



The Vulcan returns

Live long and prosper

Getting Avro Vulcan XH558 airborne after a period of 15 years represented one of the aerospace industry's most challenging restoration projects to date. **RICHARD WARRILOW** reports.

For countless aviation enthusiasts and for many individuals working in the aerospace industry, the highlight of last year was the return to air displays of Avro Vulcan XH558 — some 15 years after its supposed 'final flight' and following an extensive restoration.

The funding aspects of the project which returned XH558 to the skies received much media attention at the time and rightly so, as lack of funds almost terminated the project on a number of occasions. But this (necessary) attention distracted somewhat from the remarkable restoration project itself; which required the co-operation of many companies and organisations, the dedication of countless individuals, and engineering skills and disciplines spanning several decades.

Feasibility Study

XH558 was, in 1960, the first of the Mark II Vulcans to enter the RAF's service — where it was to operate until the RAF's Vulcan Squadrons disbanded in 1984. It then became an RAF display Vulcan, operating out of Waddington in Lincolnshire.

This life ended in 1993 though when the aircraft, by then the last remaining flying Vulcan, needed a major service in order to remain flight-worthy.

The Vulcan was subsequently sold to C. Walton Ltd, renowned for its collection of Cold War aircraft and based in Bruntingthorpe in Leicestershire. C. Walton Ltd also purchased 600 tonnes of Vulcan spares, among which were eight fully-serviced (but with zero flying time) Rolls-Royce Olympus 202 engines without which a return to flight project would have been impossible.

XH558 flew into Bruntingthorpe on 23 March 1993 and took up residency as a museum piece — which occasionally did taxiing runs. In 1997, Dr Robert Fleming, then Technical Director for Northern Europe with Cisco Systems (and an avid Vulcan enthusiast), approached David Walton with a proposal to form a small team of volunteer experts to conduct a feasibility study into returning the aircraft to flight.

Dr Fleming, now Chief Executive of the Vulcan To The Sky

Trust (see later), recalls: "It was very much a theoretical paperwork exercise into establishing that a project to return XH558 to flight was feasible. It covered such aspects as spares, documentation, fatigue life, a safety review, CAA regulations and risk assessments." One challenge Dr Fleming faced though was giving the study 'credibility', and satisfying both BAE Systems (as the successor organisation to A.V. Roe) and the Civil Aviation Authority (CAA) that it was being done by a sufficiently technical and experienced team. The feasibility study, largely undertaken in evenings and at weekends, lasted for approximately two years, during which time XH558 continued to do occasional taxiing runs.

Another challenge, and one that was to make history, was that the restoration to flight (in civilian hands) of the Vulcan Bomber would be the first ex-military aircraft to fly that was classified as 'Complex' by the CAA. Dr Fleming explains. "The CAA categorises ex-military aircraft as either Simple, Intermediate or Complex. Simple aircraft include the Spitfire and

Hurricane, so single engine piston aircraft with manual flight controls. Intermediate includes multiple piston and turbine powered aircraft with perhaps power-assisted flight controls, so are slightly more demanding. Complex aircraft have, for example, no manual reversion on flight controls, and more advanced systems."

Restorations of Complex aircraft (to flight) demand the contractual involvement of the original constructor (i.e. BAE Systems) as well as the manufacturers of all the flight safety-critical components, including, for the Vulcan, Rolls-Royce for engines, GE Aviation Systems (formerly Smiths Aerospace, before that Dowty Aerospace and before that Boulton-Paul) for the Powered Flying Control Units, and about a dozen other companies.

In May 1999, board members of BAE Systems agreed to support the project, marking the successful achievement of the first milestone in the return of XH558 to flight. However, while pledging its continued support, BAE Systems indicated that resource constraints prevented it from being the

Engineering Authority moving forward.

"Following discussions with BAE Systems, Marshall Aerospace was approached and agreed to be the Engineering Authority on the restoration project," continues Dr Fleming, "as it, perhaps uniquely in the UK, has the capability and the engineering experience to take on the role. The CAA endorsed this strategy."

The first joint activities included a Project Definition Workshop in September 1999 to decide on what needed to be done to return the aircraft to an airworthy condition, and a Technical Survey on the aircraft, which began in November 1999, to ensure there were no technical show-stoppers. It was also in 1999 that The Vulcan Operating Company (TVOC) was formed. Initially this was just a 'label' for a number of C. Walton Ltd employees, but it later became a formal business.

The Millennium Vulcan

A few months into the new century, and the Technical Survey had reached its conclusion: XH558 could be restored to flight, under an approved and well-controlled project — and at a cost of £3.5m. Fund-raising began in earnest as did a 'soft start' to the restoration project, which involved gaining the necessary approvals from the CAA and the removal of components for assessment prior to overhaul.

Steve Rogers, XH558 project manager with Marshall Aerospace, picks up the story. "TVOC had done a great job identifying the original manufacturers, or their 'descendant companies', of many of the aircraft's component and sub-assemblies. During the first few years of the restoration, these parts were dispatched, almost piecemeal, for assessment — which many of the companies did for free."

