MACH 2

Concorde magazine

FOCUS ON ENGINEERING

Concorde operations through the decades

Concorde Watch

Life under lockdown

Issue 26
May 2020

Introduction

Keeping Concorde in operation – from the first flights of the prototypes to the final journeys of the fleet aircraft – was both an awesome achievement and a monumental feat of aero engineering. In this issue we look at the British engineering operations, from the earliest flights to the end of British Airways services. Three of the engineers who made these Concorde flights possible recall the challenges and triumphs of their work.

The current COVID-19 crisis has affected communities all over the world. The specialists and volunteers who take care of the Concordes are no exception. The museums are currently closed to visitors, but in Concorde Watch we bring you a brief update on each of the aircraft, together with information on fund-raising drives for G-BBDG and G-BOAF.

Very best wishes to all the Concorde maintenance teams, all of Mach 2's readers, and your families – please stay safe, wherever you are.

In this issue

Editor: Katie John

Cover: Concorde undergoing maintenance.
Photo: Stephen Payne

A Technical Triumph

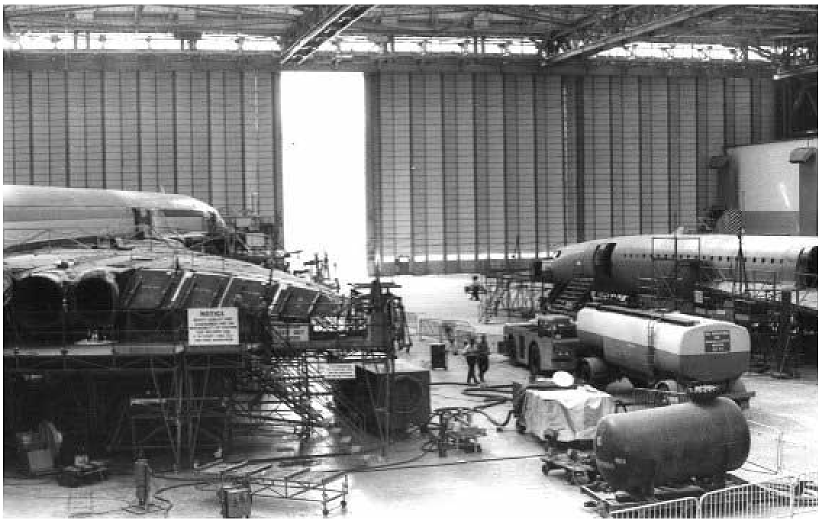
To help counteract the passage of time in recording this history, British Airways Concorde engineer Pete Comport asked John Dunlevy (BA Concorde avionics engineer) and David Macdonald (BA Concorde flight engineer), both intimately involved in the Concorde story, for their reminiscences. The three engineers share their thoughts here.

24-hour operation
Above and left: The Concorde engineering teams worked around the clock to ensure that the next day's flights would leave on time.
Photos: Peter Ugle

Manufacture and testing

John Dunlevy, BA Concorde avionics engineer

My introduction to Concorde took place in September 1965, on starting my apprenticeship as an aircraft electrical technician with the Bristol Aeroplane Company, Filton (before the amalgamation of all the British Aircraft Companies to form the British Aircraft Corporation – BAC).



Brabazon hangar, Filton
Concordes under construction, 1971: G-AXDN (left) is structurally complete; G-BBDG (right) is being assembled.
Photo: Christian Julius (with thanks to the Julius family for permission to use)

The Filton complex

The first components for the manufacture of prototype 002 had arrived (several fuselage sections) and been placed in the purpose-made jig constructed and positioned in the large centre bay of the Brabazon hangar.

Around the Filton complex were dotted various test sites, such as wind tunnel, fuel test rig, fuselage thermal test specimens, and the chicken cannon! This was a rather large gun barrel powered by compressed air rather than gunpowder, with the ability to simulate bird strikes onto various materials at supersonic speeds.

The fuel test rig (a full-size layout of the fuel tanks within the Concorde wing shape and tail) was an amazing structure. Driven by hydraulic power, it could simulate all manner of flight conditions. It could also create almost boiling fuel during the hot fuel tests (simulating heat soak at Mach 2). All was controlled from a watertight/fuel-tight control room. It was one of the most disturbing and awesome devices I have ever encountered. When venturing out to work on the rig, you signed a possible 'death by drowning in fuel/water' manifest and left your identity tag on the appropriate hook. Work was carried out with the thing live and pumping kerosene everywhere – hopefully not into the tank that you were working in. Witnessing an adjacent tank to the one you were working inside filling with fuel (through porthole-type observation windows) was a daily, disturbing event that became the norm. In an emergency (possible fire and ensuing explosion), the building housing the rig could be completely filled with thousands of gallons of water. Escape plan to avoid drowning was less than 2 minutes from klaxon sounding. Thankfully my career in flight test continued!

Wooden mock-ups were plentiful around the complex, from a full-size aircraft to a droop nose and engines, all to help with the final design, testing and trial fitting of components for production.

Machine shops were equipped with the latest technology of the time (punched tapes), which enabled the automatic machining of intricate panels and structures from solid billets of aluminium.

