

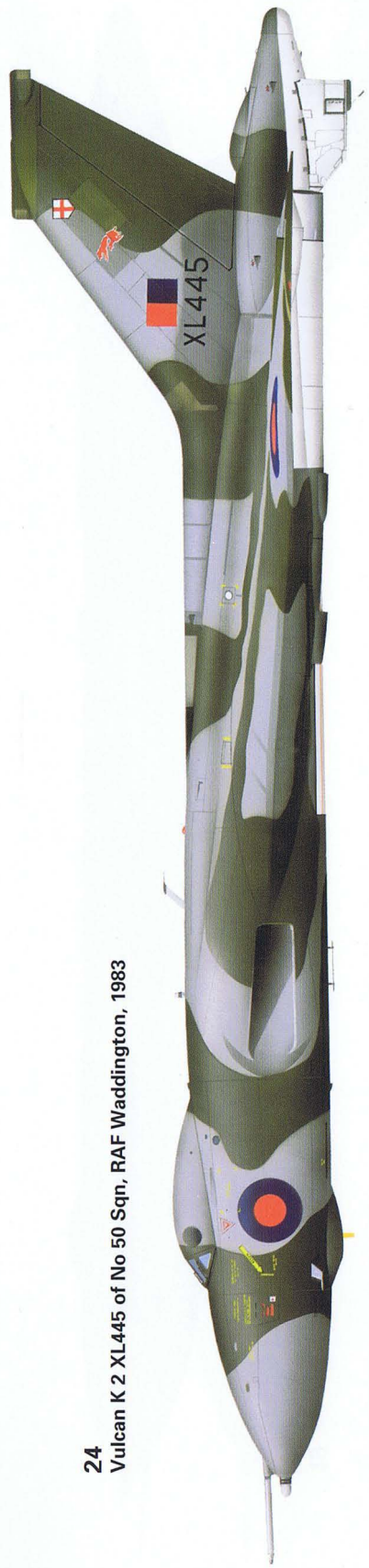
20
Vulcan B 2 XM648 of No 101 Sqn, RAF Waddington, May 1982



21
Vulcan B 2MRR XH560 of No 27 Sqn, RAF Scampton, 1982

22
Vulcan B 2 XM607 of the 'Black Buck' Detachment, RAF Wideawake, Ascension Island, June 1982

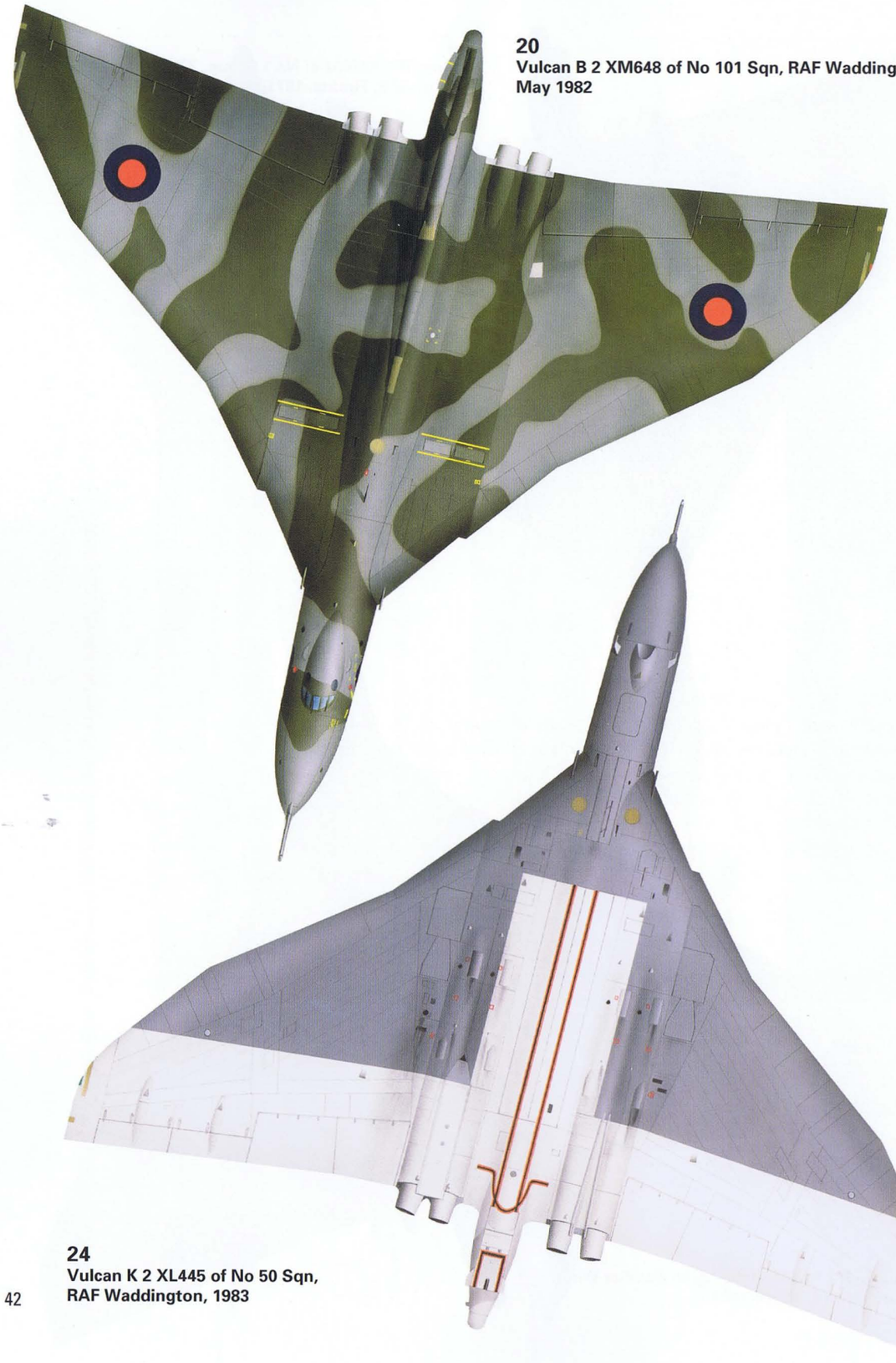
23
Vulcan B 2 XM597 of the 'Black Buck' Detachment, RAF Wideawake, Ascension Island, June 1982



24
Vulcan K 2 XL445 of No 50 Sqn, RAF Waddington, 1983

14
Vulcan B 2 XM602 of No 1 Group, 'Giant Voice 1971', McCoy AFB, Florida, 1971

15
Vulcan B 2 XL446 of the NEAF Bomber Wing, RAF Akrotiri, March 1973



20
Vulcan B 2 XM648 of No 101 Sqn, RAF Waddington, May 1982

24
Vulcan K 2 XL445 of No 50 Sqn, RAF Waddington, 1983

Vulcan weaponry after 1970. Trolleys of 1000-lb bombs act as backdrop to a WE177B. Real nuclear weapons were always painted white, with dummy weapons painted blue

warning before a missile launched from the USSR struck a continental US base, Bomber Command could expect to receive only four minutes warning between a missile trajectory first appearing on a radar screen and its impact on the British Isles. If a significant proportion of the Vulcan force could not get airborne in that time, it would be destroyed.

Warnings of impending Soviet attack came from the Ballistic Missile Early Warning System (BMEWS), which was grafted onto the North American air defences after 1958. Two forward BMEWS sites were chosen on either side of the approaches to North America – at Thule, in Greenland, and Clear, in Alaska – but this left a gap in the east which was filled when Britain agreed to position a third BMEWS site at Fylingdales, on the North Yorkshire moors. Warnings were passed to High Wycombe within ten seconds, and HQ Bomber Command relied on this data link when the Main Force Vulcans were put on QRA from February 1962.

The British could not afford to maintain standing patrols like SAC, but Bomber Command managed to increase squadron complements from ten to eleven crews (although there were no more aircraft) to keep one crew from every V-bomber squadron permanently on QRA, ready to go to war at the sound of a siren. Each unit had its own method of spreading the burden, with some nominating a different crew for every 24-hour period and others keeping a crew on QRA for several days at a time.

Even at the normal peacetime Alert Condition 4, a number of Vulcan crews were continuously at Readiness State 'One Five' in order to provide Bomber Command with a QRA capability. Nominated QRA crews lived in flying suits ready to get airborne within 15 minues in permanently fuelled, armed and checked aircraft. Even the crew's Standard Vanguard car was connected to a battery charger to ensure ease of starting.

If the siren went off in the middle of the night, as it frequently did on exercises, the crew would rush out of their beds, leap into their cars and drive straight across the airfield, irrespective of whether there was a road

there or not. Heaven help anyone in the way, for it was into the jet on the ORP, press the rapid start buttons, and off. Two-dozen practice alerts might be called in a typical month, half of them being up to engine starts and a quarter involving taxiing to the take-off position.

QRA had its compensations, as it allowed crews to catch up on target study and paperwork, not to mention Monopoly and bridge, undistracted by station life. Some airfields were so large that crews had to live in a QRA complex of caravans next to the ORP, and few relished the prospect of sitting there on Christmas Day.

A No 101 Sqn crew pelts from the Waddington Operations Block, having received the order to strap in and start engines as part of a practice scramble. In real times of tension these men would have been at Cockpit Readiness

On one such occasion Vulcan crews had their Christmas dinner early to let the cooks go home to their families, and later that afternoon their flight commander came in with cans of beer under his arm and a plea to keep this donation of Christmas cheer to themselves. An hour later, in came the squadron commander, similarly endowed, followed through the evening by OC Operations and, finally, the station commander, bearing champagne. The words of greeting were gratefully accepted and the exhortations to tell nobody rigidly obeyed, but there was quite a party in the QRA hut that night.

After Readiness State 'One Five', the next rung on the ladder was Readiness State 'Zero 5' (05 Minutes), during which combat ready jets had to get airborne within five minutes. Readiness State 'Zero Two' (02 Minutes) required 'All combat ready aircraft to start engines and taxi to the take-off position, and there await further instructions by VHF R/T'. Ultimately, combat ready aircraft could be ordered to 'Scramble'.

Vulcan B 2s had self-contained simultaneous rapid starting systems for all four engines. The captain moved all the throttles to the 50 per cent RPM position, selected the master start switch 'on' and pressed the master Rapid Start button. Four air storage cylinders, charged to 3300 psi, were stowed aft of the engine bay rear bulkhead on each side. These provided air through a pressure reducing value to a combuster unit on each engine. As the latter wound up, the alternators came on line and the flying controls started automatically. Then the instrument gyros ran up, all within 20 seconds, and it was all systems go.

A No 27 Sqn crew (note the elephant crest behind the Vulcan's roundel) jumps to it from the crew coach and dashes to their aircraft on the Scampton ramp. These men are, from left to right, J Giblen (AEO), I N Wilson (captain), R Howell (co-pilot), L J Turnbull (Nav Plotter) and C A T Richings (Nav Radar). The AEO climbed in first because he needed to switch on the electrics

Marshalls of Cambridge came up with an ingenious system of elastics and levers to disconnect the ground electrics and intercom. Spring-loading took care of the pitot head and Q-feel air intake covers as the

The Battle of Britain Memorial Flight's Lancaster B I overflies Vulcan B 2s on the ORP at Scampton

aircraft moved forward. Afterwards, all the Vulcans had to do was to roll forward onto the runway and lift off in quick succession.

Vulcan B 1/B 1As did not have an internal rapid start capability, so Bomber Command engineering staff officer Sqn Ldr C Dixon designed the 'Simstart' trolley that, with its array of batteries, enabled an aircraft crew chief to start all four engines virtually simultaneously while the crew was strapping in.

There is a classic tale of the fiery Wg Cdr Arthur Griffiths and his No 101 Sqn crew who set their B 1A to combat readiness, locked the entrance door and went off to the crewroom. When the hooter blew, they rushed out to the pan, where the crew chief had already started the engines via the Simstart trolley. 'Give me the door key', shouted 'Bootsie' Griffiths to his co-pilot, Tony Woodford. 'I haven't got it', said Tony, 'You must have it'. 'No I fucking well haven't. You must have it', and so it went while the jet, four engines turning, strained at the chocks and tried to break free. Finally, the crew chief had to use a fire axe to break in and restore order.

OPERATING AT LOW LEVEL

The second part of the deterrence equation was to get the Vulcans through once they were airborne, which is why they went down to low level to fly nap of the earth. Some feared that aircraft and crews could not stand the physical strain, and it took a series of Vulcan B 2 low-level trials over the Libyan desert to prove such fears groundless.

Low-level flight used more fuel, and even though the bombers could offset this by transiting to and from the edges of Soviet early warning radar cover at high level, the radius of low-level Vulcan operations was undeniably reduced, and this had an impact on targeting and routeing.

Vulcans would have transited out over the North Sea at height to a point just outside the forward extent of Soviet warning radar cover, where they would descend. The radar warning receivers could detect Soviet early warning radars searching for them, and most Vulcans would have let down over Norway so that they would have been shielded by the earth's curvature as they hurtled across Sweden – neutrality went out of the window in a nuclear war of survival. Vulcans would have clipped the waves across the Baltic, climbing for just long enough to get a radar fix, prior to penetrating the lengthy Soviet coastline undetected. The end of Tallinn harbour pier was one such entry point.

Low-level flying was perfectly manageable in good daylight weather, but night or bad visibility could obscure potentially embarrassing obstructions like steep hills. It also took time to disturb 80 tons of inertia, so Terrain Following Radar (TFR) was introduced to enable Vulcans to contour-fly safely at low level. Various TFRs were then under development, and Bomber Command chose a prototype made by General Dynamics for the F-111, which was incorporated into the Vulcan force after 1966. It was mated with a radar altimeter so that all a pilot had to do was select the height at which he wanted to fly, and the equipment would keep him separated by a slant range of 9000 ft from any obstacles, so long as he religiously followed climb/dive signals displayed on his instruments.

Vulcan B 1s and B 1As began low-level training in 1963, followed by the B 2s in early 1964. Crews were cleared down to 1000 ft initially, and then to lower levels when they became proficient. Vulcan navigation and bombing equipment was not unduly degraded by low-level operations, and pilots could now map-read and pass accurate visual fixes back to the navigators. Talking of which, there was one piece of kit which will never be forgotten by all Vulcan low-level strike pilots – the eye patch.

Eastern Europe in a nuclear war would be a mass of explosions, and although NATO's SIOP aimed to deconflict detonations at the release point, it could not protect strike crews from detonations around them en route. Such nuclear flashes would seriously damage, if not blind, any eye that saw them, so pilots were expected to go to war wearing a patch over one eye. If a nuclear flash damaged the uncovered eye, the patch could be removed and the pilot was expected to fly on using the good one!

Going down to low level swung the odds back in favour of the V-bombers because the Soviet air defences could not cope with a massed low-level penetration. The great limitation of radar is that, like a search-light beam, it cannot see through hills or other obstructions, nor can it bend round the curvature of the earth. SA-2 sites had mushroomed in the early 1960s, but they had been positioned to provide overlapping cover at height, not at low-level. The SA-2's minimum operational altitude back then was 1500 metres, and an AEO could listen out for the searching

Flying over the Lincolnshire countryside, B 2 XM649 shows off its gloss low-level paint scheme shortly after being delivered to No 9 Sqn in May 1964. One of the last Vulcans built, XM649 was also sold to the Bird Group for scrapping in late 1982

SAM's radars on his radar warning receiver. As he could also tell in which quadrant they were positioned, the pilot simply altered heading to bypass the threat and the bomber was through the gap, leaving the SAM radar looking fruitlessly for an intruder that never came.

Soviet fighter radars, which were designed to detect targets high above the fighter, were often useless below 3000 ft because they could not differentiate between a bomber and the returns from the ground over which it was travelling. No Soviet interceptor of the time had an airborne radar that could look downwards and pick out a bomber among the ground 'clutter', so opposing fighter pilots would have had to rely on the 'Mark 1 eyeball'. Unfortunately this would have been of little use at night, and even in daylight the amount of low cloud present on an average day in Western Europe would have done nothing to assist the defences.

Finding any intruders was hindered still further when the uppersurfaces of all V-bombers were camouflaged in 'a variegated pattern of greys and greens', while the undersurfaces remained in anti-flash white. The trend was set by XH505, which was flown from Waddington to Hawker Siddeley at Biteswell on 24 March 1964 to be finished in the new colours.

The transition to low-level left the AEO with little to do except to listen out for what was up ahead. At high-level, each Vulcan's jamming reinforced that of the others so the overall effect would have been pretty devastating. Down among the weeds, each aircraft operated in isolation, and there was no longer any scope for providing mutual jamming support. In fact jamming would only have given away the bomber's position.

The radiation patterns of Vulcan ECM antennae were also optimised for high level, and therefore they radiated downwards. The Red Shrimps, for example, radiated in a 45° semi-angle cone beneath the jet such that the footprint of the jamming on the ground was a circle whose diameter was determined by the aircraft's height. At low level, the jet had barely any 'height', so the jamming footprint was about the size of the Vulcan!

AEO Rod Powell recalled, 'We could have done something about this, but we never did. When we adopted low-level tactics, we didn't change our ECM procedures, nor did we adjust our antennae. Our route plans still required us to simply switch on our jammers as we entered enemy airspace. I seem to recall that there was a red line drawn on the maps annotated "ECM Switch-On Line". The brief was to leave the jammers on in enemy territory and switch them off when exiting – if we ever did'.

To be fair, an effort was made to provide some bombers with better jamming capability. Thirty late-production Vulcans were fitted with an X-Band (I-Band today) jammer. This had a selectable fore and aft directionality to its jamming pattern, its antenna being located on the centreline forward of the ECM bulge on the lower rear fuselage. It also had a modulated jamming output against specific threats, a 26 Hz modulated signal against SA-3 'Low Blow' tracking radar from the forward antenna and a conical scan from the aft antenna to counter fighter AI radars.

The Mk 1 version of the Red Steer tail-warning radar had a conical scan. The scope was mounted right in front of the AEO, but its presentation was a nightmare to interpret. The maximum range of the system was about 10-12 miles – on the scope, maximum range was in the centre and minimum range around the periphery. A target directly behind presented as a full circle, and if it was offset it would be only an arc.

Bearing in mind that the AEO was facing backwards, to determine where the fighter actually was he had to turn his mind around laterally and upside down and almost inside out! With practice, it could be made to work, but salvation came in the shape of Red Steer Mk 2. This was a much better radar, employing an eight-bar raster scan sweeping through ±70° in azimuth and ±25° in elevation. It had a range of 25 nautical miles, and the presentation was on a conventional B Scope. The AEO also had the option of locking onto a response. Combining this visual information with a tone in his headset, the Vulcan AEO had a pretty good idea when the fighter was about to 'loose off' a missile, so he could hit the action button to dump a load of chaff and/or flares at just about the right time.

For 20 years, the Soviet air defence network had been orientated towards coping with higher and higher-flying intruders, and now the USSR could mount no bigger single threat against a Vulcan at low level than a soldier on the ground with a rifle. 'In the early years of low-level', recalled one Vulcan AEO, 'we went in fat, dumb and happy'.

On 4 February 1964, the Secretary of State for Air disclosed at a press conference that the V-force was ready to attack targets from low level. He went on to say, 'Bomber Command will remain an effective force for years to come', and the initial consequence of this was that the life of the Vulcan force was extended beyond the introduction of Polaris to 1972.

The last Vulcan B 2 was delivered in January 1965, and a year later the Waddington Wing began to re-equip with the more powerful variant in place of its B 1/1As. No 50 Sqn converted first, and Nos 44 and 101 Sqns followed suit over the next two years, the latter receiving its aircraft from Cottesmore when No 12 Sqn disbanded on 31 December 1967. B 1/1 As were duly moved to St Athan between 11 March 1966 and 10 January 1968, either to be scrapped or dispersed as instructional airframes.

When Sir John Grandy held a press conference in September 1963 to show the Mk 2 V-bombers to the world, he said that there were six factors on which the penetration of enemy airspace depended – aircraft performance, evasive routeing, high and low level capability, electronic countermeasures, the success of earlier strikes on enemy defences and stand-off weapons. The Vulcans had the lot after 1964, and after showing the Press a map of the USSR with a line extending 1350 miles from Murmansk in the north to Odessa in the south, Sir John said that the V-force could penetrate that line anywhere, or fly around the ends.

With a maximum high level speed of Mach 0.93 and a low level dash speed of 400+ knots, the B 2 underlined Sir John's conclusion that, 'penetration by aircraft of Bomber Command of areas covered by the most modern and sophisticated air defence systems could not be successfully prevented'. For the rest of the decade the Vulcan was unstoppable.

A Vulcan B 2, its airbrakes fully extended for landing and ready to start aerodynamic braking, exudes all the power and majesty for which the delta bomber was universally famous. As is clearly visible in this view, the jet's main undercarriage legs had four wheels, each with twin tyres, because Dowty found it advantageous to have a multiplicity of small wheels rather than fewer large ones

OUT EAST

By January 1954, the Air Staff had decided that all Vulcans and Victors should be capable of flight refuelling, and that it was 'desirable' that the Valiants should be similarly capable. Such a capability meant that they could then operate with other RAF commands overseas. Later that same year, it had become 'overall policy' that 'as many V-bombers as possible' should be flight refuelling capable in the roles of tanker or receiver. Yet although the principle of aerial refuelling had been accepted for the V-force, by mid-1955 there were no jets to spare for it.

All 84 Valiants ordered in 1954-55 were to form frontline squadrons, and it was not until the Vulcans and Victors came into service that Valiants could be spared to form tanker squadrons.