The soft start (component/systems restorations and fund-raising activities continued in parallel for several years, the former at the pace of the manufacturers and the latter boosted by the formation of Vulcan To The Sky Trust (VTST), a registered charity. In mid-2004 the receipt of Heritage Lottery Funding (almost £3m), in conjunction with partnership support, gave the project a new lease of life; and in March 2005 the project was officially re-launched with VTST purchasing XH558 — plus the spares, documentation and specialist tooling — for the nation.

Rogers: "Because of its time out of service, the Project Definition Workshop had recommended an enhanced structural and electrical inspection, in addition to the major service which had effectively grounded the aircraft in 1993.

In many respects, 2005 marked the start of the 'all-out' restoration of XH558, and for many it also meant 'back to school'. One student was John 'JJ' Boyle, Marshall Aerospace lead technician for the Vulcan. He comments: "Training took place in two phases, firstly to gain a basic understanding of the aircraft and then to a more in-depth level — these were equivalent to ATA 104 levels 1 and 3."

Boyle goes on to say that, for a restoration, some of the procedures could arguably have been slackened; but it had been agreed with the CAA that, wherever possible, all training, maintenance, engineering, inspection, testing and sign-off procedures would be as per Marshall Aerospace Standard Procedures (in its capacity as the Engineering Authority).

The training course material, including exam papers, needed to be not only resurrected (after a period of more than 12 years) but also re-written, to meet the unique requirements of the restoration. Boyle recalls other key aspects: "A major [RAF] service would have utilised about 40 technicians. We were a team of 15, roughly sharing all airframe, engine, electrical and mechanical duties between us — plus we weren't doing just a service."

Let Battle Commence

For the restoration work the hangar at Bruntingthorpe was turned into a CAA-approved workshop, with bonded parts stores and all the necessary procedures in place for controlling work on a flying aircraft. Rogers adds: "Bruntingthorpe was effectively turned into a satellite operation, with computer links to Marshall Aerospace in Cambridge." This gave those on site direct access to resources such as the Aircraft Design Office (ADO); Engineering; Production Planning; Quality Assurance and Supplier Management.

One task which drew on several of these resources was the strengthening of the wing spars under 'Modification 2222'. Done to extend fatigue life, this mod' (dubbed "four twos") would have been part of the service due in 1993 and required the fitting of four steel plates; used in pairs to sandwich and strengthen the joints where the bottom of the rear wing spar attaches to the centre section of the aircraft. Rogers: "Although the basic design had been developed by BAE Systems, planning had to be created and tooling and parts manufactured, plus, during the work, specialist aircraft trestles were required to



The world's only airworthy Vulcan, XH558. Main photo left: XH558 begins its first post-restoration flight on 18 October 2007.

reduce the load on the remaining joints."

But perhaps the largest drain on resources was dealing with unexpected corrosion. The detailed survey had confirmed that, in general, the airframe was in excellent condition — a testimony to the way it was originally designed and built. However, some significant corrosion was found in the wing above the undercarriage bays. Boyle comments: "And this needed the removal of the top skins for further investigation. The picture was far worse than expected, and many stringers were in a very poor state."

While some stringers could be surface-treated many required the removal of sections and the splicing in of new material. However, the technicians were restricted by the limitations of a Structural Repair Manual (SRM) on not only how many repairs could be made to any one stringer but also how many repairs could be present on adjacent stringers. In order to avoid programme delays, a night shift was introduced to get the work completed.

Systems

The restoration of XH558 also included much electrical work — and again there were a few discrepancies (between drawings and actual) with which to contend. For example, during its life XH558 had operated as a tanker, and a number of undocumented circuits used for test purposes were discovered. Also, during its 'taxiing only' years [1993 to 1999] a number of electrical repairs had been made — repairs which did not need to be as 'strict' as for an airworthy aircraft.

"Surprises aside, the electricians had a hard time on the aircraft anyway," adds Boyle, "as the ease of replacing cables was not a design consideration all those decades ago, so terminal breaks were seldom in the best places, if used at all. Similar challenges faced those working on hydraulics, and I'm sure parts of the aircraft were actually built around some pipes."

As for aircraft systems, as the restoration got underway, it was agreed to remove or deactivate 47 systems not required for display purposes. These systems ranged

Marshall and the Vulcan

Marshall Aerospace's relationship with the Vulcan dates back to the 1970s, when the company was commissioned by Rolls-Royce to design and manufacture two air intakes — one for ground and one for flight testing. Commenting on the restoration of XH558, Michael Marshall, Chairman of Marshall Aerospace, said: "I am proud of the important contribution we made and which enabled the Vulcan to return to flight. In many ways it was an extremely challenging project, in terms of sourcing the necessary parts and utilising modern materials, plus all the complexities of working on an aircraft which is almost 50 years old. We're delighted that the project was a success and that the aeroplane was able to thrill so many people at various air displays during 2008."