Foremen were locally in charge of the various engineering sections, and departments were overseen by production managers. Quality control and inspection was carried out to civil aircraft regulations.

The joint project between Britain and France was to be carried out under the Official Secrets Act, and complicated parts and drawing numbers were devised to confuse any spies.

The flight test aircraft

Concorde prototypes 001 and 002 were test aircraft used to discover the basic handling qualities and performance up to Mach 2. In the process, information from the instruments, covering many hundreds of parameters, was recorded and stored using data and tape recorders.

The construction of the prototypes was a real learning curve as so many complex issues had to be solved; modifications were constantly needed to facilitate construction of the prototype and later the pre-production and production models.

Flight testing was shared between the British and French manufacturers, with flight programmes being designed so that there was not too much duplication unless a serious event occurred which needed more detailed investigation.

Fairford

On this side of the channel, RAF Fairford was nominated as the location for the Concorde Flight Test

Rare sighting at Fairford
7 January 1972: French prototype 001 (right) with British prototype 002 (left) and pre-production Concorde 101 (centre), at a publicity event. *Photo: John Dunlevy*

Centre; noise and close proximity to housing, as well as a nasty bump somewhere along the Filton runway, made Filton unsuitable for the demands of testing. Concorde was originally designated a 1–2 year test programme; however, due to the complexities of supersonic flight with a passenger aircraft, the test programme stretched out to 7 years.

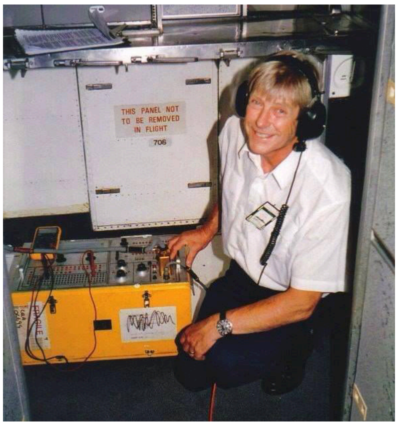
Test flights were carried out to various global destinations (some with extreme climate variations) and, where possible, on routes that would suit future Concorde airline operations.

Fairford, although operating fairly remotely from Filton, had a similar departmental structure regarding management and supervision. Aircraft Engineers (mechanical and electrical) had their own separate workshops; these, together with the Quality Control inspection department, were all housed within a single main flight shed, with the addition of a main store supplying the relevant parts and spares required. The departments for the flight test development personnel (responsible for all the on-board aircraft test equipment), test pilots, and observers were housed in an adjacent complex.

All personnel in all departments were expected to be able to work at high pressure and extremely long hours to achieve the certificate of airworthiness for Concorde.

Flight testing in Tangier
Left: BAC engineers with G-AXDN during flight testing in Tangier, Morocco; John Dunlevy is centre right, holding the ear defenders.
Photo: John Dunlevy

Aerial view
The two prototypes with G-AXDN.
Photo © BAE SYSTEMS



In-service check
Above: John Dunlevy operates the Intake Status Test Set to assess intake performance in Mach 2 cruise.
Photo: John Dunlevy

In-service maintenance

Pete Comport, British Airways Concorde engineer

The ancestral home of BA's Concorde fleet operated out of Centre and North Bay, Technical Block B East (TBBE), with minor operations executed from Centre Bay mezzanine offices.

Concorde Tech

In the 1980s, the Concorde operation (known to the team as Concorde Tech) was a unique organisation within BA Engineering. Some managers regarded it as a short-haul operation for a while, as Concorde spent so little time in the air.

Don Hullah was the first manager, followed by Mike Phillips; both reported to general managers. The foreman took full control of all airworthiness management of the fleet, with the help of an airworthiness clerk on each shift. The airworthiness clerk's role was vital in creating work package tasks from the foreman's airworthiness instructions. The foreman also signed the Certificates of Maintenance (a Civil Aviation Authority Certificate of Airworthiness regulatory requirement), confirming that all maintenance tasks complied with the CAA-approved Maintenance Schedule.

Foremen were rotated: 6 months on Minors, 6 months Major maintenance. Foremen were: #1 shift Don Dixon, Brian Stead; #2 shift Peter Comport, Trevor Leavold; #3 shift "Mooch" Manucchi, Neville Ferguson. Night shift had 2 foremen: Peter Collins, Permanent night shift (PNS) #1; Eddey Helifity, PNS #2.

Planning daily operations

All Concorde flight operations were planned and controlled by the "Minor" Concorde Tech foreman. Operations were planned by whoever was on duty on the early shift, with the next day's aircraft being allocated to individual Concorde registrations in the Maintenance control/Flight operations scheduling systems. The night shift teams were crucial to delivering the operational schedule. The duties of the late shift and the night shift foreman were to execute the plan by continuing to assess each aircraft's airworthiness, and its technical and spares needs, ensuring that the licensed engineers and their teams were given as much time as practicable to get the Concorde ready for its flight.

The early years

Initially, in the late 1970s, the BA Concorde operation consisted of five Concordes; Alpha Fox (G-BOAF) and Alpha Golf (G-BOAG) were still to be inducted into service.

