MACH 2

Concorde magazine

Going to extremes

Test flights with G-AXDN

Luxury purchase

Buying a Concorde

Concorde Watch

News from Manchester and Duxford

Issue 30
May 2021

Introduction

For this issue we look back at Concorde's early years in the 1970s – including an important part of the test flight programme, and the entry of the production aircraft into British Airways' fleet.

Former BA flight engineer David Macdonald *gives us an insight into the extraordinary task of buying and test-flying new Concordes for British Airways.*

Concorde avionics engineer John Dunlevy *was involved in the test flights carried out by the British pre-production aircraft G-AXDN to test vital systems such as the digital air intake control system. He recalls his role in the test flight programmes that formed the bulk of G-AXDN's work.*

Lastly, in Concorde Watch, we hear from Heritage Concorde about the maintenance and refurbishment work that they have done on Concordes G-BOAC and G-AXDN to make these aircraft ready for viewing as the museums open to visitors once again.

In this issue

Editor: Katie John

Cover: Concorde G-AXDN appears on display at Farnborough, while painted with the test markings for the ice trials later that year. Photo: The Peter Keating Collection © A Flying History Ltd aflyinghistory.com

Buying a Concorde

For many of us, purchasing a Concorde is the stuff of dreams. For British Airways flight engineer David Macdonald*, however, the dream became a reality. Here, he recalls the process of acquiring a Concorde fresh from the British Aircraft Corporation (BAC) and preparing her for service.*

A bitter-sweet memory
December 1967: The French prototype, 001, is rolled out for the first time, in Toulouse. The hangar wall behind him has the logos of the airlines interested in buying Concorde. By the mid-1970s, though, all of these airlines had pulled out. *Photo: Fonds André Cros, Toulouse / Wikimedia Commons (CC BY-SA 4.0)*

A GENERATION OR TWO AGO, easing into my teens and growing up in Glasgow, in an era when libraries were being opened up, not closed down, I haunted the brand-new, purpose-built example at Cardonald. Twenty minutes' bike-ride away, the library was well stocked and boasted a reading room – long, sloping lecterns and a regular supply of newspapers and magazines, including the weekly issue of *Flight* magazine waiting to be devoured. Those magazines struck a spark; in current jargon, I devised a virtual airline. Eschewing American aircraft, I 'bought' Vickers Vikings for short-haul and Handley-Page Halifaxes for long-haul and cargo. What fun!

Twenty-five years later, January 1976, accompanied by the Flight Manager and Engineering Project Manager, I found myself heading west on the M4 to Filton, home of the British Aircraft Corporation (BAC), to buy a Concorde – for real!

Politics and prestige

This was a bitter-sweet period; the culmination of 13 years of groundbreaking design, development, testing and production resulting in a fully certificated supersonic airliner, but overshadowed by the knowledge that no more Concordes would be built – no 'B' model. And we were about to take ownership of yet another from that stable.

Let me remind you of the two fundamentals that governed every facet of Concorde's life.

One … Concorde was a joint venture, funded entirely by Her Majesty's Government (HMG) and Le Gouvernement de la Cinquième Republique Française.

Two … British Airways and Air France were nationalised businesses. Both countries saw the supersonic transport (SST) project as one of national prestige, national importance; it was to challenge the American hegemony in airliner production. During this period (the latter half of the 1950s), speed was king. That was the justification.

After the Second World War, Government, airlines and manufacturers worked closely together to establish the UK as a major player in civil aviation. Major contracts were issued by HMG to the Bristol Aeroplane Company (later to become part of BAC) and Bristol Aero

Engines (later Bristol Siddeley and then Rolls-Royce) in the UK – and similarly by the French to Sud Aviation and SNECMA.