A paper prepared in early 1957 said that 'suitably fitted Valiants and Vulcans B 1s could be kept as tankers when they disappear from the front-line'. Vulcans from the 16th aircraft onwards would be fitted as receivers, and from the 26th aircraft onwards would have fixed fittings as tankers. In December 1957, a Note for the Air Council on the Provision of Flight Refuelling Capability set out the case for flight refuelling after 1961, principally that 'as the Russian air defences improve it will be essential for the medium bomber force to be given the maximum tactical freedom in routeing in order to maintain the viability of the deterrent'. However, the Treasury subsequently insisted that any aircraft used as tankers had to be found from within the V-force, and if the Valiant was used as a tanker, the Air Ministry would not seek to develop the Vulcan in the tanker role.

In October 1959, Valiant tankers of No 214 Sqn undertook refuelling practice with a No 101 Sqn Vulcan, and crews from the latter unit began converting to the receiver role. On 28 November 1960, approval was given for a spectacular demonstration of RAF ability in flight refuelling – a non-stop UK-Australia flight by a Vulcan. On 20/21 June 1961, a B 1A of No 617 Sqn, captained by Sqn Ldr Mike Beavis, flew non-stop from Scampton to Sydney in 20 hr 5 min, supported by No 214 Sqn Valiants. The jet refuelled over Akrotiri, Karachi, Singapore and 500 miles south of Singapore, nine tankers being involved along its route. The operation was proclaimed as 'an advertisement of our deterrent potential'.

But two Valiant tanker units were all that the RAF could afford, and although they supported Operation *Walkabout* – a No 101 Sqn three-Vulcan non-stop flight from Waddington to Perth, Western Australia, in July 1963 – two tanker units were insufficient to support the V-force in war. The dream of continuous airborne patrols died with Skybolt, so refuelling probes and piping installed in all Vulcan B 2s fell into disuse.

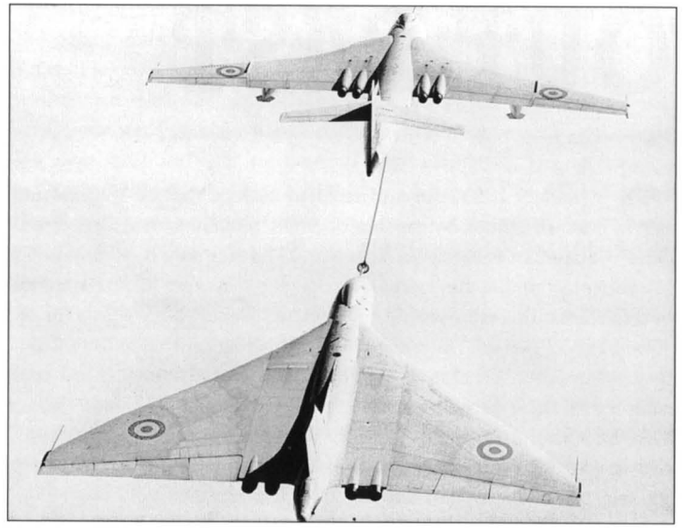
FAR EAST DEPLOYMENTS

During the Malayan Emergency between 1958-60, V-force crews were detached on Exercise *Profiteer* – 'an operation designed to enable V-force crews to gain experience in operating in climatic conditions peculiar to the Far East'. No 617 Sqn sent a B 1 to Butterworth on 14 October 1959,

The flight refuelling probe dominates this head-on view of a Vulcan B 2. The V-bomber's aerial refuelling capability was put to the test when aircraft were sent to operate with the RAF's overseas commands

from where it carried out a navigation exercise to Thailand and visited Clark AFB, in the Philippines, before returning to Scampton on 4 November. No 101 Sqn sent four Vulcans to Butterworth on 15 January 1960 for fighter affiliation with RAAF Sabres, before flying on to Clark AFB and then returning to Finningley on 7 February. No 83 Sqn then sent four jets and six crews to Butterworth 'to exercise crews in rapid reinforcement and operating in the Far East theatre'.

During Indonesian Confrontation, Vulcans were part of the forces deployed to deter Indonesian bellicosity. If the Indonesian Air Force had ever attacked targets in Malaysia and/or Singapore, V-bombers were to be on hand to eliminate its air strike capability. There were three aspects to this task – rapid deployment to the Far East, detachment to Tengah or Butterworth and possible operations against Indonesian targets using RAAF Darwin or the Malaysian island of Labuan as a base. In 1958 it was decided to build a nuclear SSA facility in Singapore at Tengah. Red Beards were moved there in 1962 to be available should they need to be dropped by V-bombers in a major war, but there was never any intention to threaten nuclear use during Indonesian Confrontation.

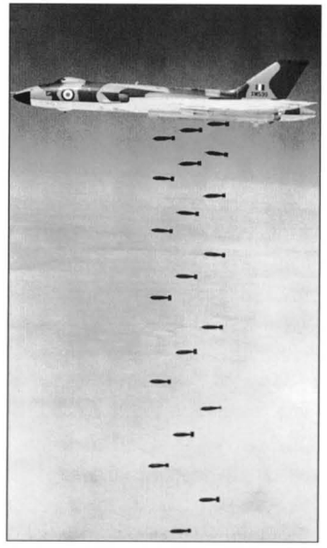


Vulcan B 1 XH478 was the test aircraft for the nose-mounted refuelling probe, and it is seen here carrying out air-to-air refuelling trials with a Valiant tanker in 1958-59. XH478 was subsequently converted into a B 1A

In November 1963, HQ Bomber Command instructed that under Operation *Chamfrom*, four V-bombers and five crews were to be sent from their parent stations to RAF Tengah or to RAAF Butterworth. On 30 September 1964, this commitment was assumed by the Vulcan B 2s of No 12 Sqn at RAF Coningsby. 'On Friday, 2 October, Wg Cdr J R Tanner, Flt Lts D H Hulse and N G Steel and their crews flew from Gan to Butterworth, bringing the squadron detachment to four aircraft and five crews. No 12 Sqn took over the *Chamfrom* commitment from the Victors of No 15 Sqn. At midnight in the Officers' Mess bar, No 15 Sqn's plaque came down and the fox's mask of No 12 Sqn took its place'. The latter detachment to Butterworth lasted two months, and all jets and crews had returned to the unit's new base at Cottesmore by 13 December.

On 7 April 1965, the MoD approved a practice reinforcement of the Far East by eight Vulcan B 2s. This rapid reinforcement, known as Exercise *Spherical*, was undertaken by No 35 Sqn double-staging from Cottesmore. After a simulated interval for political release and initiation of diplomatic clearances to overfly Turkey and Iran, XM600, flown by squadron commander Wg Cdr David Craig (now Marshal of the Royal Air Force Lord Craig) and his crew, took off from Cottesmore at 0045 hrs on 27 April and landed at El Adem at 0418 hrs. They departed at 0728 hrs and reached Muharraq (Bahrain) at 1151 hrs. That was the end of the first double stage, and after the crew had had their ten-hour rest, they took off again at 2151 hrs for Gan, which they reached at 0230 hrs on 28 April. Then at 0745 hrs on 29 April, XM600 took off for RAAF Butterworth,

Moment of release for 21 1000-lb bombs. Visual bombing was a much more practical option over the Middle and Far East where the skies were clearer. The Nav Radar directed the target run-in from his H2S and the bombs were dropped by the Nav Plotter lying prone in the visual bombing position



and landed here at 1212 hrs – in other words, getting to the Far East two days after leaving the UK, with a 6.5-hour gain in time.

The complete force of eight Vulcans reached Gan within 42 hours of the CinC Far East initiating his request for reinforcements. Bomber Command simulated the bombing-up of all eight aircraft before departure from their base. All Vulcan crews had a ten-hour rest at Bahrain, and after a quick turn-round at Gan, they could have been on target in Indonesia within 48 hours of the CinC's request. Air Commander FEAF then deployed the Vulcans forward to Butterworth and Tengah, and they could have operated from the Malaya peninsula within 72 hours of the CinC's request. As the official report put it, 'This exercise was well worthwhile, and has demonstrated once again the efficacy of the V-bomber reinforcement arrangements'.

Eight Vulcans B 2s of No 35 Sqn sit on a damp pan at RAAF Butterworth, in Malaysia, following their arrival for no-notice Exercise *Spherical* in April 1965. Parked at the very end of the line is an RAAF C-130E Hercules of No 36 Sqn

On 13 August 1965, Vulcan B 2s of No 9 Sqn took over the detachment at Tengah from the Victor B 1As of No 57 Sqn. In a report on operations in Malaysia between 1 April and 31 December 1965, CinC Far East said that 'four reinforcement medium bombers (Victor or Vulcan) were retained in the Command throughout the period. This ensured that all principal targets under contingency plans were covered with forces immediately available. There is little doubt that this force has provided a valuable deterrent to confrontation being conducted on a larger scale'.

In early March 1966, No 35 Sqn's Vulcan B 2s took over the 'Matterhorn Medium Bomber Force commitment' at Tengah, maintaining it until August 1966. That month the squadron detached three aircraft to RAAF Darwin for Exercise *High Castor* – a test of the Australian SAM and fighter defences, and Vulcan crews found the RAAF Mirage IIIOs 'formidable'. The Vulcans were still on the exercise when 'orders were received covering the withdrawal of the medium bombers to the United Kingdom. This followed the signing of the Bangkok agreement by Malaysia and Indonesia, ending the confrontation between these two countries. The aircraft returned to Tengah on 17 August'.

Vulcan B 2 XM608 of the Cottesmore Wing flies low off the coast of Singapore in the mid 1960s. The bomber is camouflaged in the original glossy polyurethane dark green and sea grey scheme that became progressively more common throughout the Vulcan force during this period. To minimise detection by a fighter pilot looking downwards, black serials reappeared on the fin and the starboard roundel was deleted

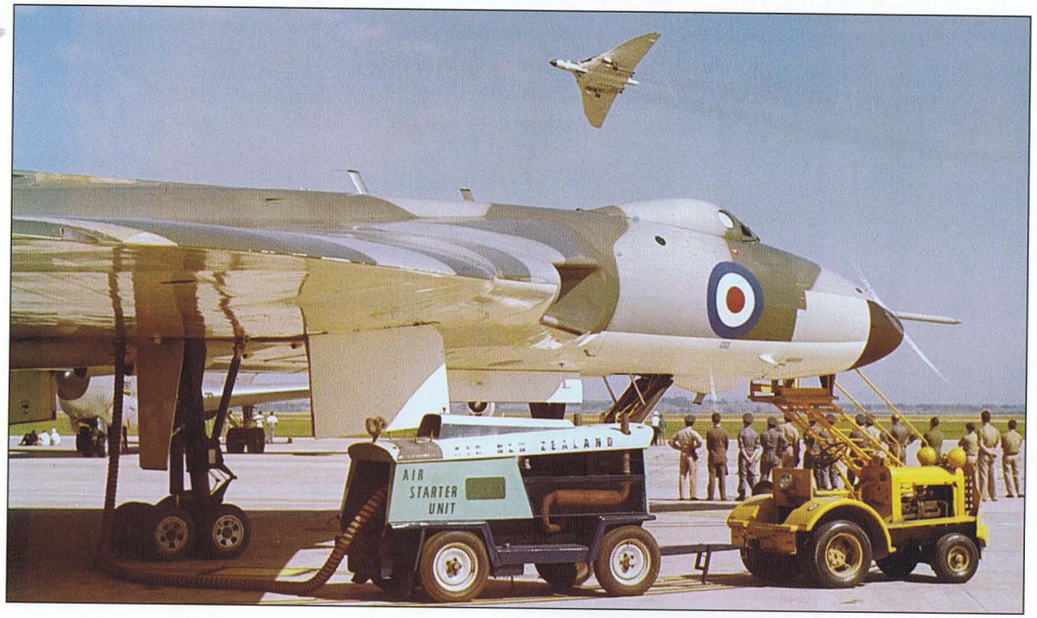
The first B 2s to be withdrawn from the Far East following the end of Confrontation (XM657 and XM645, captained by Flt Lts J M Morgan and B Dorrington, respectively) arrived back at Cottesmore on

A Vulcan leads RAAF Mirage IIIOs over Sydney Harbour Bridge. Note that the famous Opera House is still under construction in the distance. V-bombers were routinely seen in Australian skies throughout the 1960s

26 August 1966. The last arrivals (XM610 and XM612, captained by Flt Lts P G Franklin and A M Mitchell) came in four days later. Their return completed the withdrawal of the Matterhorn rotation, although individual Vulcans would continue heading East to hone the long-distance navigation skills that these missions involved, and to demonstrate a UK presence along the route.

For example, between 2-5 June 1969, a No 50 Sqn crew flew XM603 out to Butterworth via Akrotiri, Muharraq and Gan. The run-in towards the Malaysian coast met up with a Balbo of RAAF Mirages. On returning to Waddington on 10 July, the co-pilot remarked on breaking out of the low Lincolnshire clag that the QRA dispersal was empty. Polaris had taken the nuclear deterrent aboard the Royal Navy's growing fleet of ballistic missile submarines. For the Vulcan force the Cold War was over.

Vulcan B 2 XM612 of the Cottesmore Wing sits on static display in January 1966 at the opening of Auckland International Airport, in New Zealand, while XM650 displays overhead. Both aircraft flew out with a spare Olympus 301 in the bomb-bay in case an engine change was required. The Vulcans flew home via the Pacific, and a favourable tailwind enabled them to cover the distance between Hickam AFB, Hawaii, and Travis AFB, California, in 3 hrs 55 min. The local press reported this as a 'supersonic dash', and then someone asked what the engine was doing in the bomb-bay. The explanation that it was used for the 'supersonic dash' seemed to satisfy everyone!



OPERATIONAL TRAINING

The original specification for the V-bombers stressed that they were to be 'for world-wide use', and capable of attacking a target 'from a base which may be anywhere in the world'. The far-ranging nature of operations was assumed from the beginning, and individual Vulcans were constantly flying Lone Ranger flights westwards to SAC bases or eastwards to the Mediterranean area, Africa, the Gulf and beyond to Australia and New Zealand. Vulcans went all over the place to prove that the UK was still a major player on the world stage.

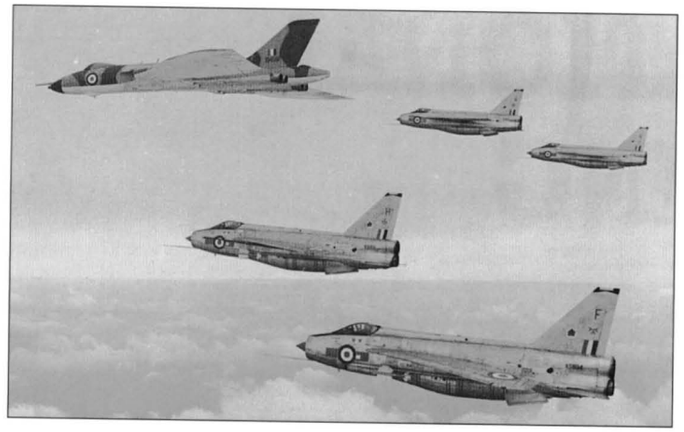
One of the first Vulcan overseas flights was to Kenya for the opening of Embakasi airport, near Nairobi, in 1958. The bomber was deliberately parked next to a Mau Mau internment camp on the edge of the airfield to overawe the inmates! Flying over the relatively flat and featureless Libyan desert, which provided few unambiguous, discrete radar returns, was a far better facsimile of the western USSR than contour flying over Welsh mountains. As AVM Nigel Baldwin, who flew four tours as a Vulcan pilot, liked to remark, the highest ground between HQ Bomber Command at High Wycombe and Moscow was Harrow-on-the-Hill!

Vulcan operational training was based around a six-monthly cycle of Basic Training Requirements (BTRs), which were exercises that had to be completed by each crew member. Pilots had to fly a minimum number of airfield and runway approaches, with some flown asymmetrically and others without airbrakes. There were navigational exercises with or without bits of the equipment working, culminating in simulated bombing attacks which often included the deposition of small 28-lb practice bombs on coastal ranges.

No 101 Sqn Vulcan B 1 XA912 manoeuvres over Mount Kenya during a Lone Ranger to Nairobi n July 1960

There were training runs through electronic warfare ranges, together with a specific number of fighter affiliation exercises with RAF Lightnings and Phantom IIs. Add in the overseas Lone Rangers and participation in Group and Command exercises, and an individual Vulcan crewman would clock up between 240 and 300 flying hours a year.

The BTR system underpinned the crew Classification Scheme. A Non Operational crew was expected to attain Combat status within six to eight weeks of arriving on a squadron. Declaration of Combat



Fighter affiliation. No 50 Sqn Vulcan B 2 XH561 and four No 5 Sqn Lightning F 6s illustrate the might of UK air power in the 1960s. In the experience of fighter pilot Rick Peacock-Edwards, it took two Lightnings to cope with a Vulcan

status told everyone that the crew was capable of doing QRA and, therefore, of going to war. Combat Star was the next step up, and this was usually attained when the crew satisfactorily completed a full BTR training period – between nine months and a year into the tour.

Next came Select, which required BTRs to be completed within more demanding limits – this was unlikely to be achieved until a crew was well into its second year, and sometimes not at all. Top of the bill, and quite rare (perhaps one per unit), was Select Star. This demanded even greater accuracy and all round professional and personal qualities. Selection required the CinC's blessing. There were supposed to be perks for Select Star crews such as first bite at the overseas Lone Ranger flight list. Towards the end of the Vulcan's life, the best became known as Command crews, but the aircraft were operated to the end by constituted crews. Working up the Classification scale demanded a team effort, and it was an article of faith that a crew trained together, flew together and, if necessary, died together.

At the end of April 1968, Bomber Command amalgamated with Fighter Command and the Vulcan force moved within No 1 Group to became part of RAF Strike Command. There were 115 Mk 2 Vulcans and Victors then in service, with the Vulcans operated by No 230 OCU at Finningley, Nos 9 and 35 Sqns at Cottesmore, Nos 27, 83 and 617 Sqns at Scampton and Nos 44, 50 and 101 Sqns at Waddington.

In February 1966, a weekend supplement magazine painted a typical picture of Waddington or, as it put it coyly, 'an RAF base somewhere in eastern England'. The station commander, Gp Capt Charles Maughan, was a married man of 42 with two teenage children, and he described the Vulcan aircrews under his command;

'The British system of training a crew is a bit different from the American. One tends to feel it isn't part of our national character to try to sell people an idea. Of course all the men must be security cleared. But once a man is cleared, we like to believe his background and upbringing will come to the fore and enable him to do his job without any need for brainwashing. He knows he won't have to do anything Fascist. A man on a V-bomber crew must have integrity and reliability. A man who believes in his country. That's why he believes in the deterrent.'

Four of his crews were constantly on QRA for 24 hours at a time, with three of them living in the QRA mess next to the armed jet and the fourth on standby in married quarters, available for duty at a moment's notice. The captain of the No 50 Sqn crew arriving on QRA duty at 0845 hrs that day was Sqn Ldr Albert Wallace, a 37-year-old family man who had flown Vampires, Venoms and Canberras before joining the V-force. All of his crew were married, but only the captain lived in married quarters.

The co-pilot was Flg Off Mark Hopgood, who at 23 was the youngest member of the crew. Most V-force co-pilots came directly from flying

training schools, and their chances of advancement were much better than in the old days, when a captain needed 1750 first-pilot hours to his name. After 18 months in the right-hand seat, a good co-pilot would do an Intermediate Co-pilots' course which qualified him to fly in the left-hand seat as a first pilot under supervision. After another year of flying alternate sorties in the left- and right-hand seats, the co-pilot would go before a Captaincy Board, and if he were good enough he would be given a captaincy of his own.

Sqn Ldr Wallace's crew spent their day studying targets or planning future sorties in the QRA Mess. This was a large converted Nissen hut, partitioned into cubicled dormitories, lavatories and a small operations room. There was a TV room, recreation room with table tennis and billiard tables and a large shabby room in which to study for promotion exams or play cards and board games. No man went off alone except to the lavatory, and if any target material was collected from the Operations Wing vault two men went to fetch it.

'The worst QRA duties are at weekends', said the Nav Plotter, Flt Lt Mike Rollins. 'You have to rely on amusements. You get a bit sick of table tennis, and mooch around looking for something to do'. Rollins had joined the RAF at 18 to be a pilot, but he got chopped, and he had now been a V-force navigator for two-and-a-half years after tours on Javelins and Venoms. 'In Fighter Command, you were free, you could see out of the aeroplane. Flying Vulcans is more relaxed, but you're completely enclosed with four other men in a small black hole surrounded by thousands of instruments. If the weapon was released there would be just a red light showing it had gone. I have thought out what would happen when the bomb was dropped. I wouldn't be worried about what had happened in Russia. I'd be worried about what happened to my family at home'.

Wallace's Nav Radar was Flt Lt Alan Hinton. 'It was wartime when I came into the RAF. Before I came to this base, I was used to Javelin nightfighters. The Vulcan is a big aircraft with a big crew and long trips. At first I was disappointed to be doing it. For one thing, I like to see out of the aeroplane. In a V-bomber you don't feel like you're sitting in an aeroplane. You sit in a dark hole in the back of the cabin. On long journeys we heat cans of soup on tiny electric heaters.'

The AEO was Flt Lt Mark Long, a 27-year-old married to a schoolteacher with a 20-month-old daughter. 'I joined the RAF because it seemed to be an exciting life. I'm interested in politics, the amount of tax I have to pay and the interest rate on my mortgage. But whether I agree with the particular government in power at the moment, I have to do my job and accept their decisions'.

'It is impossible to find any signs of undue stress in Wallace's crew', concluded the article. 'They work long, hard hours and often look weary. They grumble, but do not mean it. The comradeship and belief that they are doing a worthwhile job sees them through'.

