

Keep the fire burning

THE ONE AND ONLY FLYING AVRO VULCAN SPENDS HER LIFE PERFORMING AT AIR SHOWS THAT ARE FAR REMOVED FROM THE FAST, HIGH-ALTITUDE RUNS FOR WHICH SHE WAS DESIGNED. AEROSPACE TESTING EXAMINES THE PROJECT THAT RETURNED HER TO THE SKIES AND THE TEST REGIME THAT KEEPS HER THERE

BY RICHARD GOTCH

It was 20 years ago this year that the UK's Ministry of Defence placed an advertisement for the sale of one of the country's most popular aircraft. At its center was a simple black and white drawing of Avro Vulcan XH558 – the last of her type still flying.

She had led a charmed life. When Vulcans were withdrawn in 1984 she had recently received an expensive 'major service', allowing her to fly on for another eight years with the RAF's Vulcan Display Flight. But by 1992, another major service was due, as well as a costly modification to the rear spar – substantial expenses that the RAF was not able to justify in a financial climate where they were expected to show 'peace dividend' savings from the end of the Cold War. So the advertisement was placed, and in March 1993 she was delivered to her new private owners, C Walton Ltd, at the company's Bruntingthorpe Aerodrome in Leicestershire, UK.

In a separate and remarkably visionary transaction, the company also acquired the RAF's entire stock of Vulcan spares – around 16,000 line items weighing more than 600 metric tons – hoping that one day, it would be possible to return XH558 to the skies.

Most complex project

The return-to-flight project began in 1997 when David Walton met Dr Robert Fleming, an experienced technical manager looking for a new challenge. It was immediately apparent that the project would be uniquely complex. In addition to the technical challenges, the team would require the cooperation of well over 100 companies that had manufactured thousands of systems and components for the aircraft. They would also have to persuade the UK's Civil Aviation Authority to issue a permit to fly: something that had never been achieved for an ex-military aircraft of this power, weight, and complexity.

Testing was central to the renovation project, which began with a detailed inspection, removing almost everything that could be removed. Every aspect of the aircraft's structure was inspected visually and various non-destructive techniques were employed to reveal any hidden problems. More than 450 x-ray images were taken and numerous minor faults were found and repaired.

Even mundane components received rigorous inspection and renewal. Many miles of pipes and hoses that passed through inaccessible places were taken out, cleaned, visually examined, leak tested then refitted or replaced. The Vulcan has many critical systems powered by electricity so all critical wiring was replaced. Other wiring was checked inch-by-inch for embrittlement, chafing, and other damage to ensure there would be no in-air surprises.

"The energy put into this by everyone was remarkable," says Robert Fleming, who was leading the project as chief executive of the charity Vulcan to the Sky Trust, which had been created to buy the aircraft for the nation.

Many systems were sent back to their original manufacturers for expert refurbishment using original drawings and specifications. Often this provided a worthwhile apprentice training program and introduced a new

"Surprisingly, civilian life can be harder than military service"

generation to the precision and regulated working practices of aerospace engineering – a contribution to the future of engineering that the charity is keen to continue developing.

Early in 2007, the team was ready to start bringing XH558 back to life. Electrical power was applied, starting with 24V DC, followed by 200V 400Hz three-phase AC. One by one, the various systems were put through RAF-documented test procedures to ensure correct setup and operation.

"Everything we do is based on proven RAF procedures and test regimes that were carefully developed and enhanced throughout the aircraft type's 28-year service life," explains Fleming. "The test phase went reassuringly smoothly, but it would be wrong to imply that there were no problems – after all, that is what testing is all about. A couple of the faults were spectacular, both arising from component failures in the 3000psi hydraulics. But all of them were fixed and we eventually achieved sign-off for each of the critical systems."

Finally, after 26 months of hard work by staff and contractors totalling more than 100,000 man-hours, Avro Vulcan XH558 was ready to fly. On Thursday, October 18, 2007, there were clear blue skies above an expectant audience. "She roared down the runway, lifted her nose wheel and soared into the air," says Fleming. After a 30-minute flight, the crew brought the world's only airworthy Vulcan back to the airfield for a perfect landing.