Alpha Golf – initially registered as G-BFKW, a manufacturer's standard production 191 model – was leased from BAC whilst Alpha Charlie was returned to Bristol for wing repair. (See Mach 2, April 2020.) The lease was renewed right up until a major 'mandatory modification lay-off', at which point Her Majesty's Government (AG's owner) would not fund the work. Thus AG sat in limbo. Political tension at the time came close to terminating Concorde operations; this outcome

Work on Alpha Golf
G-BOAG needed extensive work in the early years. Here, she awaits repainting in 1984, after being grounded due to hydraulic system contamination.
Photo: David Gee

was avoided by BAC, Rolls-Royce, HM Government and British Airways agreeing that we would buy the whole UK Concorde business from Government, to include AG and development Concorde G-BBDG.

At that point AG was taken into work; she was parked outside TBB West (TBBW) for a while, until licensed Concorde engineers Keith Leyland and Eric Smith took her on as a separate project to bring her up to BA fleet standard. This was a massive undertaking; it was always virtually impossible to maintain a full set of components, due to constant shortages, hydraulic fluid contamination checks, and rectification needed to restore any breakdown of chemical structure due to inactivity of the system.

After a year or so of operations, the earliest-delivered aircraft be-

Multi-level access
G-BOAF surrounded by the platforms used for major checks. These platforms are in TBA.
Photo: Gordon Roxburgh

Flight delay
G-BOAC returns to the stand due to an intake problem. Engineering carried out preventative maintenance to keep such incidents to a minimum.
Photo: Stephen Payne

came due for the 1,200 flying hour Inter(mediate) maintenance check. These were undertaken in the North Bay, which had been newly modified with trestling and platforms to provide 'access all areas' (although, in fact, the very first may have been completed, using temporary scaffolding, in the Centre Bay).

Concorde Maintenance were particularly pro-active in the early days. Within the first year of service it became apparent that the refuelling operation would best be performed by personnel with a deeper understanding of the system, so the Maintenance team took on the role. Fuel loads would vary between about 40,000 kg (short charter) and a full-tanks figure of 96,000 kg on most westbound trans-atlantics, each load having a specific distribution between the 13 tanks. Particular care had to be taken with tank 11, located at the very rear of the 204-ft fuselage (max capacity 10,500 kg). Note that an aircraft loaded to full tanks, but without baggage and passengers, would adopt a very tail-down attitude – alarming to all but the cognoscenti!

Having taken over the refuelling duties, it was just one further step to set up a satellite Maintenance branch adjacent to Concorde's departure gates – a hut equipped with spares, a company frequency radio and a kettle. The Concorde operation sold speed and time saved; to have a rapid-response team alongside to respond promptly to departure snags was invaluable, likewise the ability for Maintenance and Flight Crew to brief/de-brief before and after each flight.

Maintenance challenges

Keeping to on-time operations was sometimes an exacting task. This was generally due to a combination of complex fault-finding and replacement of parts; naturally, if high numbers of defects were reported, more maintenance time was needed, which inevitably meant that the risk of the aircraft missing its allocated departure time was increased. Priorities were changed, with the engineering teams working together towards getting the next service departure time matched with a serviceable aircraft. Pressure to ensure an on-time departure was significant for all involved, especially as a financial supplement of hundreds of pounds for supersonic travel had to be refunded to passengers if a late departure occurred.

Concorde's maintenance was always challenging technically and logistically, especially so for component supply, as a full set of spares were not always available. Disruption to maintenance was inevitable when shortages of parts occurred; examples might include limited supplies of critical system components such as air cycle machines, flying control components and some avionic equipment, and times when spare engines were not available.

Some components, including instruments, were more taxing to maintain, parts and wear taking their toll on how many spares would be available for continued use. Some parts were actually removed from the operation: see the *Daily Mail* article for 28 March 2011 on the Concorde Mach meter, which was presented to Concorde Tech's Peter Gravestock by the author (https://www.dailymail.co.uk/sciencetech/article-1367575/Concorde-Machmeter-recorded-fastest-flight-London-New-York-goes-auction.html).

Special operations

Charter operations during summer months added more flying hours to the fleet, which inevitably took out maintenance downtime and ran down the clock towards the next major maintenance event. Typically, linking an aircraft to more than one flight – often a charter operation, followed by a scheduled flight – would be planned as flying schedules demanded. Generally, charter operation timings were planned to allow the scheduled services to run on time.

There were occasions when the Concorde team temporarily rescheduled the evening New York flight to depart an hour later, allowing Concorde Tech to do a tarmac turnaround of the first arrival from JFK (arriving 17:30) and send the same aircraft straight back again to night stop, then repeat the same thing the next day, so there would be a New York shuttle of sorts for a week or so.

Logistical demands were inevitably increased as charters operated out of terminal 1; supporting operations with spare parts having to be sourced from Terminal 4 or the engineering base added time pressures to the challenge of keeping Concorde to schedule.

Data and communications

It's worth reminding readers that engineering data management technology/hardware at this time was very basic; computer software was not user-friendly, and stock control and spares availability were not as reliable, so there were times when it was quicker to rob a part needed for a departing aircraft from a Concorde in the hangar.