Left: Back to school: Technicians from TVOC and Marshall Aerospace spend an intensive two months learning about the Mark II Vulcan, using revamped training material (based on material which would have been written in 1950s). Second and third left: Mod' 2222 ("four twos") was part of the major service due in 1993. This mod' sees the fitting of four elongated steel plates, one of which is shown above (left), to supplement the original (and much shorter) two-hole, figure of 8 shackle joints used to secure the wings to the fuselage. On the right, we see finished mod'. Right: Work on the XH558 frequently required working in confined spaces. Above, a technician squeezes his way into the leading edge of the Vulcan's wing — inside which he will work.

from simple ones, like ration heaters (which were easily removed), to the autopilot (and other complex systems) which needed to be deactivated — as their removal might have compromised aircraft integrity elsewhere. This work also included the removal of the large radar scanner in the aircraft nose and it was necessary to then use ballast to retain the aircraft's centre of gravity.

Further, for some systems, complete overhaul was impractical or impossible. For example, the military flight system (MFS — comprising compasses, gyros, attitude displays and so on) proved prohibitively expensive to refit with like-for-like parts. In such cases it was decided to employ modern commercially available solutions, which nevertheless had to be integrated into the Vulcan.

But restoring the aircraft functions of yesteryear, using either like-for-like parts or equivalents, was only part of the systems challenge. For example, the CAA required that the aircraft meet many modern certification requirements, and it was necessary to upgrade radios, add a Mode S transponder (a Garmin 330, which

pings out aircraft information for 'friend or foe' purposes) a Global Positioning System (GPS), Distance Measurement Equipment (DME) and an Altitude Alerter.

The requirement for a Traffic Collision Avoidance System (TCAS) was also considered but fortunately this was not required by the CAA. Rogers notes: "All these design changes needed to be agreed with the CAA, and the great support provided by them definitely contributed to the success of the restoration of XH558."

Then or Never

As a project, the restoration of XH558 was a remarkable feat of engineering — and this article has only had scope to mention some of its aspects. More than anything else though, there is a general opinion held by all involved in the project that the timing for XH558's restoration was just right. Dr Pleming: "Any later and the right people may not have been available, and as it was many individuals were called out of retirement."

Also, as a project, it was a mix of bad and good luck. Bad luck included the extent of the corrosion. But good luck included

Keep XH558 Flying

The restoration of XH558 to an airworthy condition is a remarkable story, and testimony to the dedication of numerous individuals and generosity of several companies. However, while XH558 has a permit to fly, and the restoration work included extending its fatigue life for several years, to keep this unique aircraft flying requires significant funding.

There are many ways in which you can help make this possible, including donations, corporate sponsorship and/or purchasing items (such as a number of DVDs which document the restoration project) from the Vulcan To The Sky Trust at:

www.tvoc.co.uk

the finding of a complete cockpit air-conditioning unit (all crated and in superb condition) and a Goodrich test set, used for checking hydraulic components. This latter item had been earmarked for scrapping and was literally rescued from a skip days before collection.

No restoration of an aircraft the size and complexity of the Vulcan had been attempted before, and may never be attempted again. Today, XH558 is the only flight-worthy Vulcan in the world, thanks to the enthusiasm and drive of countless people and the generosity of companies and the public.

Rogers: "Because of the number of companies involved, and voluntary nature of much of the work, it would be hard to put a total number of man-hours to the restoration of XH558. At Marshall Aerospace we recorded about 22,000 production hours and about 40,000 engineering hours but we suspect actual was higher than recorded. To this needs to be added the enormous amount of work done by the TVOC team and by all suppliers."

And was it all worth it? Dr Pleming answers: "Absolutely. The United Kingdom has much to thank the Vulcan for. It protected us during the Cold War and it served this country during the Falklands conflict. It's also a remarkable piece of engineering, considering only 11 years separate the first flight of the Lancaster and the Vulcan — and its

distinctive delta wing shape was of course 'stretched' to give us Concorde. ♦

The discovery of significant corrosion in the [wing] undercarriage bays warranted the removal of the top skins for further investigation and access to several stringers for repair.



From the Ground Up

On 18 October 2007, and after a period of some 14 years, G-VLCN (XH558 in its new civilian guise) once again took to the skies — for a flight which lasted 30 minutes. While considerable project management and engineering skills had made this possible the [flight] operational aspects were the responsibility of Iain Young, Marshall Aerospace's chief test pilot, who comments: "The CAA rules that flight testing of any aircraft be carried out by an approved company, so that came down to us too, and often not recognised is the volume of background work done."

As Bruntingthorpe is not a licensed airfield, it was necessary to create a sophisticated infrastructure for that 30 minute flight. This included runway surface preparation (clearing and marking) and safeguarding; the presence of fire crews and rescue vehicles; the setting up of a temporary air traffic control; and, due to the high-risk nature of a first flight, the keeping clear of the airspace around Bruntingthorpe.

A further six flights followed before the restoration culminated in the grant of a Permit to Fly by the CAA on 3 July 2008. Upon receipt of the permit (and almost immediately), the aircraft took off for Waddington, to take part in its first post-restoration air show.