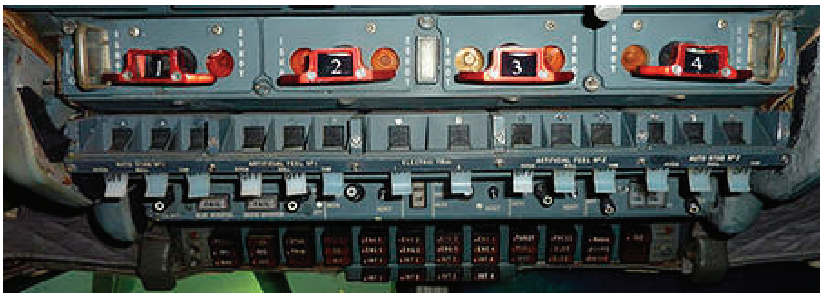
By the time the first Concorde aircraft were being manufactured, in the 1970s, 18 airlines had ordered a total of 74 aircraft. However, a combination of the 1973 fuel crisis (I still have the petrol coupons issued to my Ford Escort Mexico!), the arrival of the first wide-body/ big fan-jet aircraft and a cyclic air travel slump prompted 16 of the airlines to cancel orders, leaving only the British Overseas Airways Corporation (BOAC), soon to become British Airways, with five and Air France with four to enter service, and a potential fleet of five unsold aircraft. This is the background to what, at times, is a fairly convoluted subject.

Pre-purchase checks

The subject of buying a Concorde can be split into two distinct responsibilities: politics and finance, and technical. By January 1976 the politicians and financiers had agreed and signed a contract to purchase; our job was to ensure that each aeroplane, in turn, was 'fit for purchase'.

As each aircraft rolled off the production line it would be subject to manufacturer's engine runs, systems tests, taxy tests and post-production test flight(s), before being offered up, ready for the agreed Operator's Acceptance Checks. (Note that buying 50 or 60 additional aeroplanes from an established supplier, such as Airbus or Boeing, would be quite different – but with an order of just five aircraft of a radically different type, this is how we did it.)

Our programme began with not one, but two flight engineers. The aeroplane was ours for a minimum of two days: hangared, jacked and with all systems powered. A couple of 'minders' from production provided access all areas, keeping a close eye on us and an even closer one on their aeroplane.



Pull in case of fire
The four red Engine Shut Down Handles, located on the forward overhead panel of the flight deck. Each handle was pulled to ensure that the associated valves would close correctly. *Photo: Heritage Concorde*

Working from a pre-planned schedule, our task was to establish that when a flight deck switch, selector or control was operated, the appropriate item(s) of equipment responded correctly.

Example 1: flight control elevons and rudders would be seen to move smoothly in the right directions and to the correct maximum angles in normal and emergency modes.

Example 2: for various engine fault warnings, including engine fire, the associated Engine Shut-Down Handle (ESDH) illuminates red; under these conditions the engine would have to be shut down and a further 10 valves closed in order to isolate that engine bay from fuel, oil and air ingress. A single pull on the ESDH shuts down the engine and closes all associated valves. The acceptance team would physically check that all of those valves did, in fact, run to their shut positions.

Acceptance flights

The technical inspection complete, it was time to drive the machine 'round the block'. Two Acceptance Flights were allocated. At this stage Concorde was still a manufacturer's aircraft; thus, it carried a full flight test crew, supported by systems specialists in the cabin. On most occasions, the Flight Test Director Brian Trubshaw or his deputy John Cochrane would be in command, but with our Flight Manager flying from the left-hand seat and myself at the flight engineer position.

The Flight 1 objective was to fly the aeroplane throughout its normal flight envelope as for a passenger flight, but with one's senses 'tuned to eleven' – asking questions of the aircraft's smoothness, stability and responsiveness both during hand-flying and under autopilot control. Powerplant assessment, for a flight engineer with a grand total of 91 hours' experience, was a bit of a challenge. A turbojet is one thing – adding the wizardry of a variable-area intake at the front and the complexities of reheat and two variable nozzles at the back made one appreciative of the comprehensive technical and operations training from BAC Filton.