In my first few months as a foreman in Concorde Tech management, tools were a blank piece of A3 paper, which required you to write each and every maintenance task and any special technical instructions by hand; Microsoft Word wasn't invented then! Fax machines were standard for communications across technical issues, and a Polaroid camera was your only method of creating any imagery of an engineering issue. (It was a Polaroid image of a damaged rudder sent to me by Captain David Leney from Sydney, after an upper rudder delamination event at around Mach 1.7 on deceleration.)

No mobile phones existed, but a walkie-talkie helped, and Concorde Tech was a regular user of VHF RT between flight crews and ourselves.

Technical support was provided by a BAC technical expert, Jim Edwards – a delightful, incredibly knowledgeable gentleman who resided in an office next to the newly created Concorde Inter check dock. Snecma/Rolls-Royce also offered support in the same office. In the early days Doug Foley, another superb engineer, supported maintenance, co-ordinating with engineering system specialists.

Increasing workload

Concorde Engineering undertook preventative maintenance after evaluation of systems and components – especially those that might cause the aircraft to have to return once airborne. These events, though irregular, would often attract the attention of the news media, and as a result a returning Concorde was likely to draw TV coverage. Normally, though, it wasn't unusual for BA's office staff to set their watch by the roar down the runway of four Olympus engines, the distinctive crackle a signature for timeliness!

Concorde's unscheduled maintenance in the 1980s challenged all involved, with the following technical issues requiring resolution on an ongoing basis. As the in-service aircraft passed the test aircraft's flying hours testing thresholds, new maintenance requirements would show themselves.

The following examples illustrate the work needed on various systems.

Intakes

Rear intake ramp vibration at Mach 1.8, generated by a sharp lip: to rectify this a modified rounded lip was developed over time, and temporary revised flight crew procedures were introduced pending modification; the vibration would, however, affect the rear ramp hinge line, with a large unplanned maintenance downtime needed to re-engineer this structure.

Some of the fleet required all of the intake assemblies to be removed, to allow access to rework and rewire all circuits associated with ramp and spill door control; these were complex tasks involving months of downtime for the aircraft.

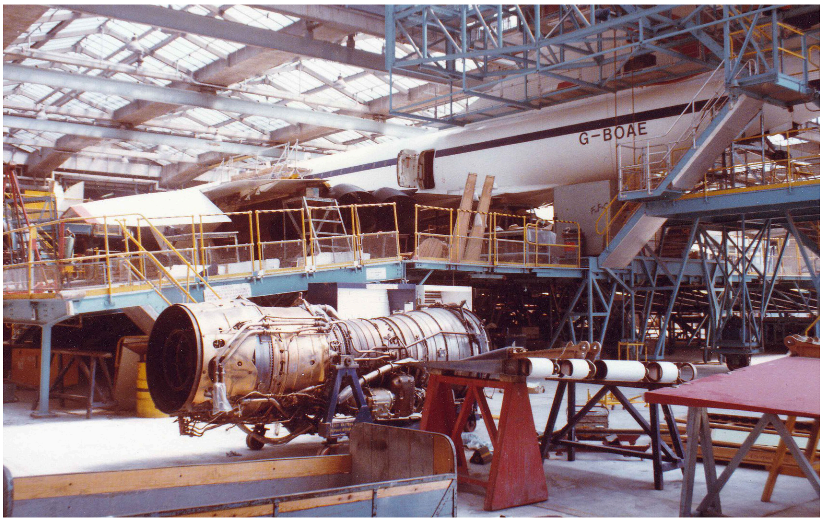
Engines

Two significant issues were:

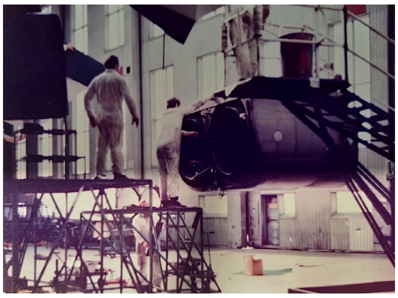
- Engine turbine blade wear, requiring regular boroscope inspections.
- Engine bearing oil leaks, requiring constant monitoring, with detailed spectro analysis of oil to ensure that bearings would not fail in flight.

Engine specialists Mike Davidson and Robin Vidler often called in to Concorde Tech to liaise with the foreman in support of maintaining operations. Nevertheless, engine changes after limited engine run times were inevitable.

Typically, one or two engines (handed odd or even) were available as serviceable spares. Removing (known by Engineering as "robbing") engines from aircraft on routine maintenance was inevitable – remembering, of course, that each engine had its own time-constrained maintenance to be carried out. Every item robbed required the licensed Engineer to certify it as airworthy



Engine change
G-BOAE awaits the replacement of an engine. Each engine had its own maintenance schedule, in addition to that for the aircraft.
Photo: Stephen Payne



Nozzle replacement
January 1982: Following work on G-BOAF, the engine exhaust assembly is lifted into place by crane for re-attachment.
Photo: David Gee

before it could be fitted to a donor aircraft. Engineers worked incredibly hard, diligently removing components across engines to keep them compliant with the approved maintenance schedule. Often, they would be working to meet a flight deadline, achieving all engine change work within an 8-hour shift, which was a true feat of engineering skills.