The senior medical officer at Waddington declared that he had treated only one pilot for an anxiety state in two years, and that man was now flying again. Two more had had stomach ulcers for a time. If anyone tended to suffer it was the wives. 'Sometimes it's just a fear of any form of flying', said the doctor. 'Some miss their husbands and get shaky. And they have the additional strain of being both mother and father to their

children for long periods at a stretch. But there is no more strain than among the wives of miners, for instance'. That said, wives married to miners or teachers would automatically have had some idea of what their husbands' jobs involved, and could talk to them about it, but in the V-force it was different. 'I never ask him about his job', said Mrs Wallace. 'The few questions I did ask were never answered'.

Vulcan sartorial chic 1978. No 35 Sqn crew (from left to right) Ray Leach (Nav Plotter), Norman Christie (Nav Radar), a visiting Luftwaffe VIP, the author (captain), Keith Trowbridge (co-pilot) and Brian Harper (AEO) pose in front of their B 2 at Scampton

Few men in the Vulcan force ever publicly debated the morality of their position, and if they discussed such matters among themselves it was usually in a light-hearted fashion. While civilians talked seriously about 'The Deterrent', the crews themselves tended to poke irreverent fun at 'The Detergent', but that was much healthier than the pompous aircrew indoctrination sessions endured by their counterparts elsewhere.

Doctors, soldiers or policemen adapt to the violence in their professions, and if a member of the V-force was troubled by what he was doing, he could ask to be taken off the job. Nevertheless, no-one was sure of crew reactions when the final hooter blew. 'You can train and test a man who accepts the philosophy of the nuclear deterrent', said AVM Deryck Stapleton, then Air Officer Commanding (AOC) No 1 Group, 'but until it comes to the crunch, no one in any country can know what would happen when men actually had to turn the switches that release the bomb. We believe they would do their job. Until it happens we don't know'.

TRAINING

The RAF only purchased two Vulcan cockpit simulators, which meant that pilots at stations without one might have to take a whole day every month to meet their training commitments. It was possible to coordinate the separate crew trainers so that they could be made to work together, even if they were in different locations. It was all a bit Heath-Robinson, but on a good day it was possible to 'fly' a war sortie as a complete crew, complete with threats and battle damage. Some found it exhilarating.

In the beginning, Vulcans carried out ECM monitor runs through a calibration facility operated by No 81 Signals Unit (SU) at Benbecula, Stornoway. Starting some 90 miles north of the site, the Vulcan was flown at high level towards it, switching specific pieces of kit on and off at predetermined ranges. The clever stuff was being done on the ground, where operators were able to assess the power output, the effectiveness of each mode, the amplitude of modulation and so on. The results were signalled back to base, with any remedial action (from box changes to tweaking) being implemented on the Vulcan's return.

No 81 SU was located in Stornoway because it allowed jamming operations to be conducted with impunity. The problem was that the Soviets stationed a picket ship off shore to monitor Vulcan transmissions

too. In the 1970s, the redundant missile engine test site as Spadeadam, in Cumbria, became a dedicated electronic warfare (EW) training facility.

It was at around this time that Vulcan B 2s were fitted with what was then a state-of-the-art radar warning receiver in the form of the ubiquitous Marconi ARI 18228. The 18228 was not allocated a curiously coloured codename, but it was a quantum jump in performance over the old Blue Saga. It covered 2.5 to 18 GHz, thereby encompassing new J-Band threats as well as all the old threat systems, and it was also able to handle continuous wave signals, which was another recent innovation.

The ARI 18228 had an easy-to-interpret polar display on a CRT four inches in diameter, which presented an incoming signal as a strobe, indicating its relative bearing. The frequency band was indicated by the strobes' being dashed, dotted or unbroken, and its length was proportional to the strength of the received signal, which could be interpreted to provide a crude assessment of range. Apart from visual cues, the AEO could also 'hear' the PRF in his headphones. A high-pitched PRF implied a high threat, so depending upon the circumstances, he could direct the pilot to turn away from or towards the threat.

One drawback was that the receiver for the 18228 was the square tipped fin that became a characteristic of latter-day Vulcans. This was the ideal place for it in the low-level environment, but at high-level, the vast area of the Vulcan's wing caused a considerable degree of radar signal blanketing. The jet should have had switchable upper and lower aerials.

Operating over Spadeadam at low-level enabled Vulcans to manoeuvre, jam and drop chaff to counter systems replicating Soviet equipment, including radars associated with the SA-2 and SA-3 missiles and the ZSU-23 AAA gun system. This exposed the practical limitations implicit in trying to employ essentially high-level 1950s technology at low-level in the 1970s. The Vietnam War had seen considerable advances in EW techniques, but lack of investment in the Vulcan's EW capabilities contrasted sharply with the USAF's constant upgrading of its B-52s. In a nutshell, the Vulcan force simply failed to keep up. The fact that the ALQ-101 pod had to be borrowed from the Buccaneer force when Vulcans went to bomb Port Stanley stood as mute testimony to the lack of investment in the aircraft's final years.

Sporting a wraparound camouflage scheme adopted for Red Flag exercises, No 44 Sqn B 2 XM575 comes in to land at Waddington. The jet's squared off fin tip housed the ARI 18228 passive warning receiver aerial which, after trials on XM597, appeared in service from 1975. XM575 survived the scrapper's torch and has been on display at East Midlands Airport since January 1983

In AEO Rod Powell's opinion, while Spadeadam may have shown that the Vulcan force had many weaknesses, 'that was in itself vital information'. Apart from its specific benefit to AEOs, using the range helped the whole crew to break out of the procedural straightjacket that had cramped the style of Vulcan flying for many years.

The key to traditional strike operations had been to stay precisely on time and on track at all costs during a tightly scheduled and coordinated nuclear offensive. Vulcan crews were expected to drop their nuclear bombs on target to within an accuracy of +90 seconds and minus nothing. In other words, crews could be up to 90 seconds early, but they could not be late! This was all about deconfliction and not being blown up by someone else's nuclear bomb – or worse, blowing up one of your colleagues. After years of that sort of rigidly disciplined approach, it took time to adapt to a more tactical approach to operations.

Over Spadeadam, AEOs learned that the best answer to enemy systems was to avoid them, rather than to deal with them. Instead of sticking slavishly to track, pilots began to weave and dodge and to take advantage of the terrain to hide from threat radars. Crews became more and more interested in survivability, which eventually meant flying in increasingly hostile EW environments such as that provided by Red Flag exercises.

EXERCISES

HQ No 1 Group would sponsor monthly exercises whereby each Vulcan squadron would field three aircraft to fly a simulated navigation and bombing profile. But as AVM Nigel Baldwin put it, 'the real test was Exercise *Micky Finn* – a no notice exercise held usually once a year, but it could be repeated if the first one didn't go well.

'*Micky Finn* required the recall of all available crews, the generation of the maximum number of aircraft and dispersal of the entire force to its wartime launch bases, where they sat on ORPs at 15 minutes readiness for a couple of days or so. After being called to cockpit readiness several times (and although you could make a reasonable guess, you never really knew which one would be "for real"), we would eventually be scrambled.

'Dispersals were usually released individually, crews then flying a simulated war mission. One year, however (probably 1967), the whole lot were scrambled at once. More than 100 Vulcans and Victors were airborne within four minutes. It worked, but it gave Air Traffic kittens, and the next problem was to get them all safely down again. The subsequent "sortie" involved everybody flying time-wasting "trombone" patterns to establish a reasonable degree of separation at the Group Dispersal Point through which we all had to funnel for recovery to our Main Bases. The lucky ones were home within the hour, but some were much later.'

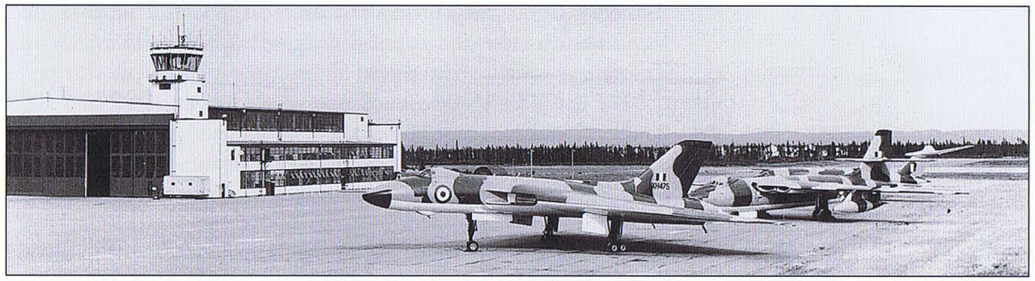
The other high point was the annual Bombing and Navigation Competition, which like so many other things was a USAF invention. Back in 1949, the boss of SAC, the irrepressible Gen Curtis LeMay, had fought long and hard for a mass of Convair B-36 bombers in the face of much opposition from those who thought the behemoth was a lemon. To iron out the bugs in the aircraft, the equipment and its crews, SAC Deputy Commander Maj Gen Clements McMullen announced in May 1948 that a Bombing and Navigation Competition would be held to focus attention on the need for improved accuracy. From then on, SAC's best crews gathered together to participate in an annual Bombing and Navigation Competition that was designed to help build morale and sharpen crew skills and equipment under exacting conditions.

Once the V-bombers entered operational service, SAC and RAF Bomber Command re-established the first combined targeting plan since the bomber offensive of 1944. It followed, naturally, that SAC should invite Bomber Command to enter the 'Bomb Comp' held at Pinecastle, in Florida, in October 1957. Three Vulcan and two Valiant crews departed for the sun on 26 September, but the RAF was up against hardened B-47 veterans who had grown wise in their aircraft over the previous five years. Thereafter, Bomber Command and SAC regularly got together to simulate dropping bombs into barrels, to drink beer and to talk tactics. 'Kissing cousins is an apt term for the relationship between these two organisations', wrote American commentator Richard C Peet in 1963. 'There is a common, almost religious, bond between them'.

The British Isles has limitations when it comes to navigational training because it is small and a distinctive shape, and its densely developed interior offered few challenges to an experienced crew. However, the empty spaces of North America are a much more realistic testing ground, and so the old World War 2 ferry station at Goose Bay, Labrador, and SAC HQ at Offutt, Nebraska, regularly hosted V-bomber detachments. Crews flew low-level and attacked targets along the USAF's network of so-called 'Oil-Burner' routes, and there was nothing to compare with never seeing a light for hundreds of miles over the 'frozen north' to bring home the importance of accurate navigation. It was a measure of USAF generosity that they never charged the RAF for any Vulcan facility or service.

RAF Bomber Command set up its own Navigation and Bombing Competition in 1957 'designed to test the operational standards and to enhance the competitive spirit of the RAF's Medium bomber squadrons'. In November 1970, the 18th US Bombing and Navigation Competition was renamed 'Giant Voice'. It did not take place in 1972 and 1973 because of the war in Southeast Asia, but it resumed in November 1974 at Barksdale AFB, Louisiana. As on previous occasions, the sophisticated equipment carried by the B-52s and F-111s was expected to carry the day in 1974. In the event, 'We did what everybody said couldn't be done – beat SAC in the USA'. These words came from a delighted AVM David Evans, AOC No 1 Group, whose four B 2 crews had lined up at Barksdale against the top crews from every SAC B-52 and F-111 wing bar one.

Two No 83 Sqn Vulcan B 1s and a Valiant B 1 share a dispersal with B-47 Stratojets at the SAC Bombing and Navigation Competition held at Pinecastle AFB, Florida, in October 1957



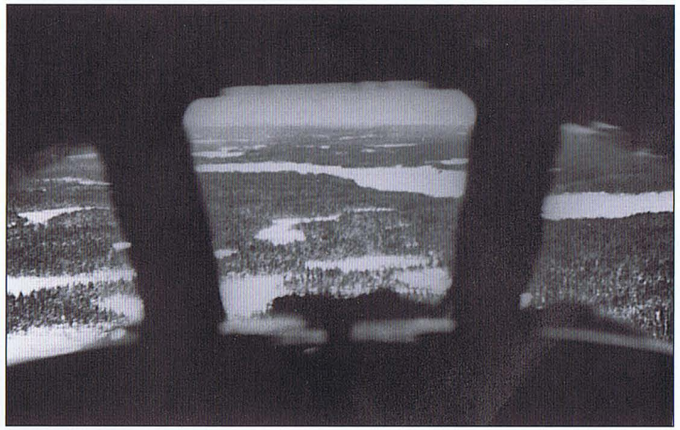
A Vulcan B 2, Valiant B 1 and Victor B 2 in low level camouflage sit side-by-side on the ramp at Goose Bay, Labrador, in 1964

There were four basic missions for all 51 jets, including one high altitude and four low-level simulated bomb releases, plus a low-level navigation route through Mississippi, Louisiana and Arkansas. What was most pleasing to the Vulcan crews was AVM Evans' statement that, 'The Americans have been impressed with the professionalism of our crews'.

A fine example of this came on the last mission, before which the No 101 Sqn crew, captained by Flt Lt Patrick Langdown, was lying second by one point in the navigation stakes. On boarding their Vulcan, the crew discovered that two pieces of primary navigation equipment were unserviceable – there was no updating facility in the entire system, so all navigation would have to be done 'manually'. On a normal training mission in the UK the crew would almost certainly have aborted, but they elected to fly and turned in the best navigation score of the competition to win the Navigation Trophy. 'I don't believe in good luck', said AVM Evans. 'You can only *make* good luck for yourself'.

But pride of place in the competition went to Flt Lt Peter Perry and his No 230 OCU crew. Perry, who had been the youngest V-bomber captain in 1961 and who had taught Prince Charles to fly the Vulcan in 1971, took off from Barksdale on the final competition sortie knowing that if his crew placed their bomb within 200 ft of the target they would win. Unfortunately, they lost their best navigation aids en route, so the team went back to basics – but that was what the training schedule was all about. They dropped their simulated bomb on target. For the first and only time, the RAF won the prestigious Mathis Trophy for the top crew in bombing and celestial navigation combined, and in so doing the Vulcan proved conclusively that it was good enough to beat the USAF at its own game in its own backyard.

The view from the cockpit of a Vulcan as the bomber heads at low level over snow-covered lakes in Canada



'We did it all by crew cooperation', concluded Peter Perry, and that was the key to the Vulcan's success. 'I would have been happy to get airborne at any time to go to war in a Vulcan. A determined crew who routed the right way, who flew very low-level very fast, and who knew what they were going for, would get there without doubt'. As if to reinforce Perry's point, selected B 2 crews from 1977 onwards took part in the toughest peacetime training exercise of them all – Red Flag.

A Vulcan B 2 and a B-52D share the pan at Barksdale, Louisiana, during the 'Giant Voice' competition staged in November 1974. The RAF dominated the event on this occasion

Staged in Nevada, Red Flag was set up by the USAF to retain its 'seasoned' combat capability after Vietnam, and it was conducted over a range nearly as large as Switzerland against targets that varied in size from trucks to industrial complexes protected by simulated Soviet missile defences and experienced fighter pilots flying to Warsaw Pact rules.

'Each Vulcan crew flew five sorties', recounted a Buccaneer wing commander after the first two Waddington Vulcans deployed with ten Buccaneers on Red Flag in 1977. 'At first we were amazed how they seemed to be gluttons for punishment. Flying high-low-high profiles, they began the exercise by flying through the gauntlet of range defences twice per sortie. Initially, they operated at 300 ft above ground level, where, despite casting the inevitable large triangular shadows on the desert floor, they performed very well in evading most air and ground threats. Later in the exercise, when cleared down to 200 ft, they used terrain masking and three-axis jinking more effectively – frequently they survived without a single claim being verified against them. To do this in the unlimited visibility of Nevada was no mean achievement, and they impressed all by their professionalism'.

Prince Charles prepares to get airborne in a Vulcan in 1971. The captain, Flt Lt Peter Perry, is standing second from the right, and another Vulcan QFI, John LeBrun (far right), operated the switches on the co-pilot's side during the flight by sliding his hand round the ejection seat

Although the Vulcan was by now becoming obsolescent, it could still punch above its weight low-level at night and in bad weather. In 1978, the USAF invited the Vulcan to take part in the first all-night Red Flag. As OC No 50 Sqn at Waddington at the time, Nigel Baldwin was told by HQ No 1 Group 'to select four jets from the fleet, six aircrews and a small but highly expert team of technicians, work them up in the UK and at Goose Bay, then participate in Red Flag and, by the way, don't have an accident.

'There were to be no technical enhancements to the kit, so it was really a question of getting the most out of what we already had – a rather basic TFR, which had languished largely unused in the Vulcan's cockpit not least because pilots had preferred to look out at the ground passing by instead of keeping

their heads down on instruments. Now, once the crews concentrated on it and improved its reliability, it served them well. The TFR was not drift or bank stabilised, nor could it anticipate the need to give a fly-down command as Vulcans approached the crest of a ridge. It simply looked at where the nose was pointing, which was not necessarily where the aircraft was going.

'Pilots overcame these limitations by close cooperation with the rear crew. So long as the Nav Radar could provide frequent accurate fixes, the Nav Plotter's kit (Decca Doppler resolved around an accurate Heading Reference System) permitted the bomber's progress over the ground to be monitored with precision. The Plotter provided a commentary, forecasting, for example, when the TFR would give a fly-up demand, and anticipating the need to push over, with the other navigator providing advice on radar "cut offs".

'Compared to the Tornado's fully automated system, this was a tactically limited approach, and one which was totally hands-on and very labour intensive. But in 1978 we did not have any Tornados, and the system certainly worked, the key being mutual confidence between front and rear crew. As they grew in expertise and confidence, the Vulcan crews certainly impressed their American hosts when we flew through the mountainous Red Flag ranges contour flying at night at 1000 ft AGL (Above Ground Level) – well below the B-52s, and most of the F-111s.

'After Red Flag, my crew returned to Goose Bay to fly routes at 800 ft AGL at night, then we went to Offutt AFB, Omaha, to fly USAF routes at 500 ft AGL over lakes and 800 ft AGL over the plains.

'My most gripping memory of the time was flying several hundreds of miles low over the flat terrain of Labrador on a pitch black night – unlike anywhere else we had flown, it was absolutely jet black, which was a phenomenon impossible to find in Europe. On one occasion we flew in solid cloud for what must have been 20 minutes or so without realising it. I don't think I told the rear crew at the time!'

Flt Lt Peter Perry (front, right) holds the Mathis Trophy after he and his crew won the 1974 SAC Bombing Competition. Also in this photograph is Flt Lt Patrick Langdown (front, left) and his crew, who won the Navigation Trophy

Les Aylott and his No 101 Sqn crew take off from Nellis AFB, Nevada, during a Red Flag exercise. The Sunrise Mountains in the background are typical Nevada terrain

MIDDLE EAST VULCANS

In 1954 there was a plan to deploy V-bombers to Mufraq, in Jordan, but after the inauguration of the Central Treaty Organisation (CENTO) it was decided to focus RAF Middle Eastern nuclear activities at Akrotiri, in Cyprus. This would serve as a forward operating base for V-bomber detachments and a permanent home for the Near East Air Force (NEAF) Strike Wing that would eventually consist of four Canberra squadrons. On 28 November 1961, a permanent nuclear SSA facility opened for 32 Red Beards at nearby Cape Gata.

The Canberras were to have been replaced by F-111Ks bought from the US, but once that order went the way of TSR 2, an Air Staff paper of July 1969 declared that 'it was decided to retain the Vulcan force in service. Present plans call for a UK frontline force of 40 free-fall aircraft from the end of 1970 when Blue Steel is phased out, reducing to 32 at the end of 1971, plus a force of 16 deployed to Cyprus'. The possibility of 'double-earmarking' the Vulcans so that they would be available not only to CENTO but also to NATO for conventional operations on its southern flank, had been considered in 1968, but the Chiefs of Staff felt unable to support it, largely because of the incompatibility of the different requirements.

Two squadrons of Vulcans (Nos 9 and 35 Sqns, each equipped with eight Vulcan B 2s) were selected to replace the four NEAF Canberra squadrons which were getting too long in the tooth. Leaving snowy Cottesmore behind them, the Vulcans arrived at Akrotiri in four batches of four – the first quartet on 15 January 1969, the second four on 5 February, the third on 26 February and the fourth on 19 March.