Every instrument response, every system performance was assessed and noted. Along the way, and certainly throughout Flight 2, we examined safety systems and exceedance warnings. For example, to test safety systems, all three methods of lowering the nose and visor and the landing gear were tested (main hydraulic power, standby hydraulic power and free-fall by muscle power and gravity) – while low speed, high speed, high altitude, and high attitude exceedances were covered during tests of exceedance warnings. In fact, these elements were very similar to the Certificate of Airworthiness renewal test flights, fully described by Pete Comport in Mach 2 issue no. 12, October 2017.

I recall only two significant question marks arising from accept-

Express delivery
G-BFKW (later re-registered as G-BOAG) was pressed into service with British Airways the very next day after delivery. For the first few months the aircraft wore a temporary livery, seen here.
Photo: Chris McKee flickr.com/people/heathrowjunkie/

ance flights. G-BOAD, at the end of 1976, had a problem with one of the two Automatic Direction Finding systems (ADFs). Ironically, by then these systems were already decades old, but they were still in use: very low-tech 'radio direction finders' using ground-based stations that work in the medium frequency band – the same as for AM broadcasting, as in "Radio Luxembourg broadcasting on 208 metres in the medium wave". (Come on now, readers, you know you remember!)

The second issue involved G-BFKW, later re-named G-BOAG (see Mach 2 Issue 25, February 2020); it was a barely discernible vibration at certain power settings. We needed the aeroplane like tomorrow, on a short-term lease, so we took her – she flew to New York the next morning. It took a while to pin down the source of the buzz to an engine Fuel Control Unit; an interesting saga, but for another time.

Thank you, Filton

The final act plays out in an overcrowded meeting room. There's a tension, punctured only when Director Flight Test announces a successful flight. All that remains is for our Engineering Project Manager to unclip his briefcase, sign, date and annotate the papers with time of day, exchange them across the table and we have one more Concorde,

"It seemed only right to depart with a flourish, a salute to the whole Filton team"

whilst BAC take receipt of another 22.5 million pounds sterling.

Just one responsibility remains. For the first two aircraft we worked from Fairford – the BAC Flight Test Centre – while we flew all of the others from Filton. It seemed only right to depart with a flourish, a salute to the whole Filton team. The grapevine did its job; now it was down to us. With just Heathrow fuel on board, a full-power take-off with reheats burning is sparkling; fly a lowish circuit, then back across the field, height undisclosed – a blur of sound and emotion! Thank you, Filton, we will do our best.

Financial juggling

But that is not all. I will reiterate that one area of Government had funded the UK half of the Concorde project and, reasonably, were looking for some sort of return whilst another department maintained an interest in keeping British Airways profitable. If this was a juggling act, then by 1978 the balls would have been on the floor. As we moved towards the end of the 1970s there were steady improvements in operating surplus as we fine-tuned the American market. It was at this point that HMG made a complete reappraisal. With no likelihood of a successor to curtail Concorde's lifespan, the feasibility of a low-utilisation, market-tailored, long-life operation was investigated: it was the antithesis of standard airline practice, which thrives on 'high utilisation, fly anywhere' until the aircraft are superseded. This resulted in an offer that could not be refused; in the light of North Atlantic predictions HMG went for the long game, seeking to recoup outlay by taking 80% of Concorde surplus for the remainder of Concorde's operational life and, for it to be feasible, cancelling the Concorde debt.

But that is still not all. In the absence of a suitor for any of the five unsold aircraft, we gained permission to buy a sixth under the same terms as for the fleet of five; with the major transfer of ownership already signed by HMG and British Airways, the Engineering Project Manager's briefcase contained only a cheque for £500 and another for 5,000 French francs to cover additional administration. Thus, G-BOAF joined the fleet.

BA takes ownership

But even that is still not all. In May 1979 Margaret Thatcher became British Prime Minister, and her Government embarked on a cost-cutting programme. In one of the ministries they found the Concorde Support Budget.