Airframe and control surfaces

Flying control surface delaminating required regular non-destructive testing and replacement if required, as spare elevons and rudders were not always readily available. The work of Jim Kinross, Specialist Structures Engineer, was crucial to developing, design and testing of the flying control surfaces as well as tertiary aircraft structure (load-bearing structures, such as brackets, webs supporting wing spars, and certain fuselage structures).

Programmes of regular overhaul and preventative maintenance of flying control surfaces (to ensure no further flying control delamination events post Alpha Fox's rudder incident) took priority, with regular testing additional to all flying control surfaces.

Structural modifications supporting flight cycle life extension on both wing and fuselage, requiring great technical skills with cutting-edge technology, were part of the emerging additional workload. These necessitated specialist cold working with structural loading of wings, and this work was undertaken by Keith Leyland and Eric's team.

Air conditioning system

Cabin air conditioning system components worked at high temperatures to maintain passengers and crew in a cabin environment where champagne could be sipped. Air conditioning was a very high-workload system for Maintenance, but never really featured as a system that caused delays or cancellation; a true credit to the design team!

Here was a system that, at Mach 2, with air entering the intakes at about 125° to 130° Centigrade, was compressed and further heated within the engine compressor. It needed two ram air heat exchangers (for the lay reader, a bit like car radiators), a fuel/air heat exchanger and finally a Cold Air Unit; together, these had to drop the incoming air temperature to about minus 10° Centigrade, to circulate between the aircraft skin and the cabin trim as a thermal barrier, before being injected into the cabin through punkah louvres at a balmy 21° Centigrade (70° Fahrenheit) or thereabouts.

(Flight engineer Dave Macdonald comments: To give a clear indication of the system's significance, rainwater seen to be trapped in a double-glazing inter-space in a flight-deck window would begin to simmer at about Mach 1.7 and by Mach 2 it would all boil away. We humans had to be protected from that heat – it was that system that kept us cool … and alive!)

As a comparison, it's worth remembering that the odd fighter jet, with a pilot in a G-suit and oxygen mask, would fly alongside Concorde during Certification of Airworthiness test flights. Engineering expertise kept Concorde passengers safe without any need for oxygen masks or G-suits, whilst flying close to the edge of space for several hours.

Secondary air doors

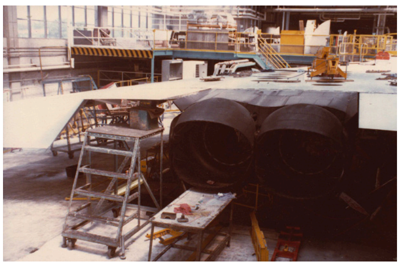
A system malfunction came to light as flying hours of the fleet increased: failures of secondary air doors (an engine cooling and fire containment component) were troublesome to the Concorde operation for a while, as they stopped supersonic flight. A fix was sought, and Concorde engineer Bill Larman developed, designed and helped install a new monitoring system that predicted when the component was likely to prevent a successful supersonic acceleration, doing so by monitoring the motor's current draw; this allowed a plan for preventative maintenance and saved many 'return from airborne' events.

Undercarriage

Another 'return from airborne' troublesome system during winter months (damp and cold ops) was the undercarriage shortening lock micro switch component; should this fail, the landing gear would not retract after take-off. The switch was necessary to avoid damage to the aircraft wing and landing gear if the landing gear failed to shorten. Replacement switches were subject to planned programmes of removal and replacement where possible, to avoid failures in undercarriage retractions.

Hydraulic system

Concorde's hydraulic system has a 4000 psi operating pressure. As aircraft flying time increased, the hydraulic system seals' durability suffered. This issue was brought about by the massive changes in



Elevon repair
Trailing edge of the port wing, showing one elevon removed for repair.
Photo: Stephen Payne

Close work
Left: Engineer Baz Glenister reconnects hydraulic hoses on an outer elevon PFCU. *Photo: Baz Glenister*

Multiple jobs
Right: The engineers would often work on more than one Concorde at a time. *Photo: Peter Ugle*

operating temperature, thus subjecting the system to sub-optimal operating standards. In response, the manufacturers developed a new seal (known as Viton GLT) specially designed for both Mach 2 high-temperature operations and subsonic low-temperature cold soak conditions. Replacement took time, with a preventative maintenance programme that entailed multiple hydraulic component changes, including powered flying control unit (PFCU) relay and feel unit replacements, all requiring leak, rigging and function testing. This was a massive undertaking, challenging all engineers tasked with supplying airworthy Concordes.

Utilisation of aircraft

Selection of aircraft for flight operations required active management of aircraft accumulated flight hours. It was important to maintain similar utilisation of all the aircraft in the fleet; to fail would mean several aircraft needing to be grounded for routine service check maintenance at the same time, and this was not practicable for numerous reasons – not least the fact that Concorde flying schedules would become unstable and we would run out of hangar space.

Some Concordes behaved better than others, so naturally they would be selected more regularly. Invariably the best aircraft for the next flight (the one that returned with few if any in-flight defects) was the one you couldn't select as it would run out of hours and clash with another aircraft's check!