The new NEAF Bomber Wing, with its 16 Vulcans, was told that its 'primary function' was to be 'continuation of the nuclear deterrent role', except that the treaty organisation of which the Vulcans formed a striking force was 'CENTO and not NATO'. The wing was required to generate

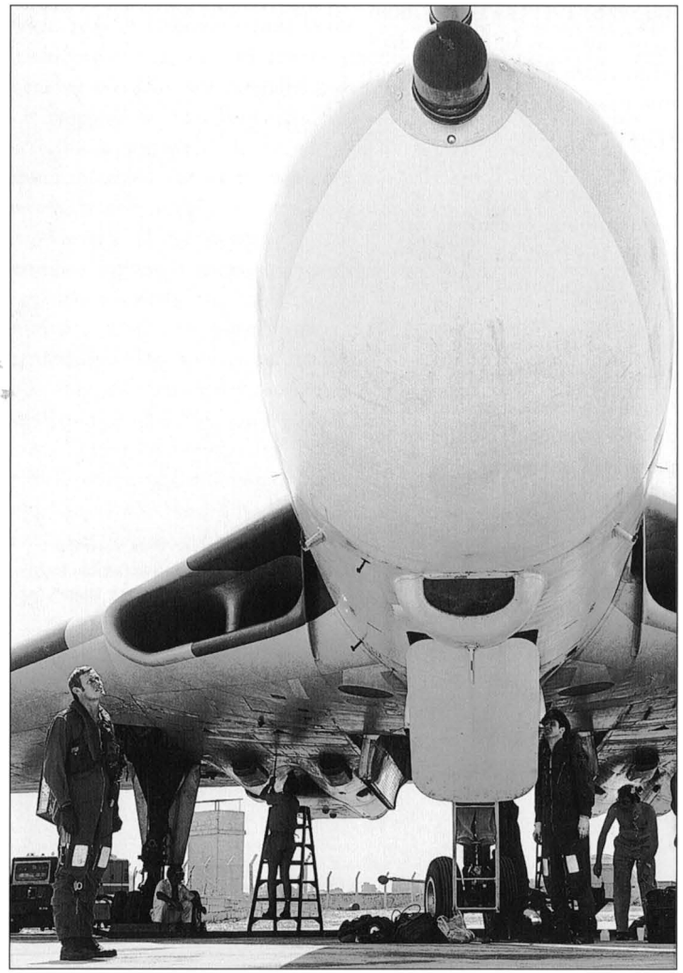
No 35 Sqn Vulcan B 2s from the NEAF Bomber Wing scramble from their dispersal at Masirah Island, in the Persian Gulf

75 per cent of available Vulcans within 24 hours, and the remaining 25 per cent as soon as possible thereafter. One-hundred per cent of available jets were to be generated within 72 hours, and three armed aircraft were to disperse to Muharraq (Bahrain) and six to Masirah Island, off Oman, where they were to maintain the state of readiness required by NEAF strategic alert procedures for up to 28 days, and be capable of flying a single operational sortie. Remaining jets would operate from Akrotiri.

The squadrons were expected to train to meet their operational role, and Vulcan crews would need to carry out routine long-range training flights to areas in which they would be required to operate. This meant deploying six detachments of three aircraft for three weeks each year to Masirah, and to detach around eight aircraft for up to ten days to a CENTO airfield, plus three detachments of up to six aircraft for up to ten days to an Iranian airfield each year.

No 9 Sqn crews were told at a briefing on 20 March 1969 that it would 'be doing Lone Rangers or detachments to Sharjah, Masirah, Muharraq, Peshawar, Tehran, Nairobi and Tengah'. In response, according to the squadron record book, 'the hollow laughter of the cynics rang round the briefing room. However, as if to shame such lack of faith, Flt Lt C Woods and crew were nominated for a Tengah Ranger'.

The pilot of this No 35 Sqn aircraft appears to be staring up at the cylindrical Terrain Following Radar (TFR) transmitter installed in the nose of his Vulcan B 2 just below the refuelling probe. This aircraft was photographed whilst taking part in the last major Vulcan deployment to Luqa, Malta, in 1978



Supporting CENTO meant contributing to the annual *Shahbaz* air defence exercises. Exercise *Shahbaz XVII* in 1971 involved Vulcans operating from Mehrbad AFB in Iran against Iranian targets. Firepower demonstrations were laid on and single Vulcans flew Lone Rangers to Tehran and Ankara. All these activities helped crews to familiarise themselves with the CENTO environment and low level routes. Regular Pedigree detachments were undertaken to Masirah Island, with more low-level flying in Iran and Oman over 'rugged and featureless terrain of the type likely to be met operationally'. There were NATO maritime exercises involving Royal Navy and US Navy forces, and low level flying was also done over Italy along the Calabrian routes, which meant that Vulcans crews operated to the west, south and east of Cyprus.

Nigel Baldwin was a flight commander on No 35 Sqn at the time, and compared to operating over the UK, he found that Vulcan

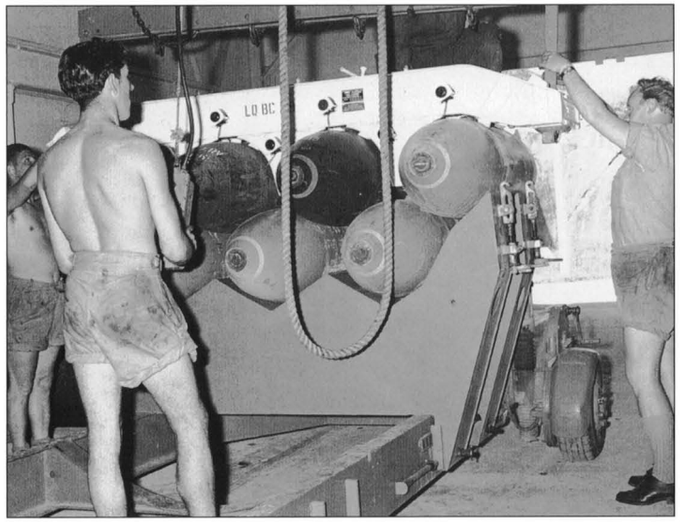
operational training in Cyprus 'was a bit limited in scope – a high-level navigation stage to Crete and back, then once around the island at 500 ft AGL. Attacking – with an F95 camera – two or three village churches was hardly demanding, but being assigned to CENTO, we did get into the Shah's Tehran and fly low-level routes over the wilds of Iran, into Masirah and Oman, Turkey and Greece occasionally, and my crew got as far as New Zealand and Mauritius. But EW training was particularly limited, and we had to make the most of the ECM ranges at Stornoway whenever we got back to the UK – which we did twice a year'.

Apart from frequent exercises to test the air defences of Cyprus (*Springtrip*) and Malta, there were quick-reaction alerts, 'generation games' (the generation of nuclear and conventional weapons) followed by a fly-off and tactical evaluations. In December 1971, a Vulcan captained by Wg Cdr Ron Dick made a goodwill visit to the Imperial Ethiopian Air Force base at Asmara, and in February 1972 he flew a 'one-off' Ranger to RNZAF Ohakea for a Royal New Zealand Aero Club Pageant. The NEAF Bomber Wing also participated in the Strike Command Bombing and Navigation Competition, the best crews being selected from the two units and sent to the UK weeks beforehand for acclimatisation training.

Perhaps the most ignominious fate experienced by a Vulcan was that which befall XJ781 from Akrotiri. It crash-landed at Shiraz, in Iran, on 23 May 1973 when the port undercarriage refused to lower. Although the crew survived a very good landing in the circumstances, XJ781 broke its back as its sliding progress was halted by a deep storm drain. Being declared beyond economic repair, the airframe was given to the Iranians, who reportedly broke it down to make beer cans!

After the Turkish invasion of Cyprus on 20 July 1974, the Vulcan squadrons performed some interesting roles, including maritime reconnaissance and acting as airborne communications posts to relay messages between the Near East Operations Centre, United Nations controllers in Nicosia and the Turkish authorities in Ankara. Although the Sovereign Base Areas were not affected by the Turkish occupation of the north of Cyprus (except by an influx of refugees), the old certainties had gone. The No 35 Sqn record book for September 1974 noted that 'flying over the Republic continues to be prohibited, and the majority of training flights have been carried out either in the UK (where a NEAF detachment had been established at Waddington) or Malta', although by October more local flying from Akrotiri, and over the offshore bombing range at Episkopi, had become available.

Armourers carefully attach 1000-lb bombs to a septuple carrier prior to hoisting the latter up into the bomb-bay of a B 2 sat on the ramp at Malta. The electrical system was such that no upper bomb on the carrier could be released until those directly below it had fallen away



In December 1974 the Vulcans were ordered back to the UK, and in January 1975 No 9 Sqn went to Waddington and No 35 Sqn to Scampton. Their WE177 nuclear weapons went back with them.

FALKLANDS SWANSONG

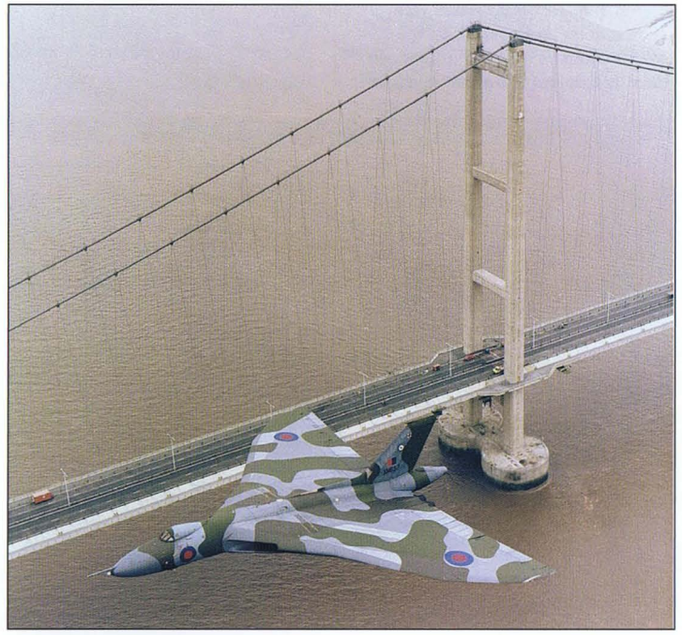
As the swept-wing and swept-up Tornado entered service to take over the Vulcan's tactical strike responsibilities in NATO, the Vulcan OCU disbanded first on 31 August 1981, followed by No 617 Sqn at the end of the year. The latter unit's last Vulcan mission was flown by XL318 on 11 December 1981 along the Derwent Reservoir route that the squadron had used to practice for the 1943 Dams Raid. XL318 was then flown off to the fire dump at Gibraltar.

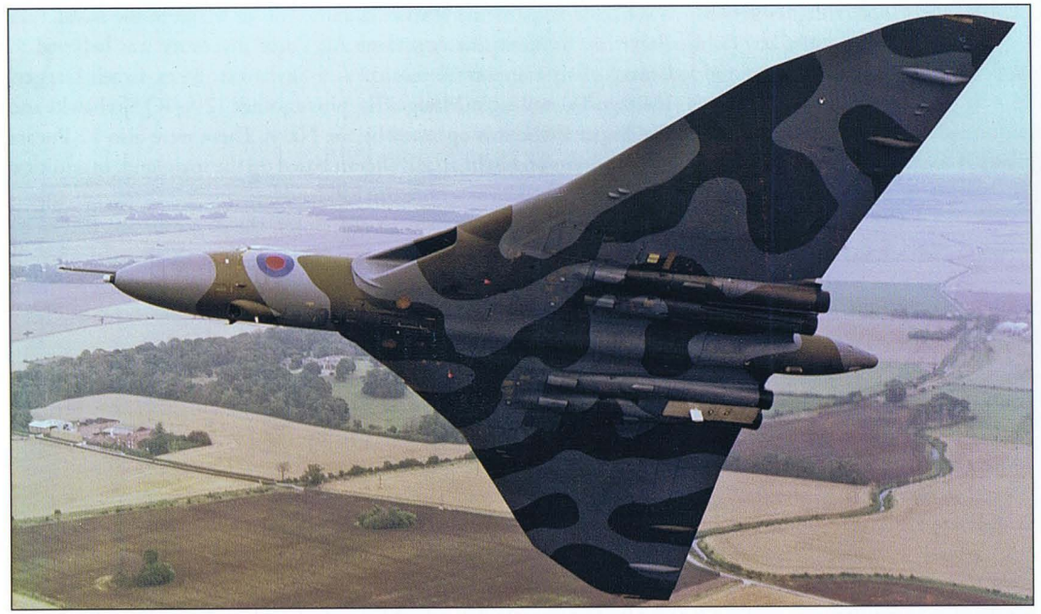
Nos 35 and 27 Sqns disbanded at the end of February and March 1982, respectively, and No 9 Sqn was to go at the end of April, followed by Nos 44, 50 and 101 Sqns on 30 June. But at the eleventh hour the Argentineans, who, coincidentally, had approached Britain in 1981 to enquire whether 12 surplus B 2s could be bought to replace their Canberras, invaded the Falkland Islands on 2 April 1982. No 9 Sqn still disbanded on schedule, but retirement plans for the last three Vulcan units were put back to the end of the year. However, Defence Minister John Nott asked that no impression should be given through MoD statements that the Vulcan squadrons had been 'reprieved'.

It is one of the interesting footnotes of history that among the first overseas flag-waving missions ever undertaken by the Vulcan was a trip to Buenos Aires in 1958. Dr Arturo Frondisi had become the first elected Argentinian president in 12 years, and on 1 May 1958 two B 1s flew an airborne salute over the Inauguration Ceremony. Some 24 years later, the Vulcan's attentions again turned to the South Atlantic.

To say that the British response to the Falklands invasion was cobbled together would be an understatement. When the naval Task Force was constituted, initially only Nimrod maritime patrol aircraft were seen as having an operational task, along with transport aircraft required to supply the forward base at Ascension Island. The possible employment of Vulcans was suggested by RAF personnel as soon as the possibility of a campaign to retake the Islands arose, but this was not part of the original options papers. Initially, Vulcan raids were ruled out because of the amount of effort involved.

XM597 over the Humber Bridge in the late 1970s. After 1973 the Vulcan finish was changed to matt camouflage colours and type 'B' roundels (red and blue only). XM597 has reverted to carrying a roundel on each upper wing surface, although the practice was not universal throughout the force





Waddington was then the only remaining Vulcan base, and the order to prepare for possible operations went out on 9 April (Good Friday). Wg Cdr Simon Baldwin, the cerebral pipe-smoking CO of No 44 Sqn, was recalled from his Easter leave to become OC Vulcan Falklands effort. He was allowed to choose his support personnel, so he roped in the experts from the Waddington Operations Wing planning staff – men like Sqn Ldr John Williams, a Nav Radar who had been on No 1 Vulcan OCU Course back in 1957, and who had been dropping bombs from Vulcans before some of the current aircrew had been born. Extra telephones were installed in the Waddington conference room, and Baldwin's team set about planning the furthest-ranging bombing mission in history.

Waddington's first task was to identify the best airframes for use over the South Atlantic. Given the distances involved – some 4100 miles from Waddington to the staging post at Ascension Island, and another 3900 miles from Ascension to the Falklands – a serviceable flight refuelling system was essential to top up en route from Victor tankers. Although each B 2 had a built-in air-to-air refuelling capability, this had been blanked off and the 'plumbing' inhibited at the probe connection for over a decade. After non-return valves and dried-out seals were replaced, and pipes checked under pressure for leaks, ten Vulcans were declared up to standard, backed by ample stocks of engines, spares and 1000-lb bombs.

It did not help that the Vulcan force in 1982 was configured purely for nuclear operations, so Waddington had to produce a long-range conventional bombing capability as quickly as possible. There were no inhibitions about bombing military targets in the Falklands, and although there was no firm objective at this stage, Wg Cdr Baldwin's planning team assumed that the Vulcans would be sent against the runway at Port Stanley.

Red Flag experience showed that the white underside of the Vulcan exposed it to fighters in tight turns. Beginning with XM657 in September 1979, Vulcans that underwent major servicing returned with a new overall camouflage scheme of matt green and dark gray, both top and bottom

There were particularly worries about the air threat to the naval Task Force. At the time the Argentine Air Force inventory was believed to consist of six Canberra B 62s, 32 A-4 Skyhawks, 24 ex-Israeli Daggers (Mirage Vs) and eight Mirage IIIs, plus another 12 A-4Q Skyhawks and five Super Etendards operated by the Navy. There were also 12 Pucara close support and light attack aircraft based on the mainland, in addition to those that had been sent to the Falklands.

With the Task Force getting ever closer, the Argentineans had to be prevented, or dissuaded, from deploying their high performance Skyhawks, Mirages and Super Etendards into Port Stanley airfield, from where they could so easily have sunk the troop carriers or blown away forces landing on the San Carlos beachhead.

Adm Sandy Woodward commanded the Task Force charged with retaking the Falklands. On 11 April he requested plans for the best use of his Sea Harriers to attack targets on the Falklands, and this finally prompted a serious Whitehall analysis of how Vulcans might be used. Bombing airfields or ports in Argentina was questionable legally, provocative politically and not worth the grief given that these facilities could not have been put out of action with anything less than massive bomber raids. Yet because mainland targets *could* be struck as soon as it was known that Vulcans had been deployed to Ascension Island, this implied threat hung over the junta in Buenos Aires.

AVM Ken Hayr in the MoD somehow obtained the Port Stanley runway specifications from the British consulting engineers who built it. The initial staff briefing for ACM Sir Michael Beetham, a former World War 2 Lancaster pilot and now Chief of Air Staff, had taken a 'robust approach', and made only a passing reference to the risks of causing civilian casualties or a great effort producing a very modest result.

The initial plan was for a single Vulcan to carry just seven bombs, thereby minimising the number of Victor tankers involved, although it was feared that this might not be enough to do the job. On Tuesday, 20 April, Beetham acknowledged to the other Chiefs the uncertainties, particularly with regard to civilian casualties, and promised a full assessment of the Vulcan's capabilities by the following Friday.

Although it was assumed the raids would take place at night to reduce the risk of interception, two weeks after Easter the Waddington engineers were asked to fit an ECM pod to the Vulcan, as Argentine ground-to-air radars had arrived in the Falklands. The Westinghouse AN/ALQ-101 jamming pod – known as the 'Dash Ten' – was borrowed from a Buccaneer, but this could only be fitted to one of the twin Skybolt hard-points under the wings of the 300 series-engined jets. This requirement reduced the pool of available B 2s to five (XL391, XM597, XM598, XM607 and XM612), and all were fitted with a Carousel twin inertial navigation system (INS) for additional navigation accuracy.

A Vulcan drops 21 1000-lb retarded bombs. During low-level free-fall bombing, an aircraft could be damaged as its own bombs exploded beneath it. The weapons could also bounce on impact because of their trajectory and hit the bomber. Both problems were overcome by fitting a retardation chute, which opened like an umbrella to slow the bomb and steepen its trajectory so that it impacted efficiently some distance behind the Vulcan (*Hunting Engineering*)

As Nav Plotter Jeff Jefford put it, 'for long-range oversea operations, the only means of fixing a Vulcan's position was astro. This sufficed for the routine 2000-mile trip to Goose Bay, but it was not adequate for an 8000-mile combat mission – after all, this was 1982, not 1942'. The solution was Carousel, a twin INS originally installed in the ex-British Airways Super VC10s then being stored at Abingdon awaiting conversion into tankers. Carousel was essential if the Vulcans were to navigate accurately over vast stretches of water miles from identifiable land features.

The standard Vulcan navigation technique was to use the H2S radar to take fixes off land features such as the tip of Iceland and use these to update the Nav Plotter's Ground Position Indicator. There were no land features to take a fix from in the South Atlantic, and the crew did not want to use the H2S for fear of giving away their position. Carousel did the overwater navigation, leaving the radar dormant until bombing run-in.

The engineers then honed the five B 2s to perfection. Their Olympus 301s, which had previously been limited to 98 per cent power to extend service life, were restored to full thrust. As the Vulcan had been operated exclusively in the nuclear role in recent years, the carriers and controls had to be changed to accommodate 21 1000-lb high explosive bombs. The co-pilot received an additional radar altimeter, and a triple offset radar fit – designed for greater accuracy in bombing competitions by enabling three offset points to be used during a bombing run – was installed. There was an element of good fortune here because the triple offset boxes had to be rescued from a skip at Scampton, as they were about to be scrapped!

The aircraft were then 'tweaked' and calibrated to work as accurately as their elderly components and design specification would allow. XM597 and XM607 eventually proved themselves to be the best bombers – 'the aircraft chose themselves', said Simon Baldwin.

Three crews were initially selected to complement the aircraft – Sqn Ldr John Reeve's crew from No 50 Sqn, Flt Lt Martin Withers' crew from No 101 Sqn and Sqn Ldr 'Monty' Montgomery's crew from No 44 Sqn. Experience was the key to crew selection, with two out of three crews having recent Red Flag experience over Nevada, but all had much to learn when it came to in-flight refuelling and iron bomb dropping.

Airborne flight refuelling training began on 13 April, and each crew was to complete three refuelling 'prods' by day and two by night. Air-to-air refuelling instructors (AARIs) from the Victor tanker OCU at Marham were initially attached to each Vulcan crew to give instruction.

The AARIs were particularly valuable because none of the bomber pilots had experience of tanker formation techniques, but when it became clear that there would only be time to train Vulcan captains and not co-pilots, it was decided to retain the AARIs on the bombing missions. The AARI would sit in the co-pilot's seat and fly, or supervise, the 'prods' all the way down to the Falklands. The co-pilot sat in the sixth seat, and after the final 'prod' he would swap seats with the AARI for the bomb run – afterwards, they would swap seats again for the return leg. This arrangement made a lot of sense because it relieved the strain on the captain, who would need all his wits about him for the attack, and it provided a valuable reserve capability in case the captain was incapacitated.

The pressure was on to train the bomber crews as quickly as possible, because it was clear that as soon as they got it right, they would go.

Weekends went by the board, and the three crews flew 50 hours in ten days, of which 70 per cent was at night. The bombing side was no great problem. Crews flew routes round the Scottish Western Isles to gain experience in long sea legs with little land crossing, and they came down progressively to 300 ft above the darkened waves, relying on TFR. Apart from overcoming the fear factor in operating so close to the ground without visual reference, much of the training was spent calibrating kit and carrying out bombing practice at Garvie Island and Jurby Ranges so that Nav Radars became familiar with their equipment and conventional arming procedures – 'we didn't want to go all that way and drop safe bombs'.

The MoD paper circulated on 23 April increased the bombing and in-flight refuelling requirement. Bombing runs over the Garvie range showed that seven 1000-lb bombs were not enough, but a full load of 21 should do the job. If they could be dropped at a low level on the Stanley runway, there would be a 90 per cent probability that this would cause one runway crater and a 75 per cent probability of inflicting two. The attack should also cause considerable damage to the parking area, and any parked aircraft, but to get a single Vulcan to the Falkland Islands from Ascension Island would require a force of ten Victor tankers.