Upon completion of a manufacturer's test programme, a new aircraft type would be awarded a Type Certificate by the national regulatory authority. Throughout the aircraft's life the manufacturer would maintain a support organisation. This was to be funded by sales of aircraft and spares.

In Concorde's case such funding was part of the contract between HMG and BAC. Notice to reduce such support was issued and hard on the heels, a notice to terminate. This was a bit of a shock – the bottom line was 'no support budget, no type certificate, no operation'.

This bombshell dropped round about the time that British Airways had created the Concorde Division, and promoted the Concorde brand, with Captain Brian Walpole in charge. This was make or break.

Was the Government playing hardball? For sure, but not as a game. Talks were held between British Airways, BAC and Rolls-Royce; meanwhile the Concorde operation continued, with anxious glances cast towards HQ's chimney looking for 'white smoke'.

Finally, word filtered out that the three companies had achieved a tentative way forward. A level of support was agreed, one that satisfied technical and operations requirements and at a funding level to be met by Concorde Division – provided that the 80%/20% profit split could be re-negotiated.

The three company meetings became four as HMG joined in. The outcome was probably better than we had imagined. We bought our way out of the 80/20 profit split, bought the seventh aeroplane, bought G-BBDG, took over HMG's complete Concorde spares holding in the UK and bought our independence – almost – all for a one-off lump-sum payment. We had actually bought the whole UK side of the business. Finally, our future was secure.

How did this new arrangement work? Here is a simple example: some years earlier, a modification to facilitate use of a lowered engine-idle speed in flight was drafted – it was a fuel saving mod., but too expensive to implement. Post agreement, we took the mod. and paid BAC the going rate; they then deducted their share and passed the rest not to Government, but back to us – the new owners.

Virtual Vikings and Halifaxes were much less trouble!

Delivery dates for BA Concordes

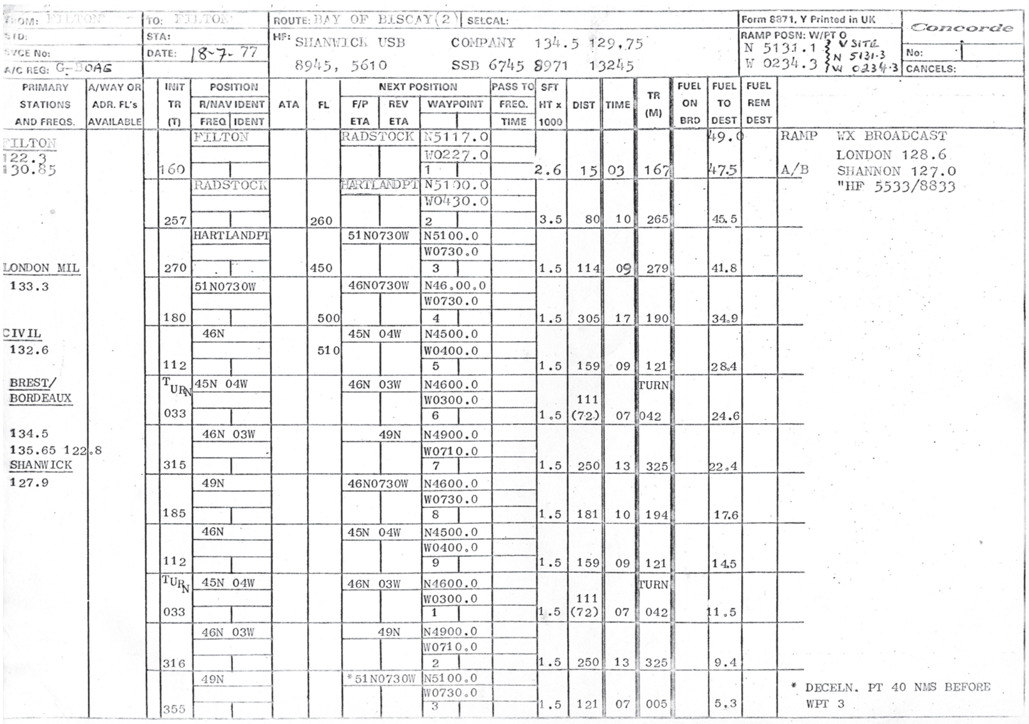
G-BOAA	14 Jan 1976
G-BOAB	30 Sept 1976
G-BOAC	13 Feb 1976
G-BOAD	6 Dec 1976
G-BOAE	20 Jul 1977
G-BOAF	9 Jun 1980
G-BOAG	6 Feb 1980