Typically between 3 and 5 aircraft were available for selection to fly operations in the winter months, with an additional aircraft added during the summer months. Long-duration charters such as the world tours, requiring engineering staff support and spares logistics management, all inevitably reduced resources for the daily operations out of Heathrow.

Having any aircraft on routine maintenance meant that the choice of remaining aircraft to fly the daily schedules became limited. For this reason, Concorde's Inter checks were scheduled in the winter months, to help alleviate tight timelines in selecting a serviceable Concorde for any given flight.

'Flying' over the floor
Below: G-BOAE raised on jacks, with the landing gear up and the engine bays open, as the engineers correct a problem with the hydraulics.
Photo: Peter Ugle

Modification programmes

Large-scale modification programmes kicked in during the mid-1980s/early 1990s. These included rework of the flight recording system, mandated following an accident involving flying controls on a US-based airline Airbus; modifications on wing, fuselage and intake structures following some due fatigue testing results; and other life extension programmes.

The rework of the Cabin Mach number indicator feed from the Captain's Mach number to the Marilake cabin display system took place in this era. This system offered

Replacement landing gear
August 2003: The last ever landing gear change on G-BOAG. The gear from Alpha Golf is now fitted to G-BBDG, at Brooklands Museum.
Photo: Peter Ugle

the passengers more detailed information, including Mach number, speed in miles per hour, altitude, outside air temperature, and distance to destination in miles. (This latter information was fed from #3 Inertial Navigation system (INS) and Air Data Computers (ADC).)

Undercarriage overhaul for the early-delivered aircraft kicked in during this time. Limited spare sets of undercarriages inevitably affected downtimes of routine maintenance. Fitting, rigging and testing took significant time, especially if no spare undercarriage was available.

Delays to return of service due to heavy maintenance events impacted on the planning and execution of the daily operation, as other aircraft would have to fly operations. This meant that those other Concordes would rack up flying hours faster towards the 'never-exceed' limit of their own next maintenance event.

The other significant unscheduled workload dictating routine Inter check downtimes was the rectification of fuel leaks. These leaks were large time consumers of manpower, with many engineers spending weeks at a time with heads and bodies buried in fuel tanks.

During conversations with other supersonic (some military) aircraft maintenance engineers, all agreed that supersonic aircraft needed unscheduled fuel tank sealing. Realistically, flying a metal aircraft at Mach 2+, with the high temperatures hardening the fuel tank sealant and the structure expanding and contracting, made it impossible to keep the aircraft as fuel-tight as subsonic aircraft. Needless to say, a logical assessment and repair plan was devised in conjunction with manufacturers and authorities to maintain a safe operation.

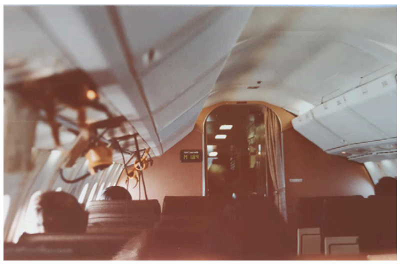
Concorde fuel tanks held almost as much fuel as a Boeing 747; however, getting inside a jumbo wing tank was considerably easier than working in Concorde's wing tanks. Concorde was made even more difficult by structural limitations for tank access. Notwithstanding this issue, leaks of even the most minute levels were not allowed; the consequence of fuel being superheated in front of the intake was not something to be contemplated at all. The truly unsung engineering heroes were the many engineers who spent months inside cramped, smelly fuel tanks on all the fleet, to ensure safe daily operations. There was little glamour in returning home to wives and girlfriends day after day smelling of Concorde fuel!

Naturally modification work following the Air France tragedy in 2000 led to many engineers spending huge amounts of time in fuel tanks fitting special liners.

The end – and beyond

Spares availability continued to be a challenge in later years. Worn-out parts increased with use and age, and this resulted in serviceable spares becoming ever more difficult to source.

The task of keeping Concorde serviceable was rewarded with special tea mugs celebrating 100 departures without any technical delays – remembering that a Concorde delay was anything over 3 minutes late from the published timetable!



Test flight
Post-modification Certification of Airworthiness test flight on G-BOAF, March 1982. *Photo: David Gee*

Dave Macdonald reminded me of the opportunity for engineers to join flight crew on flights across the Atlantic. A unique and truly memorable experience for Concorde engineers, these flights created a learning opportunity for them to see their systems functioning during supersonic flight and appreciate the complexities of operation.

In 2019, the year of the 50th anniversary of the first Concorde flight, the Honourable Company of Air Pilots recognised the entire British Concorde team for a special award (see Mach 2, November 2019). The award was not just for flight and cabin crew; included in the citation were the engineers who built and maintained her. Rather fitting, and a genuine recognition that engineers were very much a part of the Concorde story.

The view from the flight deck

David Macdonald, BA Concorde flight engineer

David Macdonald *ends this feature with an overview of the whole Concorde operation in the UK, from the earliest days to the highlights of Concorde services.*

The Maintenance task was like no other. There had never been an aircraft that flew at twice the speed of sound for hour after hour (although the SR71, the American spy plane, has to be acknowledged; its maintenance crews worked to the same standard).