The main threat would be AAA and SAMs around Stanley, and related air defence radars. The Vulcan's best chance of coming through unscathed was to approach the target at low level at night. The proposed direction of attack should keep the population in Stanley outside the impact area. Risk to the crews would be reduced by the lack of Argentine air defence aircraft in the Falklands, and they were unlikely to be intercepted by jets from the mainland. Post attack battle damage assessment was to be carried out by Sea Harriers overflying at high level.

If authority was given the next day, two Vulcans would deploy to Ascension Island, of which one would be ready to make a first raid on Stanley airfield on the night of 26 April – three days before the carrier battle group was within range to carry out an airfield attack with Sea Harriers. The advantages of an early raid would lie in surprise and stopping the Argentine aerial re-supply operation as quickly as possible.

Sir Michael Beetham was a hawkish proponent of the Vulcan option, but others felt that the use of long-range bombers might shatter any chance of a negotiated settlement. The use of Sea Harriers to attack the airfield had political advantages, but there was merit in conserving them for air defence duties. The Chief of Defence Staff reported to Defence Minister Nott that, 'The Chiefs-of-Staff are confident that such an operation is militarily feasible, and stands a good chance of success'.

Deploying two Vulcans to Ascension Island would not in itself be a commitment to the operation, but might by itself have deterrent value. Prime Minister Margaret Thatcher, who was caught up in the complex diplomatic end game surrounding US mediation efforts, was by this time well aware of the issues connected with the Vulcan raid.

Further delays were brought about by problems with Vulcan aerial refuelling. Unlike the Victor, where the receiver probe is mounted above the cockpit, the Vulcan probe was in the nose below the cockpit. The first few Vulcan 'prods' over the UK revealed that fuel leaked out of the probe and back over the windscreen. The airflow over the nose kept it on the windscreen – the wipers could not clear it and the moisture obscured the

view forward, which did nothing for station keeping with the tanker ahead. A colander was placed around the probe base to disperse the fuel, but to no avail. Then deflector blades were fitted on the nose to break up the airflow keeping the fuel in place, but this 'fix' did not work either.

Very large spillages also occurred, and these monster gushes proved to be a real menace as a large leak could cause the engines to flameout – several double-engine flameouts resulted, and 'Monty' Montgomery suffered a particularly nasty one at night. All was gloom and despondency by 24 April because no matter how adept the crews became at bombing, if they could not take fuel on board safely, they would never get near their target. Fortunately, the following day it all came right.

Leaks were reduced to a minimum when it was found that the original Vulcan refuelling valves had not been assembled to specification. A helicopter was despatched to Marham to pick up some Victor probes that had been fitted to different standards, and these did the trick late on 26 April. Deployment was authorised the following day, and on the 29th, XM597 and XM607 flew to Ascension Island.

The Vulcan raid was designated 'Black Buck', and many outside the RAF considered it to be an expensive and demanding attempt to grab a piece of the action. Adm Woodward believed that denial of Port Stanley airfield could be achieved far easier using Sea Harriers – a view he expressed forcefully in a signal on 27 April as the War Cabinet considered whether to deploy the Vulcans to Ascension. While 'freely admitting total ignorance of Vulcan capability', Woodward suspected that the Vulcan attack would be 'too little, too late'. He therefore preferred to use Sea Harriers for the attack, backed by naval gunfire support.

Adm Woodward was hindered by not having his own RAF adviser, who would have been able to brief him that Sea Harriers optimised for air defence are not best suited to attacking runways. Post-attack reconnaissance from high altitude would still have had to be done, whether or not the Harriers had mounted the main attack.

The reply to Woodward the next day was to the point. Considerable assets had been devoted to mounting this operation, and Whitehall was concentrating on the most valuable role for the Vulcans. Woodward was told that, 'On receipt codeword from Vulcan for successful attack you are to initiate target recce at earliest opportunity from organic air resources'.

That the Sea Harriers were to give priority to air defence was confirmed in the concept of air operations agreed on 28 April. This document again raised the possible role of the Vulcans not only in the neutralisation of Stanley airport, but also in attacking mainland bases, assuming that they participated in the conflict and 'political approval is obtained'. They would thereby 'inflict maximum damage and maximum effect on morale of Argentinian forces'.

Woodward was told on 29 April that the Vulcan bombing run was timed for 1 May at 0700 hrs, and

Loading bombs on XM607 at Wideawake, on Ascension Island, on 30 April 1982 in preparation for 'Black Buck 1'

that Sea Harrier photo reconnaissance sorties should be attempted as soon as possible after the first strike. Subsequent Vulcan missions would depend on the success of the attack as revealed in the damage assessment photos. It was also explained that the Vulcan had the advantage over the Sea Harrier in its blind bombing capability should the weather be bad.

Woodward was still unhappy, arguing that daylight photographic reconnaissance would put the Sea Harriers at a severe risk, and so would negate the aim. 'If photo recce is essential to "Black Buck", cancel "Black Buck"'. If it was not, he would cancel the photographic mission and trust in naval gunfire on 2 May to finish the job. On 30 April Woodward was told that the 'Black Buck' raid had been approved. It was explained to him that the Sea Harrier photo-reconnaissance mission was needed not just to confirm the success or otherwise of the raid, but also to show that any damage had been confined to the airfield in case Argentine propaganda claimed that Britain was indulging in indiscriminate bombing.

Sqn Ldr Montgomery was nominated as detachment commander, and his crew became the operations crew at Ascension, leaving the Reeve and Withers crews to fly the missions. The outbound formation was to consist of 11 Victor K 2s, including two airborne reserves, plus the primary Vulcan and its airborne reserve. At 2250 hrs on 30 April, the aircraft took off at one minute intervals in radio silence, the last jet leaving the runway 12 minutes after the first.

Sqn Ldr John Reeve captained the primary crew in XM597 because his Nav Radar, Flt Lt Mick Cooper, had previous experience of conventional bombing. XM607 was the reserve jet, captained by Flt Lt Martin Withers – an Australian serving in the RAF – but as they climbed, the Withers' crew heard the news that XM597 had turned back because its cabin could not be pressurised. Instead of being back at Ascension in four hours, the Withers crew, with AARI Flt Lt Dick Russell, was now faced with a 16-hour flight sustained only by sandwiches and flasks of hot coffee. It was fortuitous because XM607 had the better bombing kit, and 'Black Buck 1' set off in formation with the tankers needed to get it to the Falklands.

By the time they reached cruising altitude, the first and last Victors were separated by some 85 nautical miles. The formation had been split into two waves, the second flying 4000 ft higher than the first, giving it a higher true airspeed. Lead aircraft on the two waves used air-to-air TACAN (TACtical Air Navigation) to evaluate closing rate, and all elements of the two waves merged some two hours south of Ascension.

To say that 'Black Buck 1' was refuelled seven times en route to Port Stanley does not do justice to the complexity of the task. Vulcan flight time from Ascension to Port Stanley was over eight hours and, if a crow could have managed it, the shortest distance each way was 3886 miles. The first fuel transfer took place 1¾ hours after take-off at a point 840 miles south of Ascension. Four Victors topped up the tanks of four others before turning back, and this 'cascade' refuelling plan was repeated several times until only one Victor tanker remained with the bomber. Unfortunately, by the time the solitary pair were an hour away from Port Stanley, it had become clear that fuel consumption was much higher than forecast.

Despite its long record of service, the 'Black Buck' Vulcan was operating in the unknown. Take-off weight had been 210,000 lbs, compared with the normal maximum of 204,000 lbs, and the 'Dash Ten' pod was causing

extra drag under the starboard wing. Moreover, because the heavy Victors could not reach the optimum Vulcan cruising height of around 40,000 ft, the B 2 had to stay at 30,000 ft so as to keep formation with the tankers, which increased fuel consumption still further on the long flight south. Finally, the crucial Victor tasked to top up the Vulcan prior to attack broke its probe while itself taking on fuel in turbulent air. The Victor donor immediately reversed roles with the damaged tanker, taking back its fuel from the latter before rendezvousing with the Vulcan.

Thus, when XM607 refuelled for the last time six hours after leaving Ascension, Martin Withers found himself some 6000 lbs short of the fuel he should have had at this time, and the donating Victor had sacrificed so much that it would need a tanker itself to get home. As Withers throttled back to begin his descent 290 miles north of the target, his crew was relying more than ever on meeting a Victor on the return journey.

XM607 had only enough fuel to get in and out in a straight line, so the Waddington planners had gone for a low-level penetration to maximise surprise and minimise warning time to launch land-based interceptors. Consequently, as the Vulcan levelled out at 2000 ft over the sea at a point 233 miles from the target, it was well below Argentinean radar cover. From there Withers made a gentle descent to 300 ft to make doubly sure that no prying electronic eyes would see the Vulcan coming.

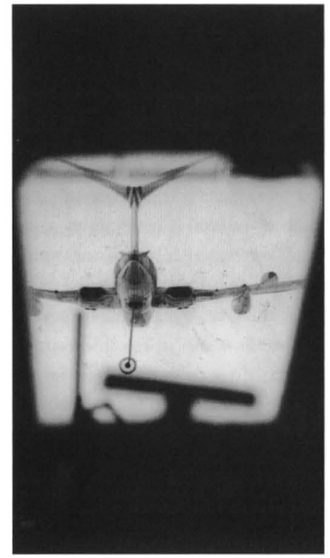
Only one imponderable now remained. Having left Ascension eight hours earlier, and having flown a route far from ground fixes in radio and radar silence so as to mask the approach, Nav Plotter Flt Lt Gordon Graham could only hope that the Carousel INS lived up to expectations.

Given meteorological predictions of strong winds, low cloud and severe turbulence, together with the lack of guiding lights on the airfield, the planners had no choice but to opt for a radar attack. At first glance, the best way of closing a runway is to start at the threshold and drop a stick of 21 1000-lb bombs all the way down it. Unfortunately, there are errors in every system, and only the slightest misjudgment could result in a neat line of bomb craters parallel to the runway, and much enemy merriment. The best statistical chance of hitting the runway was to fly across it at an angle of 35° and release the bombs in a line at quarter-second intervals.

This approach and stick spacing would never put all 21 bombs on the runway, but given the known errors in the Vulcan bombing system, it stood a 95 per cent chance of putting at least one bomb on the runway. Thus, as it approached the east-west runway at Port Stanley, XM607 was on an attack track of 235°.

As the range to target came down to below 60 miles, the Nav Radar, Flt Lt Bob Wright, finally turned on his H2S radar, which up to then had lain dormant to prevent warning emissions. There was no sign of the expected return from Mount Usborne, in the middle of East Falkland, but as Martin Withers eased the Vulcan up to 500 ft to widen the radar horizon, the mountain suddenly appeared exactly where it should be. The Carousel, combined with Gordon Graham's astro-navigation, had the Vulcan almost exactly on track. More ominously, the crew received a further position check when the passive warning receiver started to pick up signals from the Westinghouse TPS-43 early-warning radar at Port Stanley.

A conventional bomb dropped from 500 ft may bounce, and at best cause a crater only 12 ft wide by 3 ft deep, which would not put a runway



XM607 closes on a Victor K 2 from No 55 Sqn during the return flight to Ascension on 1 May 1982 (*via Dr Alfred Price*)

out of action for long. A bomb dropped from 2000 ft+, however, would have time to reach terminal velocity and drive into the runway. With a delayed action fuse, it produced a crater 65 ft wide and up to 20 ft deep.

But 'Black Buck 1' could not overfly at 2000 ft because of the Argentine defences. The planners knew that the enemy had Tigercat SAMs, which were potent by day up to 8500 ft, and Oerlikon 35 mm fast-firing twin-barrelled guns linked in some cases to Skyguard or Super Fledermaus fire-control radars. The elderly Tigercat was the least dangerous, but the Oerlikon was a greater threat up to 6500 ft. The nastiest opponent of all was the Roland SAM, which was a threat up to 16,000 ft. Bombing from 20,000 ft would have degraded accuracy, so it was a great relief to the planning team and crews when it was discovered shortly before the raid that Roland was probably not defending Port Stanley.

With 46 miles to go, Withers pulled XM607 into a climb to 10,000 ft. This would overfly Tigercat and the Oerlikons, give Bob Wright more time to identify his aiming offsets and ensure maximum penetration of the runway by the bombs. There was five-eighths cloud over the Falklands that night, and although the outline of the island could be seen through gaps in the undercast, the airfield could not be relied upon to give a good radar return, so Wright used nearby ground features as his offsets.

As they ran in at 320 knots, Withers and his co-pilot, Flg Off Pete Taylor, expected the defences to open up at any moment. The bomb-bay doors were opened ten miles from the target, and Withers waited expectantly for the flak and possibly missiles, but nothing happened. It was perhaps misleading to say that the enemy was caught well and truly napping, as the AEO, Flt Lt Hugh Prior, certainly heard the high-pitched scratching note of a Skyguard fire-control radar on his radar warning receiver.

Finally, about two miles short of the runway, the bombing computer signalled bomb release. A single nuclear free-fall weapon is gone in the blinking of an eye, but Martin Withers had to maintain a steady straight and level bombing platform until all 21 bombs were on their way. They were gone in five seconds, but to the crew 'it seemed like an age'.

It took 20 seconds for the bombs to hit the ground, by which time Withers was hauling the Vulcan round and into a full power climb. As he peered out of the cockpit window into the night sky, co-pilot Taylor suddenly saw the clouds over the airfield light up from below. As the darkness returned, the crew felt the distant crump of explosions merging together.

The South Atlantic dawn was breaking as the bomber reached top-of-climb, and Hugh Prior sent the single codeword 'Superfuse' to report a successful attack. But the Vulcan was still not out of the woods. 'Black Buck 1' returned to Ascension via a route planned to stay outside mainland radar range. Two waves of three tankers separated by 90 minutes, together with a supporting Nimrod, were launched and sent to the first rendezvous point to meet the returning long-slot tanker and the Vulcan.

Reduced fuel transfer at the final inbound rendezvous made an early link-up with a Victor tanker essential. In the event, with a Nimrod monitoring the area well south of the planned point, contact was made in good time. As he saw the underside of the Victor swinging into position, Withers thought it was 'the most beautiful sight in the world'.

Unfortunately, not only did precious fuel start to flow into the tanks, but it also flooded back over the Vulcan's windscreen as well. Even with

the wipers going full chat, Withers could only see the blurred outline of the tanker. He could not afford to break contact because he might never regain it, but fortunately Bob Wright had come forward to watch the operation from the ladder between the pilots' steps, and he noticed a strip at the base of the centre windscreen that remained clear. Through this he gave a running commentary on the tanker's position, which enabled the pilot to hold station. It took ten fraught minutes to fill the Vulcan's tanks with sufficient fuel to get back to Ascension, and only then could contact be broken. Immediately the airflow cleared the spillage and all was sunshine and blue skies in the Vulcan cockpit. It was time to go home.

The 'Black Buck 1' Vulcan was airborne for 16 hrs 2 mins and the long-slot tanker for 14 hrs 5 mins, while the the total Victor flight time was 105 hrs 25 mins. The outbound and inbound waves of Victors uplifted 1,955,000 lbs (244,000 imperial gallons) of fuel, of which XM607 received seven per cent. The fuel transferred to the Vulcan at the final outbound refuelling had passed through five different Victor tankers.

British Attack Sitrep 1 delivered to the MoD at 1737 hrs on 1 May described the problems in assessing the effectiveness of the attack. Photo-reconnaissance was difficult because of the need for AAA suppression before the low-level approach required by the Sea Harrier could be safely made. The weather also did not permit easy damage assessment, with rain under a 1200-ft cloud base. Visual assessment, however, was 'scar 20 m long and 70 m wide across airfield, straddling centre of runway northeast-southwest, with three apparent craters, one on runway and one each side'.

In a follow-up report the next day, Adm Woodward reported that photographic reconnaissance now showed that the 'Vulcan attack made single crater with first bomb halfway down runway just south of centre, remaining bombs landed over to southwest over 1000-m run without further damage'.

The most immediate Argentine response came in the form of an inadequate air attack against the Task Force. The single Vulcan appears to have confused the Argentine air staff, as they were expecting a mass assault on the airfield, and so the response was more cautious than intended. When they appreciated the role played by the Vulcan, the Argentine commanders also had to contemplate the possibility that the same aircraft might be used against the mainland. The threat to the mainland became a theme in Argentine planning from this time onward.

XM607 taxies in at Wideawake shortly after returning to Ascension following the completion of 'Black Buck 1'. The aircraft had been airborne for 16 hrs 2 mins during the epic mission

How should we judge the Vulcan's performance on 1 May 1982? It is not surprising that the bomber managed the equivalent of flying from London to bomb Chicago before coming back to Heathrow, although it was the first time that a Vulcan crew had flown in such a large formation at night. The Vulcan, despite being long in the tooth, was a hardy old warhorse, and once the cobwebs were blown out of the in-flight refuelling system and the kit updated, it was more than capable of living up to the worldwide capability called for in the original specification.

RAF personnel gather at Wideawake to welcome back the crew of XM607 on the morning of 1 May 1982 following the first 'Black Buck' raid. Note the Sea Harrier FRS 1s parked behind the bomber. Having been flown in from Yeovilton (via Gambia) the previous day, these aircraft were loaded onto the ill-fated *Atlantic Conveyor* on 6 May and sent south to the Falkland Islands

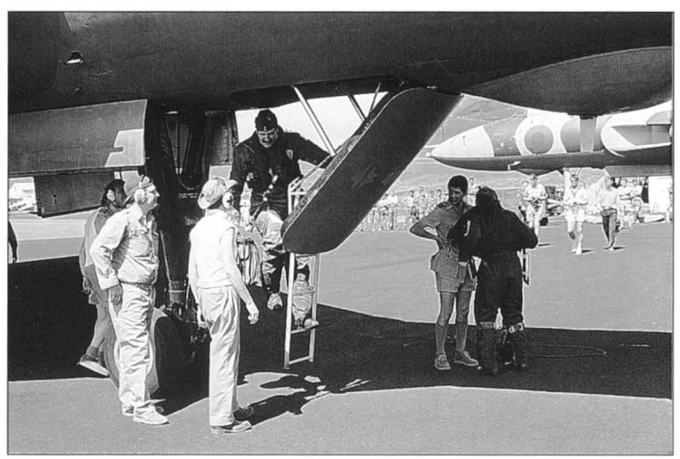
The first bomb in the stick hit the centre of Port Stanley runway, and others hit a small hangar, a store dump by the control tower and closed the only road to Stanley, which caused the Argentineans a great deal of trouble because their vehicles then sank into the mud on either side.

Given that XM607's radar bombing system was designed 30 years earlier, and that the specification only called for an accuracy of 440 yards at low level, there are not many bookmakers who would have given reasonable odds on hitting a target as small and narrow as a runway obscured by cloud in total darkness. In the event, Bob Wright and his kit dropped with no line error whatsoever, which was not only almost unheard of but was also a tremendous tribute to the groundcrew who tweaked the bombing system to perfection. 'It all went smoothly, like training', said Wright, but those modest words belied a great deal of effort and commitment.

The 'Black Buck 1' crew was Mentioned in Dispatches, while Martin Withers was also to be awarded the Distinguished Flying Cross (DFC) for his leadership, determination and presence of mind, which inspired his crew on a mission fraught with potential hazards beyond enemy action.

There has been criticism of the apparent futility of flying the equivalent of Waddington to the Russo-Chinese border to place just one 1000-lb bomb on Port Stanley airstrip, especially as Argentine Hercules transport aircraft flew into the airfield until war's end. But this misses the point. A Hercules is designed to operate from small strips, and it would have taken many repeat sorties to deny the airfield permanently to the enemy. Even so, from 1 May onwards the Argentineans only managed to fly 70 tons of materiel and 340 personnel into Port Stanley airfield.

The crew of XM607 disembarks after 'Black Buck 1'. Nav Plotter Flt Lt Gordon Graham is climbing down the ladder, while co-pilot Flg Off Pete Taylor (back to the camera) removes his lifejacket (*via Phil Jarrett*)



'Black Buck 1' forced Buenos Aires to disperse Pucara aircraft and logistical supplies away from the airfield, and to divert troops to defend them by day and by night. The raid also sustained national morale, and gave hope to the Falkland Islanders for the first time in a month. What the Vulcan was sent to do, and did most successfully, was to deny Port Stanley runway to high performance Skyhawks, Mirages and Super Etendards, which could have crippled the Task Force or the San Carlos beachhead had they been based at cockpit readiness on the island.

Just as the sinking of the cruiser *General Belgrano* kept the Argentine Navy in port, so the Vulcans' implied threat to the mainland forced the Argentine Air Force to move *Grupo* 8 – its only specialist all-weather Mirage III interceptor unit, armed with Magic missiles – north to defend Buenos Aires. This move thereby sacrificed air superiority over the Falklands and surrounding waters. That showed the disproportionate leverage that relatively modest air resources could exert from afar, but it would never satisfy those who were simply disappointed by the absence of a spectacular demonstration of destruction.

The last word on 'Black Buck 1' should go to Martin Withers;

'I would like to be sure that everyone gets the message. We *did* hit the runway with that bomb! I have had that confirmed, both by the Royal Engineers who repaired the hole and by the pilots of Phantom IIs who hit the lip of the repaired crater with their nosewheel on take off!