Maintenance and test

Today, XH558 is well into her fifth display season. This year will be particularly special as it combines the 60th anniversary of the prototype Vulcan's maiden flight with the Diamond Jubilee of Her Majesty Queen Elizabeth II (although the aircraft's part in this had to be canceled, see *Broken Arrow*) and the 30th anniversary of the only time that a Vulcan was used in anger: the remarkable 8,000-mile Black Buck raid on the runway at Port Stanley during the Falklands Conflict. The captain on that famous flight, Martin Withers DFC, is now chief pilot with Vulcan to the Sky Trust.

Broken arrow

Two of the engines of the Vulcan, which failed to take off in a test run at the end of May, are beyond repair. The aircraft experienced engine problems and smoke was seen pouring out of the XH558 bomber with debris covering the runway. A statement from Vulcan says that the last flying Vulcan's Jubilee programmed flights will have to be called off: "The technical team has investigated the engine damage on XH558 to determine its cause and to start assessing the timescale and cost of rectification.

"We have already established both engines, on the port side are sadly beyond repair, both having suffered blade damage and the effect of excessive heat. The primary cause of the damage has been determined to be ingestion of silica gel desiccant bags. The most likely event was that material was ingested by one engine, which surged and suffered LP compressor blade failure. Debris was then sucked into number two, which then also failed."

Flying your name

The biggest challenge for Vulcan to the Sky Trust is not technical, it's financial. Maintaining and operating XH558 costs around £2 million (US\$3 million) a year, which comes from a mix of commercial activities, corporate sponsorship, and public support. To learn more about the Avro Vulcan and how to support the last flying example, visit www.vulcantothesky.org, where you can also find out where to see her flying and register for email newsletters.

XH558 has successfully completed her pre-season test flight following the most extensive service since her return to the skies. "Some of the systems that were renewed during the restoration had reached the end of their five-year installed service life," explains technical director Andrew Edmondson. "Safety-critical items such as the ejection seats must be sent back to their suppliers for specialist testing and maintenance every year, and some extremely costly items such as the brake parachutes must be replaced."

Surprisingly, civilian life can be harder than military service. During Cold War peace-keeping duties, the Vulcan's typical mission profile created few worries for those monitoring her fatigue life. "She was designed to cruise at constant speed and high altitude, traveling continents on the way to her target," says Edmondson. "Today, her Permit to Fly is for Visual Flight Rules, which means she must fly much lower, where the air is less stable. Even more demanding is the change in her mission profile, which is now typically only a few hundred miles and involves delivering an air display, with regular transient accelerations in all axes."

Working closely with the engineering team, the flight crew has learned to deliver a visually and aurally dramatic display while minimizing stresses on the engine and airframe, but the need for rigorous testing remains paramount. "We are very proud that thorough testing and maintenance has

delivered safety and reliability that outstrips many modern military jets," says Edmondson.

Non-destructive

The most sophisticated element of the test program is the extensive non-destructive testing (NDT), which includes x-ray, dye penetrant, eddy current, and ultrasonic techniques. X-rays are taken at night when the hangar is empty to minimize unnecessary risks to personnel as each exposure involves a dose equivalent to 50 chest x-rays. The position on the airframe of each film, the strength and duration of each exposure, are all specified by the RAF procedures adopted by the charity.

Preparation for NDT is also defined in procedures. XH558 spends much of the week prior to the NDT program with daylight under her wheels – not flying, but carefully suspended on jacks so that her wings deflect the appropriate amount to reproduce the effect of flight stresses and reveal any potential problems. Even lowering the aircraft from her jacks onto the undercarriage is a sophisticated process, carried out slowly to avoid any over-stressing of the structure.

New test technology is employed where appropriate. Borescopes are used to check for corrosion or loose rivets inside sealed areas, such as the internals of the Olympus engines, and digital recordings are made to enable repeated study of critical areas, as well as to provide an auditable record of the procedure.

"The procedures to which we work must comply with the current, extremely rigorous standards set by the CAA, as well as meeting the requirements of the highly professional design authorities, whose support is vital in allowing us to fly a complex ex-military aircraft," concludes Fleming. "We are now starting to think about how we can combine these skills with the excitement of a living, breather delta-winged aircraft to enthuse young people with a passion for engineering and to provide training throughout their careers." ■

Richard Gotch is spokesperson for Vulcan to the Sky Trust based in the UK

Servicing of jet pipe on Vulcan XH558