Concorde is the most thoroughly tested airliner ever. It had to be – it broke so much new ground. The bulk of the nearly 6,000 flight test hours was shared between 2 prototypes, 2 pre-production aircraft and 2 production aircraft. Thus, the maximum number of hours flown by any one aeroplane was only 910 – by aircraft 201, F-WTSB – and of those only 340 were supersonic. And this is perfectly fine; the step-by-step exploration of such an expanded flight envelope was meticulous – as was the preparation for Entry-Into-Service.

Arrival at Heathrow

Concorde Maintenance found a home in a building named 'Technical Block B' (TBB) at the east end of Heathrow. But that hangar wasn't always so named; it was originally 'The Wing Hangar', designed to house the Bristol Britannia 102 and its Bristol Proteus turbo-props. Just the forward fuselage, wings and engines were inside.

The Wing Hangar
Bristol Britannias in the Wing Hangar, 1958. The building accommodated just the wings, engines, and fuselages.
Photo: Mirrorpix / Alamy

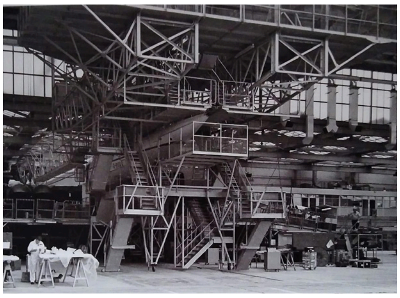
A few years later, following BOAC's investment in the Vickers VC10, the hangar was extended outwards and upwards to accommodate that aircraft's high T-tail and rear-mounted engines – all under cover. Boeing 707 heavy maintenance lodged here during this period. And then came Concorde: it is a pleasing symmetry that TBB's final tenant was the Bristol-designed Concorde 102 and its Bristol Aero-engine Olympus turbo-jets!

TBB was a rectangular building split along its length into 3 bays facing east and 3 facing west. One of the westerlies (North Bay) was fitted out with permanent multi-level platforms that would close in around an aircraft to provide 'access all areas', invaluable for the annual Intermediate Checks and the Major Checks arising after 12,000 flying hours. (See Mach 2, August 2017.)

British Airways operations

Within BA, utilisation gradually built up to about 1,100 hours per year. As our experience grew, it became clear that the BAC and Rolls-Royce Concorde Support Groups, together with BA's Engineering and Maintenance and Flight Ops, were embarking upon what may be called 'in-service development'. This is not unusual; in fact history shows it to be the norm at each step, from biplanes to supersonics. In Brian Trubshaw's book, *Concorde: The Inside Story*, he says, probably tongue-in-cheek, that "the problems with aircraft only arise after airlines take delivery". Or words to that effect.

It must be understood that, during Concorde's Mach 2 supercruise,



Technical Block B
June 1992: G-BOAG surrounded by work platforms in the enlarged hangar.
Photo: Baz Glenister

the whole aeroplane is bathed in a temperature of 125 to 130°C – well above the boiling point of water. Ally to this the ever-present vibrations associated with flight – the ones we don't feel, but Maintenance know are there; throw in a dynamic structure that expands with heat and contracts again during every supersonic flight; and you have the makings of problems – not Concorde problems, but those presented by physics. We learned quickly; special checks were instituted on a range of electrical and hydraulic connectors, cables, seals; engine internal inspections in the hangar and real-time internal assessments in the air, and pragmatic rules for fuel tank sealing, were all part of our life.

An appropriate metaphor for Maintenance would be, 'not so much an A&E; more an ICU department'. Problems were there to be solved, and solved they were. We had the confidence to dispatch aircraft on Royal flights, 4-week luxury world air cruises, and high-profile corporate charters, visiting over 300 airfields worldwide – as well as making Concorde available to the great British public, whose taxes had originally paid for the project.

Concorde watch

The current COVID-19 crisis has led to the closure of visitor attractions in many countries – including all of the museums that house Concorde aircraft. Some museums, though, are still working to take care of the aircraft, and many offer on-line attractions that may appeal to Concorde enthusiasts and their families.

F-WTSS (001)
F-BTSD (213)

French prototype aircraft

French production aircraft

Location: Musée Air et Espace, Le Bourget, France

The website has extensive information in French on their collections, including the two Concordes: https://www.museeairespace.fr/aller-plus-haut/collections/?fwp_halls_dexposition=hall-concorde

The page on Sierra Delta also includes an account of the celebrations for the 40th anniversary of the first Concorde flight, an event put together by Cap Avenir Concorde.

F-WTSS (facing) and F-BTSD
Photo: Alex Beltyukov / Wikimedia Commons
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G-BSST (002)

British prototype aircraft

Location: Fleet Air Arm Museum, Yeovilton, UK

Information on 002 can be seen here: https://www.fleetairarm.com/aviation-museum-concorde.aspx

The Fleet Air Arm Museum is currently working to raise funds to help preserve their collections. Further information is available here: https://www.fleetairarm.com/support-naval-aviation-museum.aspx

G-AXDN (101)

British pre-production aircraft

Location: Imperial War Museum, Duxford, UK

Maintenance tasks are still being carried out on G-AXDN; this includes testing the hydraulic system and lowering and raising the nose.