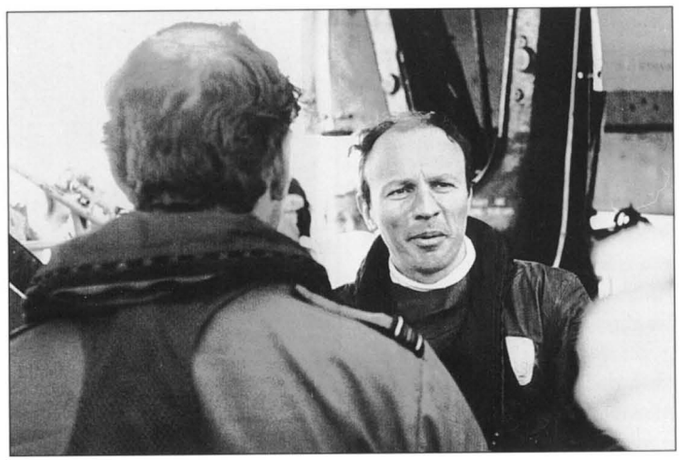
'For all us V-bomber types, Operation "Black Buck" was something totally unexpected. We were prepared only for a nuclear exchange with Russia, which meant that we had led a very sheltered existence within an air force which wasn't used to going to war. We therefore had to adapt very quickly. It was a considerable culture shock, and we all had to learn fast, but we did, and I think that we did it every effectively.'

FURTHER 'BLACK BUCKS'

With 'Black Buck 1' judged to be a success, 'Black Buck 2' was launched late in the evening of 3 May. XM607 was back in action, having proved itself to be the best bomber. Bomb load and target were the same as before, but this time Sqn Ldr Reeve and his crew were to be given their chance. The lessons of the first raid had been taken to heart, and major changes were made to the refuelling procedures, which worked very well. As the Roland SAM was now believed to be in the Falklands, John Reeve flew the bomb run at 16,000 ft.

The raid took place at 0820 hrs on 4 May, and again XM607 performed very well with no aircraft error, but this time the stick of bombs narrowly missed the western edge of the runway. This was not known for a few days until the weather cleared sufficiently for reconnaissance.

Flt Lt Martin Withers after his historic flight. He is still wearing his immersion suit, an all-encompassing rubber garment designed to preserve body warmth for long enough to climb into a dinghy after abandonment at sea (*via Phil Jarrett*)



As Argentine diesel submarines were feared to be on patrol, priority was now given to Nimrod anti-submarine missions. By using 18 tanker sorties the Nimrod could stay on task for up to five hours in the Falklands area, but the two Vulcans were on standby at Ascension for use if necessary against Argentine air defence radars on the Falklands, or in a last ditch effort against enemy air bases on the mainland.

'Black Buck 3' was planned for 16 May against Port Stanley runway, but strong forecast headwinds threatened to reduce fuel reserves below acceptable limits and the raid was cancelled. It was probably fortunate because the element of surprise had been lost. It was time to hit new targets with other weapons.

Back at Waddington in the hectic latter half of April, a whole variety of Vulcan missions had been considered, including firepower demonstrations, mining sorties and leaflet dropping. Once the 'Dash Ten' ECM pod was fitted, it seemed sensible to carry something on the port Skybolt point. The first candidate was Sidewinder. The new AIM-9L version of this heat-seeking missile was to win its spurs on Sea Harriers in the conflict, and feasibility studies were carried out to fit two Sidewinders on the port pylon for Vulcan self-defence. No AIM-9s were test-fired, although there was a suggestion that a Vulcan so equipped might take out the Boeing 707 that the enemy was using in the airborne early-warning role over the South Atlantic.

This post-attack photograph taken from a Sea Harrier shows Stanley runway after 'Black Buck 1'. The line of bomb craters is clearly visible, the first bomb from the stick holing the centre of the runway

Of all the novel loads proposed, the one that found the most favour was the anti-radar missile. This weapon is designed to home in on radar transmissions, and as the enemy was using its Falklands-based TPS-43 radar to direct air raids against the Task Force, provide target information for Exocet attacks and to warn its own aircraft of Sea Harrier patrols, it was decided to try and put out these radar 'eyes' as a matter of urgency. The same priority was applied to the Oerlikon gun-laying control radars.

The anti-radar AS37 Martel was the weapon initially chosen for fitment to the Vulcan because it was currently in service with the Buccaneer. Waddington engineers duly designed and manufactured a carrier beam that could carry a single round suspended from the Skybolt hardpoint. XM597 carried out two flight trials on 4 and 5 May, with the latter sortie also including a live firing over the Aberporth range after a cold soak at altitude, because there was doubt about Martel's performance at the end of a high-altitude mission. The two Vulcans deployed to Ascension were each armed with a single missile, but there were doubts about Martel's reliability when it came to target acquisition. A stray missile could easily cause civilian casualties in the target area, so this option was discounted.

Fortunately, American-built Texas Instruments AGM-45A Shrike anti-radar missiles were already under investigation as a readily available alternative. Thousands of these had been tried and tested in Southeast Asia during the Vietnam War, and they were being worked on at Waddington from 21 May. A week later there were eight Shrikes, with technical backup, at Ascension.

One missile was initially fitted, but then the US Navy twin-launcher was adopted. At this point it was decided to dispense with the 'Dash Ten' pod on Shrike missions, thus enabling four missiles to be carried. The

Photographed on 16 May 1982, XM612 is seen being loaded with 21 1000-lb bombs for the aborted 'Bluck Buck 3' raid. The bombs were held in clips of seven, and these were individually hoisted into the bomb-bay (*via Phil Jarrett*)

whole flight fitment and trials programme was repeated for Shrike, and the weapon went from concept to operational use in just ten days.

As all three primary Vulcan crews were needed to plan and execute the conventional bombing raids, Sqn Ldr Neil McDougall's crew from No 50 Sqn was nominated to work up for anti-radar missile duties. It deployed to Ascension on 27 May, with XM597 as its primary aircraft and XM598 as the reserve.

'Black Buck 4' was to have been the first anti-radar sortie, but the mission on 27 May was aborted after five hours when the refuelling hose motor on one of the tankers went unserviceable before the penultimate 'prod'. XM597 and the McDougall crew were back in the air on 'Black Buck 5' on 31 May. As the Vulcan carried no bombs, it had room for the two bomb-bay tanks which normally surrounded a nuclear weapon, thereby increasing fuel capacity by 16,000 lbs and reducing the airborne refuelling requirement to four 'prods' on the outbound leg.

Like its predecessors, 'Black Buck 5' approached Port Stanley at low level before climbing to 16,000 ft to attack the TPS-43 radar while Sea Harriers were simultaneously attacking the airfield to keep the radar on. Unfortunately, the B 2 crew did not know exactly which enemy radar the missiles had locked on to. XM597 was carrying only two Shrikes and they were range-critical – accuracy fell off above seven miles from the target.

Moreover, because of the rigid nature of the missile's seeker mounting, Shrike had to be pointed directly at the TPS-43 target at launch. The AEO, Flt Lt Rod Trevaskus, had to call out changes of heading from an instrumentation console very similar to an Instrument Landing System, with azimuth and elevation bars. Consequently, even though Shrike picked up the TPS-43 on the way in, the radar was switched off a few minutes later and Neil McDougall had to fly a complex pattern around the island trying to get into the right attack position again.

After 40 minutes Trevaskus detected the radar again, whereupon McDougall flew north and then swung round to ripple-launch his two Shrikes. The missiles disappeared into the cloud below, and although flashes were seen on the ground, only one exploded. The first detonated about 45 ft from the TPS antenna, inflicting significant damage, but the second missile missed the target altogether.

On 3 June the McDougall crew flew XM597 on 'Black Buck 6'. This time the jet carried four Shrikes – two pre-tuned for the TPS-43 and the others optimised against the Super Fledermaus fire-control radars. Again, the B 2 approached from the northeast at low level and then popped up to 16,000 ft, but the crew was hampered by poor intelligence on the location of the radars. The TPS-43 was believed to be on Sapper Hill, but it was actually at the west end of Port Stanley. The secondary TPS-44 radar was also in the wrong place, while the Skyguard radars were mobile.

The weather was too poor for the usual Sea Harrier decoy sortie and the Argentineans also knew what to expect, so as 'Black Buck 6' got to about nine miles from Port Stanley, the radars went off, only to come back on again once the Vulcan flew past. This cat and mouse game continued for 40 minutes and, as the time came for a final run before having to go home, McDougall decided to dive towards the airfield to try and tempt some reaction. The ploy worked, and as XM597 approached 10,000 ft, a radar came on and guns started firing. Rod Trevaskus was able to lock-on two

For 'Black Buck 6', XM597 carried four anti-radiation Texas Instruments AGM-45A Shrike missiles split two per underwing pylon. This weapon was considerably lighter than the AS37 Martel that had first been trialled with the B 2, and it also created fewer integration problems (*via Phil Jarrett*)

Shrikes and off they went. One warhead detonated close to a Skyguard radar that had been acting as a fire control unit for a GADA601 AAA battery close to Port Stanley. The weapon inflicted much damage and killed four of its crew – an officer, a sergeant and two conscripts.

McDougall climbed away, but on the return leg his refuelling probe broke, necessitating an emergency diversion into Rio de Janeiro. With barely 3000 lbs of fuel remaining in his tanks, and needing 2500 lbs to fly a circuit, he found himself four miles high only six miles from the runway. Exhibiting superb piloting skill, McDougall racked the giant bomber round into an almost vertical bank and a steep descending orbit to bleed off height and eventually made a perfect landing – he did not even need to stream the tail parachute to bring the Vulcan to a halt on the short runway. It was a wonderful achievement by both man and machine, and Neil McDougall deserved his subsequent award of the DFC for a superb demonstration of flying skill.

Although the Argentine government drew attention to the fact that the aircraft had just attacked Stanley airfield, the McDougall crew had been told to say that they had been on a training flight from Ascension Island, and had had to divert when practising air-to-air refuelling. The MoD was unclear whether any Shrikes had actually been used during the mission, and it did not want it to become public knowledge that these missiles had been supplied by the US. To get the Vulcan back, the British government agreed, on 4 June, that Lynx helicopter spares could be supplied to Brazil as soon as it was clear that the incident had been satisfactorily resolved.

Brazil announced the next day, however, that it would retain XM597 until deciding how to respond to an Argentine request not to release it. A few days later British diplomats succeeded in persuading the Brazilians to let it go.

By now the British forces were firmly ashore in the Falklands and 'yomping' towards Stanley. British Land Forces commander Maj Gen Jeremy Moore was worried that Pucaras operating out of Port Stanley airport could strafe his troops, and he requested another 'Black Buck' raid on the morning of 12 June. Just as the McDougall crew belatedly returned after their seven-day sojourn in Brazil, Martin Withers and his crew took-off at 0850 hrs on the seventh, and final, 'Black Buck'.

The aim was to cause maximum damage to 'soft' targets such as parked aircraft and vehicles in the general area of Port Stanley airfield, and XM607 was armed with iron bombs fused to 'air burst' and scatter lethal fragments everywhere. Unfortunately, the impact fusing was set in error and the 21 bombs fell wide of the target. Apart from an engine flameout, which took three attempts to relight, the mission was uneventful. At 2120 hrs on 13 June, Adm Woodward reported that 'Photo-recce of Stanley airfield today shows "Black Buck 7" bombs dropped on identical line to "Black Buck 2" without damage to target'.

Two days later the Argentinean commander on the island surrendered.

So ended the most complex and longest-ranging bombing missions to date in the history of military aviation. Credit must go to the engineers who made it all work, the planners who came up with the goods from their memory banks and the aircrews who flew jets in configurations few had ever experienced before, but who put it all together when it mattered.

The 'Black Bucks' were a prime example of British ingenuity and flexibility. When refuelling probes were needed for the Nimrod force in a hurry, someone remembered that several Vulcans with probes attached had recently been donated to museums across the USA. So a small team of RAF technicians in civilian clothes hurried across the Atlantic and went sneaking around American museums removing Vulcan probes. At the end of the conflict, the British defence attaché in Washington, D.C. got a signal from Castle AFB Museum, in California, congratulating the Brits on their success and demanding the return of its stolen property.

Today, devising a refuelling plan to fly a Vulcan, with full bomb load, all the way to Port Stanley and back from Ascension would be done by a computer programme. In April 1982 it was done with an electronic pocket calculator bought for £4.95 in Swaffham market!

It has to be said that 'Black Buck 1' was a close run thing due primarly to a larger than expected fuel consumption. This was not really surprising, as it involved two different types of aircraft operating over distances never attempted before. The parking apron at Ascension was only sufficient for 24 large fixed-wing aircraft, and the layout of the airfield provided only one access from the parking apron to the threshold of the 10,000-ft Runway 14. If the wind direction had required the use of Runway 32, it would have been impossible to launch formations of 'Black Buck' proportions because to reach the loop at the threshold of runway 32, jets had to taxi along more than two-thirds of the runway length. Fortunately, the prevailing wind throughout the Falklands campaign favoured Runway 14.

Fortune favours the brave, and it shone on the Vulcan delta bomber as it went into battle for the first and last time.

Farewell flypast by four Vulcans of No 44 Sqn on 21 December 1982, just hours before the squadron disbanded. XM607, the bomber of Stanley airfield, is in the lead, while Shrike carrier XM597 brings up the rear. XM612 (foreground, which also deployed to Ascension) and XL391 complete the diamond four (*Lawrence*)

CURTAIN CALL

After Blue Steel retired from service, Nos 27 and 617 Sqns at Scampton and Nos 44, 50 and 101 Sqns at Waddington continued in the tactical free-fall service of NATO, reinforced by Nos 9 and 35 Sqns when they returned from Cyprus. The dividing line between 'strategic' and 'tactical' targets was blurred because more than sheer distance was involved. Strategic targets were major political or industrial objectives, whereas tactical targets were supposed to have a purely military purpose. My tactical nuclear target in 1979 was a major military airfield in Belorussia, but it just so happened to be sited next to a city of 80,000-100,000 souls.

Seven squadrons of Vulcans filled the tactical bomber gap between the demise of the Canberra and the arrival of something better. The fact that the RAF eventually kept the Vulcan soldiering on until the introduction of Tornado in 1982, and moreover in a low-level role diametrically opposed to that for which it had been conceived, says everything about the quality of the original Vulcan design.

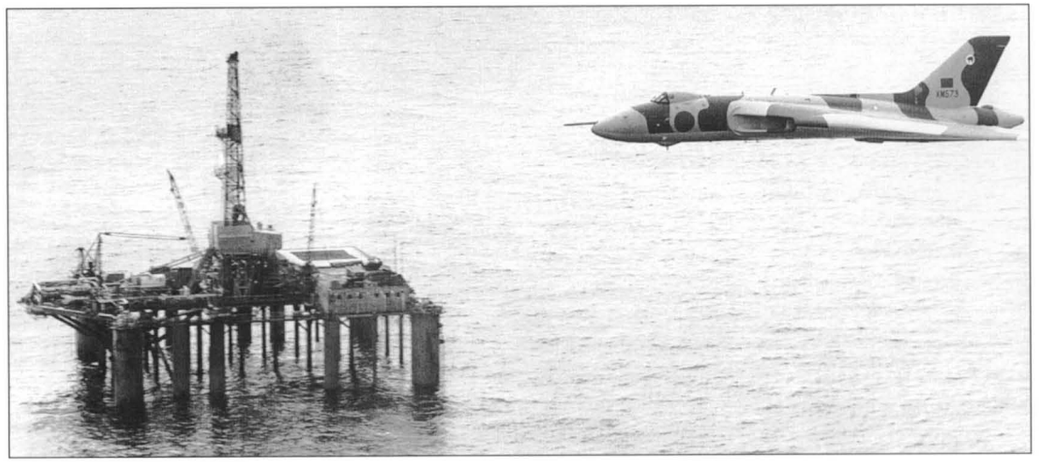
Ideally, it would have been preferable to produce a new Vulcan for low level operations, with one-third the wing span and improved systems, but this would have been to reduce the chances of detection and increase speed rather than to enhance fatigue life because the B 2 was built to last.

In the quest for simplicity and speed of construction, Avro had built the Vulcan structure around two mass-spar booms with mechanical joints because the firm had perfected this technique on the Lincoln and Shackleton. Both the RAF and the South African Air Force had bought the Mk 3 Shackleton, and the strain imposed on the section spars by low-level flight from the North Sea to the Tropics occurred in plenty of time for Avro to become well versed in the fatigue implications of mass-spar booms by the time the Vulcan went low-level.

Avro placed the 60th production Vulcan B 2 airframe, which had never flown, into a test rig where powerful hydraulic jacks simulated the gusts and manoeuvre loadings of a four-hour flight in about eight minutes. This fatigue specimen accumulated simulated flying hours far in excess of those clocked up by operational aircraft, so when cracks started to appear on the rig, remedial action could be taken on the fleet in good time.

Skybolt wing strengthening modifications also proved a boon in the low-level role, and as the years went by enough reinforcing iron plates were bolted into Vulcan wings to add up to 10,000 lbs to the basic aircraft weight. But it all paid dividends in the end.

Although the original Vulcan specification called for a life of 3900 flying hours in the high-level role, Avro estimated that its creation was sturdy enough to survive for 5900 hours. This was termed the 100 per cent fatigue life, or 100 Fatigue Indices (FI), but by the end the Vulcan was cleared to 320 FI in the low-level role, or 484 per cent of the original requirement. Given that the Victor B 2 cracked up under the strain of low-level operations as early as 1969, there was no denying the robustness



Vulcan B 2(MRR) XM573 undertakes a low level maritime reconnaissance mission over a North Sea oil rig in the mid-1970s. This aircraft was issued to the unit on 17 April 1974

of the delta design. 'Ironically,' said Vulcan Chief Designer Stu Davies, 'if the RAF had asked for a low-level bomber in the beginning, the Vulcan wouldn't have been at all like it was'.

MRR

No 27 Sqn disbanded as a bomber unit on 29 March 1972, only to reform at Scampton on 1 November 1973 in the Maritime Radar Reconnaissance (MRR) role to replace the Victors of No 543 Sqn, which had to be converted into tankers. It acquired XH534, XH537, XH558, XH560, XH563, XJ780, XJ782, XJ823 and XJ825, and over succeeding years these jets were standardised and given an improved Loran C navigation aid, their TFR nose cones were removed and they were finished in gloss paint, with light grey undersides, to protect against sea spray.

'27' was now employed to counter the growing Soviet naval threat. A Nav Radar in two five-hour high-level sorties could plot every vessel in the Norwegian Sea on his H2S screen. He would identify sightings as 'large', 'medium' or 'small', with large Soviet capital ships being particularly noteworthy. The plots would be sent out by the AEO, and a Nimrod maritime patrol aircraft might go in to make a formal identification. Five B 2(MRR) aircraft were further modified with former Sea Vixen under-wing drop-tanks for air sampling duties. Whenever the French, Russians

XH560 at Scampton in No 27 Sqn colours as a B 2(MRR) with Sea Vixen underwing 'sniffer' pods beneath its wings. This aircraft subsequently became a K 2 tanker

or Chinese carried out an above-ground nuclear test, a Vulcan B 2(MRR) would fly downwind to 'sniff' particles from which Aldermaston boffins could determine the yield. The Vulcan MRR role terminated when No 27 Sqn disbanded on 31 March 1982.

LAST HURRAH

The last great Vulcan exercise took place during the 1980 Taceval (Tactical Evaluation), when 28 Vulcans were dispersed from Waddington. The traffic lights had stopped all vehicles on the A15, which passed the runway threshold, and the sight of the long line of Vulcans, framed in the heat haze of 112 idling Olympus engines, must have generated awe, fear and wonder in the eyes of waiting motorists.

XL321, which retired in September 1982, clocked up 6996 flying hours, the largest total for any Vulcan. The final Vulcan practice bomb was dropped in December 1982, when No 44 Sqn stood down.

VULCAN TANKERS

The Falklands conflict stretched air-to-air refuelling (AAR) resources close to breaking point, and once the battle was over, it became clear that 22 Victor tankers were too few to support operations from the far north of the UK Air Defence Region to the South Atlantic. Plans had been laid to convert nine ex-commercial VC10s to three-point tankers, but the two-year lead time did nothing for the immediate shortfall. A stop-gap tanker became a top priority, so it was decided to convert the six best Vulcans – XH558, XH560, XH561, XJ825, XL445 and XM571 – from disbanded squadrons into Vulcan K 2s using Mk 17 hose-drum units (HDUs) destined for the VC10 tanker programme.

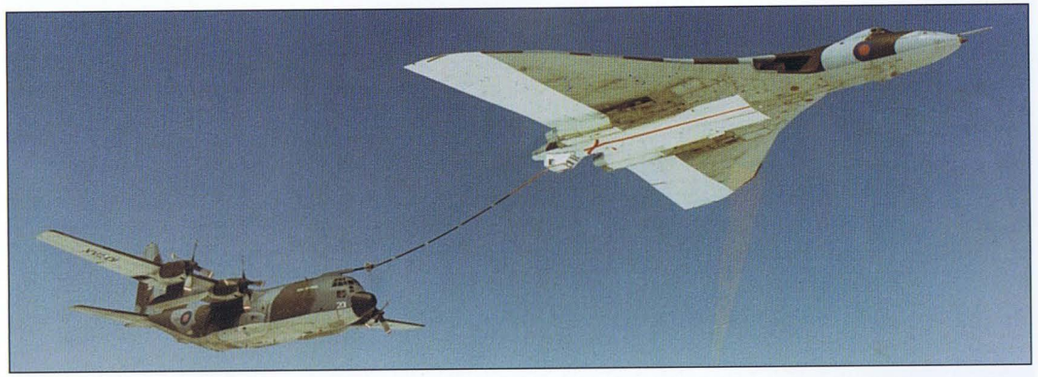
It was a relatively simple task to strip out the ECM gear from the tail cone and fit the HDU in a rather ungainly box-like fairing under the rear fuselage. A third bomb-bay tank was also installed in place of the nuclear weapon to bring the total fuel capacity of the Vulcan K 2 to 96,000 lbs. Little work was needed to permit all the fuel to either be used by the Vulcan or given away, and voila, there was a low cost tanker force-multiplier.

Such was the ease of conversion that British Aerospace was notified of the requirement for a Vulcan tanker on 30 April 1982, the first flight was made from Woodford on 18 June and Release to Service was obtained on 23 June – the same day that the first Vulcan K 2 returned to Waddington from the Falklands campaign.

No 50 Sqn, which was the only Vulcan unit to survive the 1982 drawdown, had a complement of ten crews for its six K 2s that supported UK air defence aircraft, thereby freeing Victors for the South Atlantic.

XM571 was the first of six B 2s modified into K 2 tanker configuration by British Aerospace at Woodford. Still wearing its No 101 Sqn livery, the aircraft made its first flight as a tanker on 18 June 1982. Tested at Boscombe Down, XM571 subsequently flew with Nos 44 and 50 Sqns prior to retiring in early 1984. The bomber was flown to Gibraltar for preservation in May of that year, although it was eventually scrapped in September 1990

The Nav Radar was responsible for fuel management during refuelling. The Vulcan K 2 retained its camouflage, except for a broad strip painted up the belly and across the bottom rear of the wing, with alignment markings added to help 'chicks' line up for refuelling. Floodlights were fitted for night



refuelling. Nick Wilcock, a former Vulcan pilot, recalls 'prodding' the Vulcan K 2 from his Phantom FGR 2, and he found it to be 'a nice stable platform. It was a bit weird at night with those twin underwing anti-collision lights, and the "MFI wardrobe" HDU housing looked hideous'.

Roger Dunsford was a flight commander on No 50 Sqn at that time. As he remembers it, 'When the K 2s started to enter service, and we were building up the fleet, teaching ourselves AAR and finding out the peculiarities of the K 2, the other squadrons were disbanding around us. This led to us receiving some of the remaining B 2s, which we then delivered to their final resting place (museum, gate guard etc.), where the owning squadron couldn't do it themselves – usually because the recipients could not accept the aircraft until after squadron disbandment.

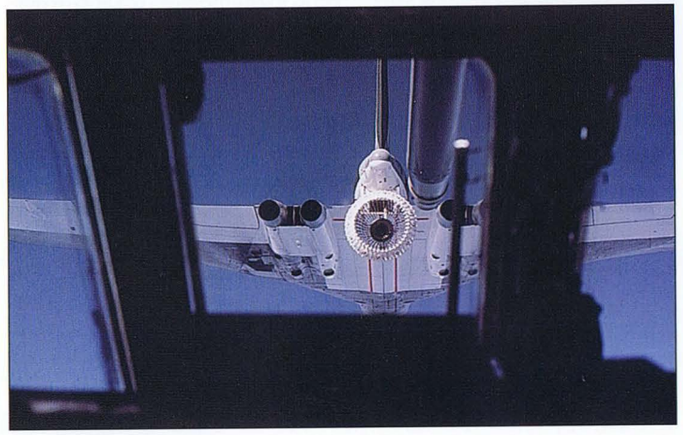
'To begin with, when we were very busy with the K 2s, the B 2s gathered dust, but we soon realised that we not only needed to keep the jets ticking over (Vulcans hated sitting on the ground), we also needed to keep our hand in with B 2 flying techniques that we were losing by constantly flying the K 2. In particular, this meant aerodynamic braking on landing, which was often needed on delivery of a B 2 to its final resting place when use of the tail brake 'chute was inadvisable or undesirable. We couldn't use any significant aerodynamic braking on the K 2 because it could easily write off the "Skip" (the refuse skip-shaped HDU) – a tail brake 'chute landing was the norm, except in cases of severe headwinds.

'Although we would mostly use K 2 techniques when flying the B 2 in the circuit (shallow approach angle, little round-out/flare, no aerodynamic braking for rollers etc. – anything to protect the "Skip"), for final landing, we tried not to use the tail 'chute for practice. This also relieved pressure on the dwindling stocks of 'chutes and, more importantly, it got serious brownie points from the ground-crew, who were spared packing yet another 'chute.

'So the B 2 became the aircraft of choice for continuation training on No 50 Sqn because for the first two years at least, K 2 tasking was always

XM571 conducted flight trials with all probe-equipped aircraft in the RAF during a series of test flights from Boscombe Down in the summer of 1982. Here, it refuels a Hercules C 1 in July of that year

A Hercules pilot's view of the Vulcan drogue. The ECM equipment was removed from the K 2 tail to accommodate the piping leading to the unattractive HDU 'Skip'. As originally envisaged, the Vulcan tanker would have carried the HDU in the rear bomb-bay. However, this was felt to place the receiving aircraft too close to the tanker, so the EW bay was chosen instead (via *Phil Jarrett*)



into overload, particularly in support of the UK air defence QRA commitment. With Victors maxed out on the Falklands air bridge, UK-based fighters were desperate for any off-load we had, and usually begged for more. We often gave full off-load before reaching top-of-climb!

'Those B 2s that had had their refuelling circuits reactivated became precious because we could practice plugging in, whilst conserving K 2 hours (always an issue) and allowing K 2 downtime for essential servicing. We would often get a B 2 airborne with a K 2 to practice tanker-to-tanker stuff between "chicks". The only continuation training we could not replicate on the B 2 was the back-end work, so these B 2s became front-end "hacks" in the eyes of the rear crew.

'As time passed, the K 2 commitment gradually decreased, and our attention returned to display flying and the run-on post No 50 Sqn via the Vulcan Display Flight (VDF). It was then that we seriously started grooming B 2s for display flying. Apart from availability, the K 2s did not lend themselves to display flying because flying past with bomb-bay doors open was not considered a good idea with the three fuel tanks lashed inside. Indeed, the bulk of VDF displays during the 1984 season, post-No 50 Sqn disbandment, were flown in unconverted B 2s.'

It was during this season that the decision was taken, based on fatigue and flying hours, to re-convert XH558, which had served both as a B 2(MRR) and as a K 2, back into a B 2 to act as the long-term VDF solution. Many B 2s passed through No 50 Sqn's hands during the K 2 era, but at any one time there were only a maximum of four on the unit.

The Vulcan K 2 could certainly have continued in service well beyond 1984, but the Mk 17 HDU had been out of production for some years, and Vulcan HDUs were needed on the VC10s. No 50 Sqn and the K 2 finally retired together on 31 March 1984. The last Vulcan flight in RAF service was an air display made by B 2 XH558 on 23 March 1993.

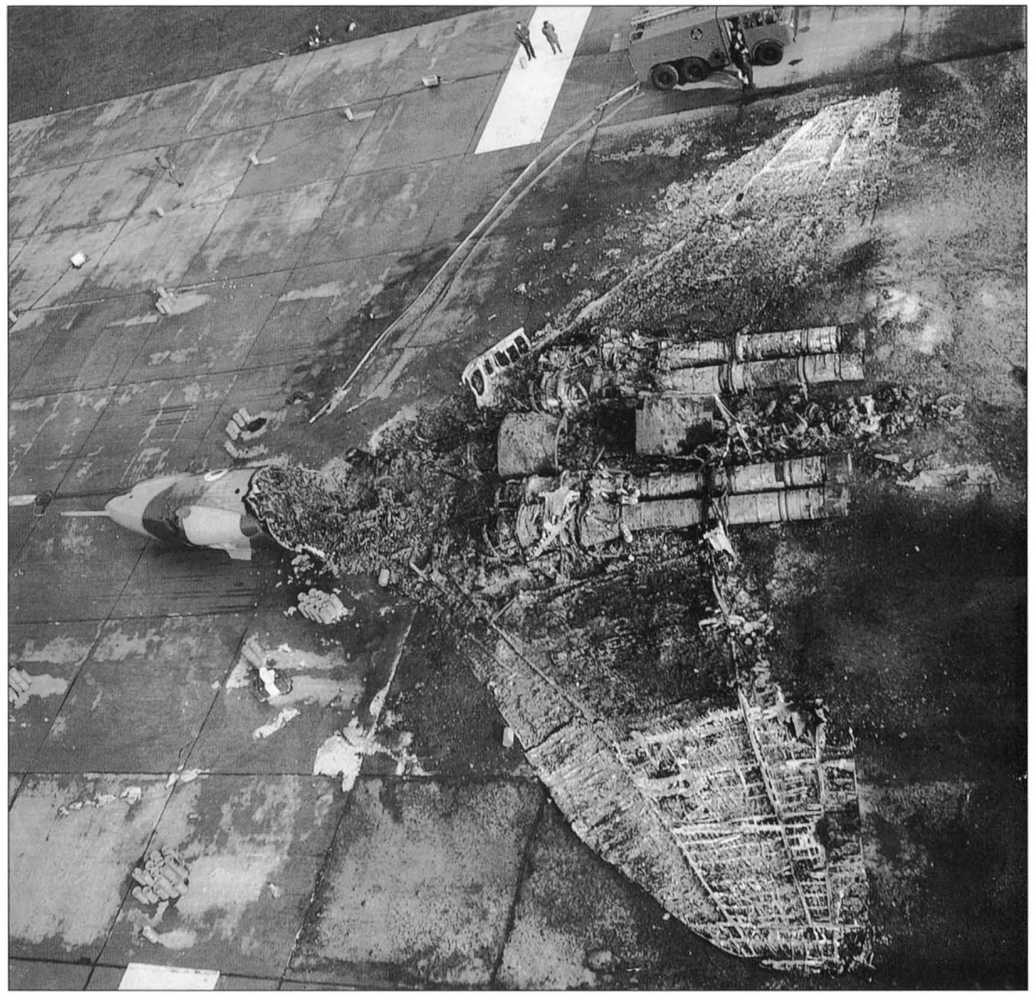
FINALE

Some 42 B 2s were sold for scrap for a total of £69,574, while 175 Olympus engines were knocked down for £350 each. Built originally at a cost of over £1 million each, or at least ten times that amount at present day values, the Vulcan B 2 was very much a multi-role combat aircraft.

In its time, the Vulcan had been a high and low-level bomber, a tanker, a stand-off and anti-radar missile carrier, a maritime radar reconnaissance platform and had also been mooted as an air defender with a host of air-to-air missiles under its mighty delta wing. There was even a proposal for a VTOL Vulcan, with missiles slung beneath its wings and the bomb-bay filled with two rows of engines facing vertically downwards. God knows what would have happened if one side had failed at the crucial moment.

More practically, Avro designed a bomb-bay crate to turn it into a photo-reconnaissance platform, but along with other conversion schemes this was never implemented. 'We like to think', said John Sheraton, Assistant Chief Designer of the Vulcan, in 1978 'that we didn't get any of them accepted because the Vulcan was the best bomber'. And it has to be said that many of today's stealthy designs for bombers of the future look very similar to the iconic delta-wing Vulcan.

Despite the tragedy of individual accidents, the total loss of Vulcan B 2s from all causes remained low, and represented a wastage rate not



The bitter end. The charred remains of XL385 of No 617 Sqn at Scampton after an explosion in the port engines on start-up on 6 April 1967. The crew got out safely

much greater than half of one per cent per year throughout the aircraft's in-service life. In flight safety terms, the write-off rate for all Vulcans was only 0.33 per 10,000 hours – a fine record for a frontline aircraft with more than 25 years of operating service in a demanding role by day and night. With its great reserves of engine power and structural strength to cope with all but the most dramatic crisis, no aircraft could have served its air and groundcrews better than the Vulcan. In most fatal accidents, the Vulcan was found to be more sinned against than sinning.

Looking back, the international leverage exerted by the Vulcan, and its ability to deliver a 'basket of sunshine', was considerable. Hordes of people admired the Vulcan wherever it was displayed, including a Soviet air attaché at Waddington in 1981. Walking straight past the shiny Jaguar, Harrier and Tornado without so much as a glance, he made straight for the elderly Vulcan because, as he admitted candidly, 'that is the only one that can reach my homeland'. Power alone is one thing, but it has to be 'projected' if it is truly to impress friends and overawe potential adversaries. And the Vulcan did that during the Cold War to the very end.

APPENDICES

VULCAN SQUADRONS

No 230 OCU – Formed Waddington 31 May 1956 with Vulcan B 1 (City of Lincoln coat of arms insignia); Finningley 18 June 1961, Vulcan B 1/B 2 (white Yorkshire rose insignia); Scampton 8 December 1969, Vulcan B 2 (yellow sword on blue and white disc insignia). Disbanded 31 August 1981

No 9 Sqn – Formed Coningsby 1 March 1962; Cottesmore 10 November 1964; Akrotiri 20 February 1969; Waddington 15 January 1975; disbanded 1 May 1982. Vulcan B 2 throughout (bat insignia)

No 12 Sqn – Formed Coningsby 1 July 1962; Cottesmore 17 November 1964; disbanded 31 December 1967. Vulcan B 2 throughout (fox's head insignia)

No 27 Sqn – Formed Scampton 1 April 1961 with Vulcan B 2; disbanded 29 March 1972. Re-formed Scampton 1 November 1973 with Vulcan B 2(MRR); disbanded 31 March 1982 (elephant insignia)

No 35 Sqn – Formed Coningsby 1 December 1962; Cottesmore 2 November 1964; Akrotiri 15 January 1969; Scampton 16 January 1975; disbanded 1 March 1982. Vulcan B 2 throughout (initially Pegasus flying horse and then numerals '35' joined together and called 'the Skyhook' insignia)

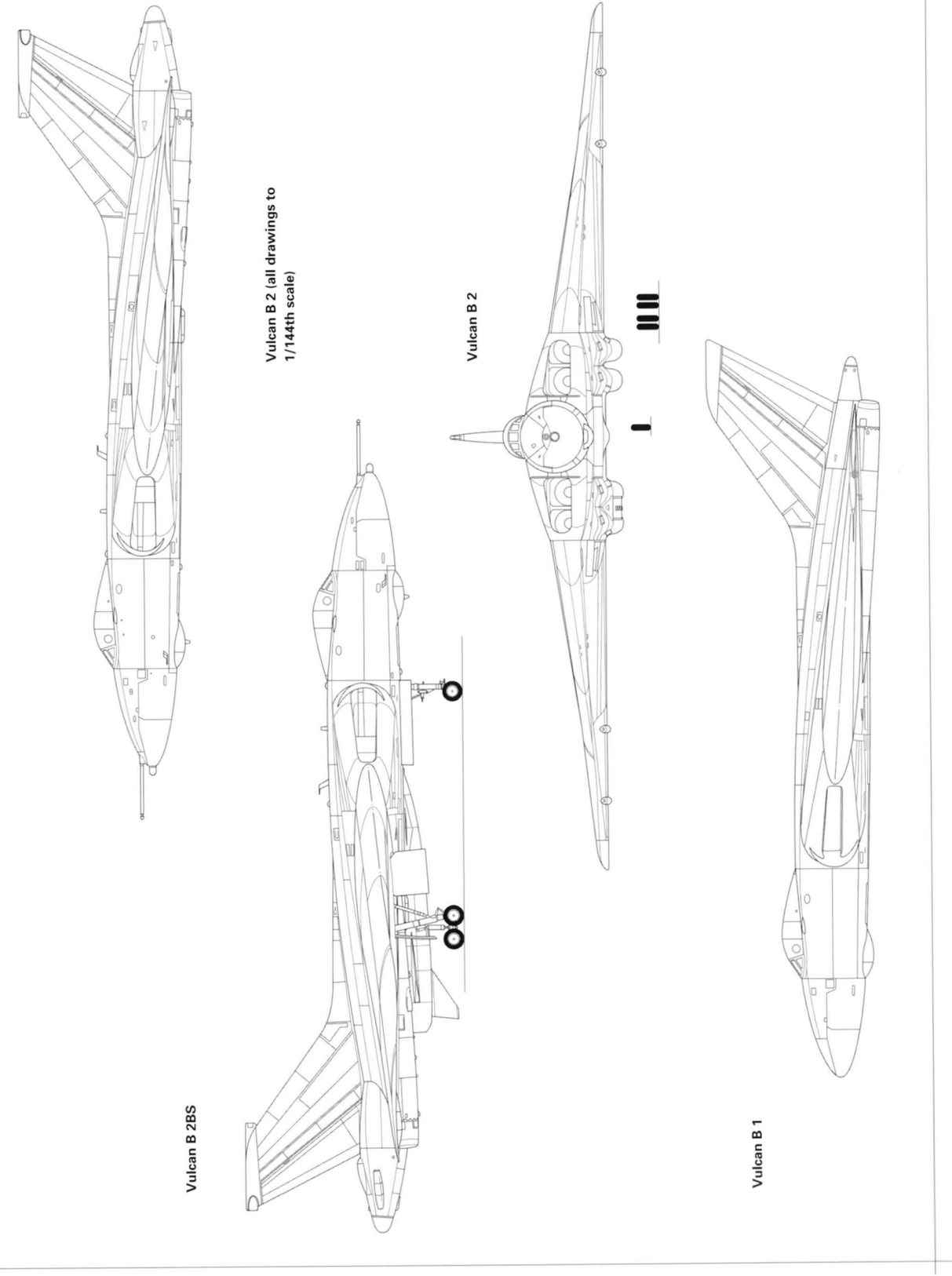
No 44 Sqn – Formed Waddington 10 August 1960 with Vulcan B 1 to August 1962; B 1A January 1961-September 1967; converted to Vulcan B 2 September 1966; disbanded 21 December 1982 (numerals '44' insignia)

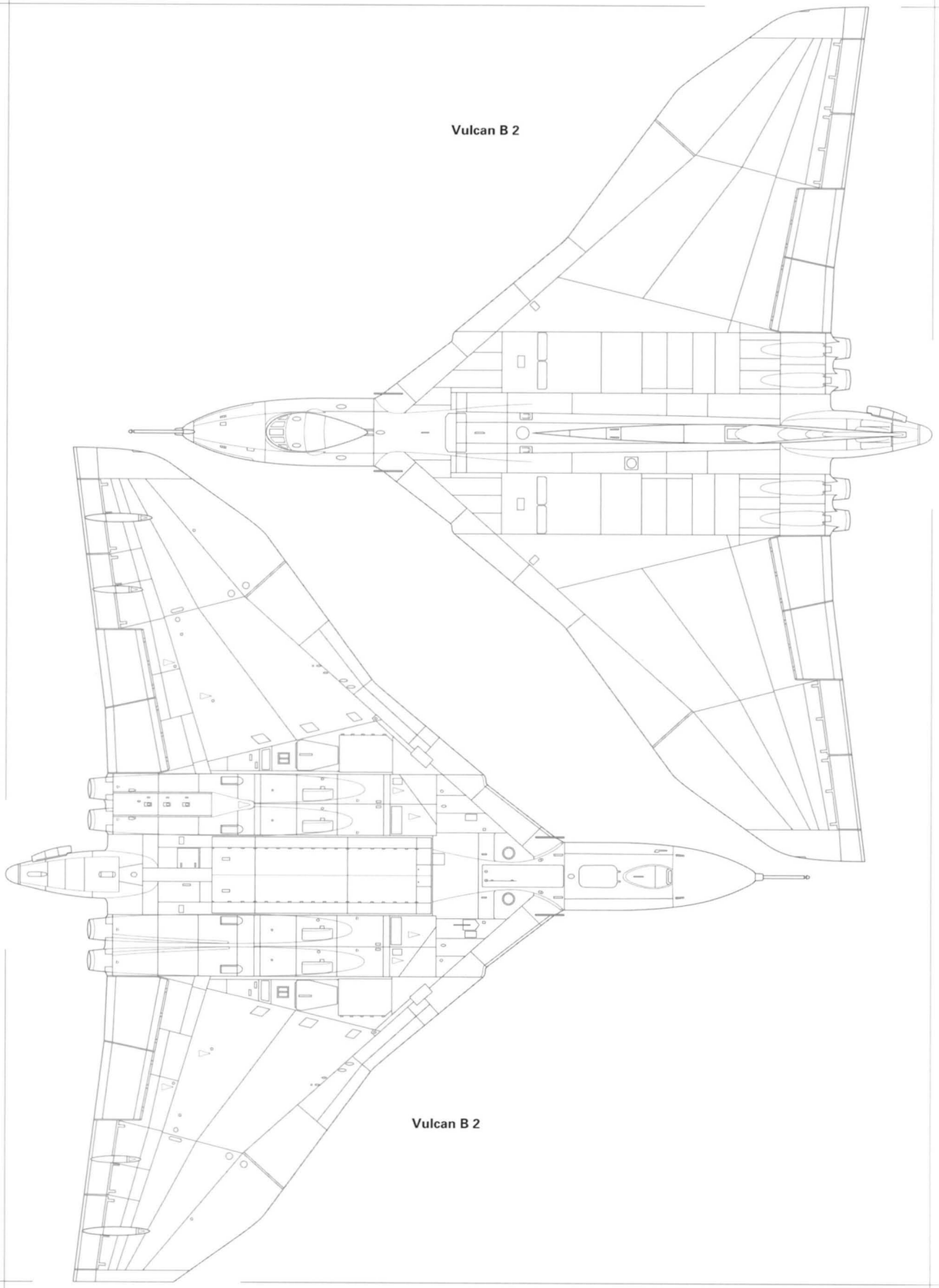
No 50 Sqn – Formed Waddington 1 August 1961 with Vulcan B 1 to August 1962; B 1A August 1962-October 1966; converted to Vulcan B 2 January 1966; K 2 June 1982; disbanded 31 March 1984 (two running dingoes insignia)

No 83 Sqn – Formed Waddington 21 May 1957 with Vulcan B 1 to August 1960; B 1A March 1961-December 1967; converted to Vulcan B 2 December 1960; disbanded 31 August 1969 (antler insignia)

No 101 Sqn – Formed Finningley 15 October 1957 with Vulcan B 1 to May 1962; B 1A March 1961-December 1967; Waddington 26 June 1961; converted to Vulcan B 2 1967; disbanded 4 August 1982 (numerals '101' incorporating Squadron crest of lion in turret insignia)

No 617 Sqn – Formed Scampton 1 May 1958 with Vulcan B 1 to July 1961; B 1A October 1960-July 1961; converted to Vulcan B 2 September 1961; disbanded 31 December 1981 (initially three lightning flashes, then breached dam on diamond background insignia)





Vulcan B 2

Vulcan B 2

COLOUR PLATES

1
Vulcan B 1 XA901 of No 101 Sqn, RAF Waddington, 1962
No 101 Sqn reformed with the Vulcan on 15 October 1957 as part of the Finningley Wing, becoming the second RAF unit to fly the Vulcan, and the first to be armed with British H-bombs.
No 101 Sqn moved to RAF Waddington on 26 June 1961 and converted to upgraded Vulcan B 1As, using these to become the first Vulcan unit to qualify in air-to-air refuelling. Its aircraft had worn the squadron badge high on the tailfin for much of their time at Finningley, but this was relocated to the nose to make room for the City of Lincoln shield that was used as a wing insignia by many Waddington-based jets. Some aircraft briefly wore a squadron badge on the port side of the fin, with the Lincoln crest to starboard. XA901 was the first Vulcan issued to the RAF in the overall gloss white colour scheme, previous aircraft having been delivered in silver.