The British Airliner Collection website offers a Concorde app for 99p, which gives 360° virtual tours of the aircraft, including detailed information and videos: https://www.britairliners.org/airliner-detail?type=aerospatiale-bae-concorde&id=23

F-WTSA (02)

French pre-production aircraft

Location: Musée Delta, Orly, France

There is no maintenance work happening with Sierra Alpha at the moment, but the website is still being updated daily with articles on what has been done so far, and it has plenty of information about the aircraft, in both French and English: https://museedelta.wixsite.com/musee-delta/home

F-WTSB (201) — French development aircraft
F-BVFC (209) — French production aircraft

Location: Aeroscopia Aeronautical Museum, Toulouse, France

The website provides information on the Aeroscopia collection, including the two Concordes, in both French and English: http://www.musee-aeroscopia.fr/en/discover-the-aeroscopia-museum/the-collection/aircrafts

F-BVFC
Photo: Katie John

G-BBDG (202)

British development aircraft

Location: Brooklands Museum, Weybridge, UK

The aircraft in the collection, including G-BBDG, are being inspected daily, and regular maintenance jobs are still being done. In addition, the website provides plenty of information about Concorde and the other exhibits, and there is a page of activities: https://www.brooklandsmuseum.com/concorde

Brooklands has also created free online jigsaw puzzles of Concorde: https://www.brooklandsmuseum.com/learning/family-learning/jigsaw-puzzles

Brooklands is currently facing some financial challenges, made more acute by the current COVID-19 situation. The museum has launched a fund-raising drive to raise money for the upkeep of the collections and the site; for further details or to make a donation, please see their "*Love*BROOKLANDS" page: https://www.brooklandsmuseum.com/about/support-us/lovebrooklands

G-BBDG *Photo: Justin Robson*

G-BOAC (204)

British production aircraft

Location: Runway Visitor Park, Manchester Airport, UK

Information on G-BOAC can be seen on this page: https://www.runwayvisitorpark.co.uk/visit-us/explore-our-aircraft/

The team at the Runway Visitor Park invite visitors to check the website and social media for updates on when the museum will reopen: https://www.runwayvisitorpark.co.uk/whats-on/news-and-alerts/

F-BVFA (205)

French production aircraft

Location: Stephen F. Udvar-Hazy Center, Chantilly, VA, USA

The National Air and Space Museum "Air and Space Anywhere" page offers virtual tours of the museum: https://airandspace.si.edu/anywhere

The museum already has a page giving facts about Concorde and outlining Fox Alpha's history, which can be accessed here: https://airandspace.si.edu/collection-objects/concorde-fox-alpha-air-france/nasm_A20030139000

G-BOAA (206)

British production aircraft

Location: National Museum of Flight, East Fortune, UK

The "Museums at Home" feature has a page on Alpha Alpha: https://www.nms.ac.uk/explore-our-collections/stories/science-and-technology/concorde/

There is also a "Concorde blog", including articles by Concorde pilot Tony Yule, and a post by Ian Brown, Assistant Curator of Aviation, on Alpha Alpha's recent role in the award-winning film *The Wife*: https://blog.nms.ac.uk/tag/concorde/

F-BVFB (207)

French production aircraft

Location: Technik Museum Sinsheim, Germany

The team at Sinsheim has recently given Fox Bravo an internal clean while the museum is closed. Fans of exhibits including Concorde and the Tu-144 are invited to keep in touch via social media. The web page on Fox Bravo can be accessed here: https://sinsheim.technik-museum.de/en/concorde

G-BOAD (210)

British production aircraft

Location: Intrepid Sea, Air and Space museum, New York, USA

The museum website includes virtual tours of aircraft including Concorde. The Intrepid has also instituted an Oral History Project, featuring interviews with people associated with the various aircraft, and including an interview with Concorde Captain Leslie Scott: https://www.intrepidmuseum.org/digital-resources

G-BOAE (212)

British production aircraft

Location: Grantley Adams International Airport, Barbados

The Concorde Experience museum has been closed for some time now, but the Barbados Tourism Board page on the exhibition gives some information on what it includes: https://barbados.org/concorde.htm#.XqTe0i3MzOY

G-BOAG (214)

British production aircraft

Location: Museum of Flight, Seattle, USA

The museum has set up an on-line area called "The Museum At Home", which includes virtual tours, videos, podcasts, and other activities, including features on Alpha Golf: https://pages.museumofflight.org/museum-at-home

G-BOAF (216)

British production aircraft

Location: Aerospace Bristol, Filton, UK

G-BOAF *Photo: Aerospace Bristol*

The museum web page "At Home With Aerospace Bristol" offers videos about the exhibits, including Alpha Fox; an invitation to online reminiscence sessions, including one about Concorde; and suggestions on commemorating Concorde with champagne, cocktails, or afternoon tea. Details are available here: https://aerospacebristol.org/at-home-with-aerospace-bristol

Aerospace Bristol has also launched a "Return to Flight" appeal for donations to help the museum continue their work in preserving their collection: https://aerospacebristol.org