2
Vulcan B 1 XA895 of the Bomber Command Development Unit, RAF Finningley, 1962
XA895 was delivered to No 230 OCU at RAF Waddington in 1956, and was used for training until transferred to the Bomber Command Development Unit, where it was selected to serve as the trials aircraft for the ECM equipment that would be fitted as standard in the B 2. These systems would also be retrofitted to some Olympus 104-engined B 1s to create the B 1A. Still in the earliest Vulcan's original high speed silver finish, XA895 had the later aircraft's ECM tailcone, but differed from the definitive B 1A standard in that it retained Olympus 101 engines and was not fitted for in-flight refuelling. The B 1As had a number of other improvements, including explosion suppression, revised windows and modified internal wiring. XA895 was withdrawn from use in 1967 and scrapped in 1968.

3
Vulcan B 1A XA910 of the Waddington Wing, RAF Waddington, September 1964
XA910 served at Finningley with No 230 OCU and No 101 Sqn before being transferred to Waddington. It was modified to B 1A standard in 1962. The jet is seen here in the anti-flash white colour scheme adopted from 6 May 1960, with serials and national insignia in the toned-down (60 per cent reflectivity) pastel shades designed to reflect the flash from an atomic explosion. XA910 subsequently became an instructional airframe at RAF Cottesmore, wearing the maintenance serial 7995M, prior to eventually being scrapped.

4
Vulcan B 2BS XL427 of No 83 Sqn, RAF Scampton, 1963
XL427 was delivered to No 83 Sqn at Scampton in 1962 in the Blue Steel fit. The aircraft wears the unit's distinctive antler insignia on its tailfin and (much smaller) in the full heraldic frame on the forward fuselage aft of the roundel. The introduction of centralised servicing at Scampton in 1963 led to the station's aircraft being pooled, and individual squadron markings were removed. Instead, the wing and squadron badges were painted on the crew entrance door.

5
Vulcan B 2BS XL317 of No 617 Sqn, RAF Scampton, 1963
This 'Dambusters' Vulcan B 2 wears the unit's 'lightning flash' tail marking in pastel shades and has a full colour squadron badge on the forward fuselage. The aircraft carries a W100A pre-production Blue Steel missile under its belly. The W100A variant lacked a warhead, but otherwise closely resembled the operational W105. The W100As were used for familiarisation and early training by the RAF. A few rounds were test fired at various ranges, and they may have been painted blue to aid visibility. War stock W105 Blue Steel missiles were painted white. XL317 had a long career, serving with a large number of units before ending its days with No 617 Sqn, after which it was retired to become a crash/rescue training airframe at RAF Akrotiri in 1981.

6
Vulcan B 2 XH556 of No 230 OCU, RAF Finningley, 1963
XH556 was the last Vulcan to be fitted with the early shallow engine intakes. The jet spent its early life undertaking test and development work, before entering frontline service with No 27 Sqn at RAF Scampton in September 1961. When No 27 Sqn began receiving Blue Steel-capable aircraft in early 1963, XH556 was transfered to No 230 OCU at Finningley, gaining the Finningley Wing's White Rose tail badge in the process. The aircraft was written off in April 1966 after its undercarriage collapsed on start-up. The bomber was then stripped of serviceable spare parts and unceremoniously towed to the Finningley fire dump.

7
Vulcan B 2 XM604 of No 35 Sqn, RAF Coningsby, 1964
Vulcan B 2 XM604 was used by No 35 Sqn in 1964, and all of its unit markings were in toned-down, pastel shades. The final batch of B 2s was delivered with in-flight refuelling probes already fitted from XM603 onwards. This aircraft (by now in the hands of No 9 Sqn) was lost on 30 January 1968 when it crashed shortly after performing a 'touch and go' at Cottesmore. An engine failed catastrophically, sending a turbine disc shooting through the bomb-bay, taking the control runs with it. The crew lost control as they tried to burn

off fuel to get down to landing weight. Pilots, Flt Lt P Tait and Flg Off M Gillett ejected, but the rear crew (including a crew chief) were unable to bale out and were killed.

8
Vulcan B 2BS XM576 of No 27 Sqn, RAF Scampton, 1964
XM576 was another short-lived Vulcan, being written off after a crash-landing at Scampton on 25 May 1965. The aircraft wears full toned down anti-flash colours, although the squadron's badges (aft of the roundel and on the tailfin) use normal colours. The aircraft is portrayed as it appeared on QRA during mid-1964, carrying a live Blue Steel W105 missile. XM576 was subsequently pooled into the Scampton Wing, losing its squadron markings.

9
Vulcan B 2 XH560 of No 12 Sqn, RAF Coningsby, 1963
This B 2 wears classic anti-flash colours, with roundels, fin flash, squadron badges and tail insignia all rendered in pastel shades. XH560 (also shown in profile 21 later in its career) was a long-lived airframe, serving multiple tours at Waddington and Finningley as an OCU training aircraft, as well as in the free-fall bomber role with No 12 Sqn at Coningsby during 1962-63, and then with the Cottesmore Wing from 1965 (apart from a brief spell at Waddington) until the wing moved to Akrotiri in 1969. Some Coningsby aircraft briefly wore a station fin badge (a representation of nearby Tattershall Castle) instead of squadron colours. The aircraft was converted into a B 2MRR in 1973, but returned briefly to the bomber role in 1982, and was then retained as a spare for the Vulcan Display Team (VDT) until 1985. XH560's cockpit survives with the Cockpit Collection at Rayleigh, in Essex.

10
Vulcan B 1A XH506 of the Waddington Wing, RAF Waddington, September 1967
The Vulcan fleet was camouflaged for low-level operations from 1964. The B 2s underwent considerable wing strengthening for low-level flying, but the B 1As did not, resulting in speed limitations being imposed on these older airframes. As one of the first Vulcans to be camouflaged, XH506 had a soft (unmasked) demarcation line between the uppersurface colours. With the adoption of camouflage and centralised servicing, unit markings were limited to the crew entrance door. By 1967 XH506's camouflage was looking decidedly well worn, especially when compared with its immaculate appearance in the 1965 James Bond film *Thunderball* – Vulcans, including XH506, played a major part in the motion picture. In the film, a Vulcan carrying a pair of nuclear bombs is hijacked by SPECTRE henchman Angelo Palazzi (played by Paul Stassino), who has undergone plastic surgery to allow him to replace a NATO observer (Maj Francois Derval) who was due to join the mission. Once in control of the aeroplane, Palazzi ditches it in the ocean and the aircraft drifts down to the seabed, where the weapons are recovered, and the bomber forms the backdrop for the film's underwater scenes. XA913 was used for ground filming and XH506 for flying shots, and a huge model, constructed on location by Pinewood's William Creighton, played a starring role in the underwater scenes.

11
Vulcan B 2BS XM610 of No 44 'Rhodesia' Sqn, RAF Scampton, January 1969
From 1965 to 1975, squadron tail markings were rarely seen on camouflaged Vulcans, although there were some exceptions, as depicted here. Very small insignia were applied to a number of aircraft, with larger, but more temporary, unit markings also being seen in dayglo tape. This Vulcan B 2 of the Waddington Wing wore a tiny representation of No 44 Sqn's elephant badge during a transatlantic detachment, causing some confusion, since the insignia was very similar to that previously used by No 27 Sqn. During this very detachment, XM610's port undercarriage leg fell through an underfloor heating duct as the aircraft was being pushed out of the hanger at Goose Bay, necessitating repairs. Just two years later, on 7 January 1971, the aircraft was lost after an engine exploded while climbing out from low level. Unusually in a V-bomber accident, the three rear crew escaped successfully, and the pilots stayed with the aircraft until they could guide it clear of Tyneside, and then ejected. Flt Lt Garth Robert Alcock of No 44 Sqn won an Air Force Cross for his handling of the situation, and the remainder of the crew received Queen's Commendations for Valuable Services in the Air.

12
Vulcan B 2 XM595 of No 27 Sqn, RAF Scampton, 1970
With Waddington-based No 44 Sqn appropriating the heraldically correct elephant as its tail marking, No 27 Sqn at Scampton retaliated by using a 'Disneyesque' 'Dumbo' insignia from 1971, initially applied in simple dayglo sheet. XM595 was the last Vulcan built from new to carry the Blue Steel missile, and it was converted for the free-fall role (with TFR and provision for WE177) during the winter of 1969, prior to rejoining the Scampton Wing. No 27 Sqn disbanded as a bomber squadron in March 1972, but reformed as an MRR unit (still with Vulcans) in November 1973. XM595 saw service with all of the Scampton squadrons prior to being scrapped at the base in 1982.

13
Vulcan B 2 XM574 of No 617 Sqn, RAF Scampton, June 1970
XM574 had been the first production Blue Steel Vulcan to fly with Olympus 301 engines, and it was also the first 301-engined B 2BS delivered to the Scampton Wing in June 1963, although XH557 and XJ784 had already been retrofitted with the new engines and XL391 had been delivered with Olympus 301s as a trial installation. Built as a Blue Steel carrier, XM574 was converted for the free-fall role between December 1969 and January 1970. By June 1970, No 617 Sqn was converting from Blue Steel to free-fall bombing, and it operated a mix of Blue Steel and non-Blue Steel aircraft. Most of these (including some of the Blue Steel carriers, like XL321) were fitted with nose-mounted Terrain Following Radar. XM574 remained as part of the Scampton Wing until November 1971, when it transferred to Waddington. The aircraft was sent to the Akrotiri Wing in August 1973, and returned to Scampton in January 1975, where it rejoined the 'Dambusters' after a brief sojourn with No 35 Sqn. The jet was finally scrapped at St Athan in 1982. XM574 was unique in being a Blue Steel aircraft with only a single underwing ECM plate.

14
Vulcan B 2 XM602 of No 1 Group, 'Giant Voice 1971', McCoy AFB, Florida, 1971
RAF Vulcans made numerous visits to the USA, and participated in a range of USAF and SAC bombing competitions over the years. Aircraft frequently had their unit markings replaced by a No 1 Group Panther's head badge on the nose or tail, and a Union Jack was applied to the tailfin. XM602 of the Waddington Wing was a participant in the 18th Bombing and Navigation Competition (Giant Voice), held at McCoy AFB in 1971, and it wore typical markings for the exercise. The same aircraft was later used by the VDT in 1981, participating in the International Air Tattoo at Greenham Common and in the international airshow at Ontario. After the bomber was scrapped, its nose was passed on to the Avro Heritage Society at BAe Systems Woodford, and it has been used as a mobile exhibit by the Vulcan to the Sky Trust.

15
Vulcan B 2 XL446 of the NEAF Bomber Wing, RAF Akrotiri, March 1973
Although toned down red and blue national insignia were principally associated with aircraft wearing the later matt camouflage finish, small numbers of Vulcans combined the older polyurethane gloss camouflage finish with red and blue roundels and fin flashes. Sometimes this was achieved through the simple expedient of overpainting the white areas with red and blue, as seen on NEAF Wing B 2 XL446, on which some white is just showing through on the roundel. XL446 was one of the final batch of seven 200-series engined Blue Steel Vulcans (XL445, XL446 and XM569-573) to be built. They were followed by five new-build Blue Steel aircraft with 301 series engines, and were supplemented by seven conversions of older aircraft with Blue Steel and the later 301 engines (XL384-390). The aircraft were soon judged to be surplus to the requirements of the Blue Steel force, and were converted for free-fall bombing in 1966, replacing B 1As with the Waddington Wing. Unlike later conversions, these aircraft were able to carry cylindrical bomb-bay tanks instead of the saddle A & E bomb-bay tanks fitted to later Blue Steel machines. XL446 was transferred from Waddington to No 230 OCU at Finningley in December 1967, and then moved with the OCU to Scampton in December 1969. XL446 joined the Akrotiri Wing in July 1972. After its service in NEAF, the aircraft returned with No 35 Sqn to Scampton in January 1975, serving with Nos 617 and 35 Sqns until scrapped in 1982.

16
Vulcan B 2 XJ783 of No 35 Sqn, RAF Scampton, September 1975
Permanent squadron markings were still uncommon when the V-Force switched from gloss to matt camouflage from 3 September 1971 with the issue of Mod 2327. However, they began to appear again from about 1972, when Waddington's aircraft started to carry the Lincoln shield on their fins and a handful of OCU aircraft were adorned with badges. The Scampton Wing was quick to apply squadron markings, initially in temporary stick-on dayglo, but later painted on. Even as late as September 1975, XJ783 of No 35 Sqn at Scampton still had its squadron identity in dayglo, although the unit's stylised '35' was soon painted in yellow on a black oval background. XJ783 was scrapped in 1982.

17
Vulcan B 2 XL444 of No 617 Sqn, RAF Scampton, mid-1970s
Sometimes known as 'Trouble Four', or, even less affectionately, as the 'Trembling Whore', XL444 had an unenviable reputation among Vulcan groundcrew due to its frequent unserviceability and faults. Early on, all the ECM fuses were reputedly removed after fuel kept on leaking into the ECM bay, and tales of the aircraft's problems are legion. Having been demodified from Blue Steel standards in 1970, XL444 remained with the Scampton Wing until 1981, when it was transferred to Waddington and scrapped the following year. The aircraft was re-painted in matt camouflage in 1976, and was the subject of a famous series of low level air-to-air photographs.

18
Vulcan B 2 XL391 of No 9 Sqn, RAF Waddington, 1976
When XL391 returned from Akrotiri in 1975, it wore the unusual combination of gloss camouflage with toned down red and blue roundels and fin flash. Although relatively common among Akrotiri Wing aircraft, and later adopted by the MRR fleet for corrosion resistance, this combination was unusual among Vulcan bombers. The aircraft is seen here with No 9 Sqn's

famous bat insignia and Waddington's City of Lincoln crest on its tailfin soon after arriving back in the UK. XL391 enjoyed a long and illustrious career, even serving as one of the reserve aircraft for 'Black Buck', with underwing pylons fitted and its underside painted dark sea grey, with all unit markings removed. As the first Vulcan B 2 to be fitted from new with Olympus 301 engines, XL391's delivery was delayed and the aircraft was fitted with 'complete' Skybolt attachment points that were otherwise incorporated in just 16 late-build aircraft (XM597-612). These attachment points were the core feature of all the 'Black Buck' aircraft. XL391 survived to the end of the Vulcan force, being ferried to Blackpool for static display in February 1983. However, salt-laden sea air and vandalism combined to take a terrible toll, and the old lady was scrapped in 2006 – even the cockpit was too far gone to be saved.

19
Vulcan B 2 XL445 of No 230 OCU, RAF Scampton, October 1980
No 230 OCU's XL445 is shown here in the final Vulcan colour scheme, with the camouflage wrapping around to cover the lower surfaces. The old V-bomber medium sea grey was replaced by the dark sea grey used by smaller, tactical fast jets like the Jaguar and Buccaneer. Wraparound camouflage was intended to prevent 'blinking' as the light grey undersides were highlighted against the ground when an aircraft manoeuvred at low level. It was applied to relatively few Vulcans before the type was retired. The aircraft also carries ARI 18228 radar warning receiver equipment in a fin-top fairing. XL445 was returned to No 35 Sqn in July 1981, only to be transferred to No 44 'Rhodesia' Sqn at Waddington that November. The jet subsequently became a K 2 tanker with No 50 Sqn, as shown in profile 24.

20
Vulcan B 2 XM648 of No 101 Sqn, RAF Waddington, May 1982
XM648 was originally delivered to No 9 Sqn in May 1964 and remained with the Coningsby Wing until it moved to Cottesmore. The jet transferred to the Waddington Wing in January 1968 and subsequently served with Nos 101, 44 'Rhodesia' and 9 Sqns – it joined the latter unit in September 1980, and celebrated the Vulcan's 25th anniversary the following year. XM648 was transferred to No 101 Sqn in September 1981, but was withdrawn from service exactly one year later and scrapped at Waddington soon afterwards. The aircraft wears the Lincoln coat of arms on the tailfin and a unit badge consisting of the squadron's lion and turret superimposed on the number '101' in red.

21
Vulcan B 2MRR XH560 of No 27 Sqn, RAF Scampton, 1982
XH560 served as a bomber at Coningsby, Finningley, Cottesmore, Waddington and Akrotiri, before being converted to B 2MRR standards in 1973. The aircraft was delivered to No 27 Sqn in 1974, and was one of five MRRs able to carry ADAM (Airborne Detection And Monitoring) sampling pods under its wings. As a B 2MRR, the jet wore gloss camouflage (for corrosion protection overwater) and did not carry TFR. It served briefly with No 44 Sqn in 1982, before being converted to K 2 standards and issued to No 50 Sqn. After the Vulcan was retired from operational service in 1984, XH560 was retained at Waddington for the VDT, but was scrapped when it was found that XH558 had more airframe hours left before it would require a major overhaul. XH560 was subsequently broken up at Marham in 1985, its nose going to the Cockpit Collection at Rayleigh, in Essex.

22
Vulcan B 2 XM607 of the 'Black Buck' Detachment, RAF Wideawake, Ascension Island, June 1982
The need for the Falklands Vulcans to carry underwing pylons meant that the aircraft had to be selected from the survivors of a pool of 18 Vulcan B 2s that had been fitted with the 'complete' Skybolt attachment points (with double front attachment points, rear attachment point and coolant blister). The lack of tanker support meant that only three Vulcan crews could be trained for 'Black Buck' – one from No 44 Sqn, one from No 50 Sqn and one from No 101 Sqn. Five aircraft were modified, consisting of XL391, XM597, XM598, XM607 and XM612, while XM654 was the trial aircraft for Carousel INS and was not fully modified. XL391 and XM654 remained at Waddington, while XM612 made it to Ascension but flew no missions. XM607 flew 'Black Bucks 1', '2' and '7', and the aborted 'Black Buck 3'. It carried an AN/ALQ-101(V)-10 ECM pod beneath the starboard wing. The 'Black Buck' aircraft wore standard matt camouflage on the uppersurfaces, with dark sea grey undersides. The mission markings shown were applied post-war, and each consists of a stylised bomb falling on a raid-dated Argentine flag. XM607 is preserved at RAF Waddington.

23
Vulcan B 2 XM597 of the 'Black Buck' Detachment, RAF Wideawake, Ascension Island, June 1982
The 'Black Buck' Vulcans wore the same basic colour scheme, and all had their unit and wing badges crudely overpainted. XM597 flew 'Black Bucks 5' and '6', firing Shrike anti-radar missiles carried on twin adaptors against Argentine radar units. XM597 carried and fired two Shrikes during 'Black Buck 5', and carried four for 'Black Buck 6', firing two 'in anger'. The aircraft is seen here as it appeared post-war, with mission markings consisting of Argentine flags and missile silhouettes and a Brazilian flag, and carrying a Shrike training round (coloured blue, with no fins) on the underwing pylon. The Brazilian flag marked the aircraft's unscheduled visit to Rio de Janeiro after 'Black Buck 6', when its refuelling probe tip broke as it attempted to refuel. The aircraft has been fitted with an L-band jammer aerial in place of the forward Red Shrimp aerial. In December 1982 XM597 was transferred to No 50 Sqn, with whom it served until April 1984 – one of three standard bombers augmenting the squadron's dedicated K 2 tankers. The aircraft was then delivered to the Scottish National Museum of Flight at East Fortune Airfield, in Lothian, Scotland.

24
Vulcan K 2 XL445 of No 50 Sqn, RAF Waddington, 1983
The former Blue Steel carrier XL445, depicted in profile 19, moved from the OCU to Nos 35 and 44 Sqns, before returning to Woodford in May 1982 for conversion to K 2 tanker standards. The aircraft was delivered to No 50 Sqn in July 1982. It was one of the few K 2s to boast wraparound camouflage, against which the tanker white trailing edges and centre section 'stripe' stood out exceptionally well. In March 1984 XL445 was flown to Lyneham for crash rescue training. The nose section was saved when the aircraft was scrapped, and it is preserved by the Blyth Valley Aviation Collection at Walpole, in Suffolk.

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