Official hand-over to British Airways

15 January 1976: the day after her delivery flight from Filton, Concorde G-BOAA is formally signed over to British Airways at North Bay, Technical Block B on the BA engineering base at Heathrow. The next four aircraft would follow in the subsequent 18 months, with G-BOAF and G-BOAG finally joining the fleet in 1980.
Photo: Steve Fitzgerald / Wikimedia Commons (GFDL 1.2)

Acceptance flight for Concorde G-BOAE

Alpha Echo (Concorde no. 212) was delivered to British Airways on 20 July 1977. Here, David Macdonald *shows the flight plan and map for one of the acceptance flights, which took place on 18 July.*



FROM: FILTON | TO: FILTON | ROUTE: BAY OF BISCAY (2) | SELCAL: | Form 8871, Y Printed in UK | Concorde
STD: | STA:
SVCE No: | DATE: 18-7-77 | HF: SHANWICK USB 8945, 5610 | COMPANY 134.5 129.75 SSB 6745 8971 13245 | RAMP POSN: W/PT 0 N 5131.1 W 0234.3 { V SITE N 5131-3 W 0234-3 | No: | CANCELS:
A/C REG: G-BOAE

PRIMARY STATIONS AND FREQS.	A/WAY OR ADR. FL's AVAILABLE	INIT TR (T)	POSITION R/NAV IDENT FREQ IDENT	ATA	FL	NEXT POSITION F/P ETA	NEXT POSITION REV ETA	NEXT POSITION WAYPOINT	PASS TO FREQ. TIME	SFT HT x 1000	DIST	TIME	TR (M)	FUEL ON BRD	FUEL TO DEST	FUEL REM DEST	
FILTON 122.3 130.85		160	FILTON			RADSTOCK		N5117.0 W0227.0 1		2.6	15	03	167		49.0 47.5		RAMP A/B WX BROADCAST LONDON 128.6 SHANNON 127.0 "HF 5533/8833
		257	RADSTOCK		260	HARTLANDPT		N5100.0 W0430.0 2		3.5	80	10	265		45.5		
LONDON MIL 133.3		270	HARTLANDPT		450	51N0730W		N5100.0 W0730.0 3		1.5	114	09	279		41.8		
		180	51N0730W		500	46N0730W		N46.00.0 W0730.0 4		1.5	305	17	190		34.9		
CIVIL 132.6		112	46N		510	45N 04W		N4500.0 W0400.0 5		1.5	159	09	121		28.4		
BREST/ BORDEAUX		TURN 033	45N 04W			46N 03W		N4600.0 W0300.0 6		1.5	111 (72)	07	TURN 042		24.6		
134.5 135.65 122.8 SHANWICK 127.9		315	46N 03W				49N	N4900.0 W0710.0 7		1.5	250	13	325		22.4		
		185	49N			46N0730W		N4600.0 W0730.0 8		1.5	181	10	194		17.6		
		112	46N			45N 04W		N4500.0 W0400.0 9		1.5	159	09	121		14.5		
		TURN 033	45N 04W			46N 03W		N4600.0 W0300.0 1		1.5	111 (72)	07	TURN 042		11.5		
		316	46N 03W				49N	N4900.0 W0710.0 2		1.5	250	13	325		9.4		
		355	49N			*51N0730W		N5100.0 W0730.0 3		1.5	121	07	005		5.3		* DECELN. PT 40 NMS BEFORE WPT 3

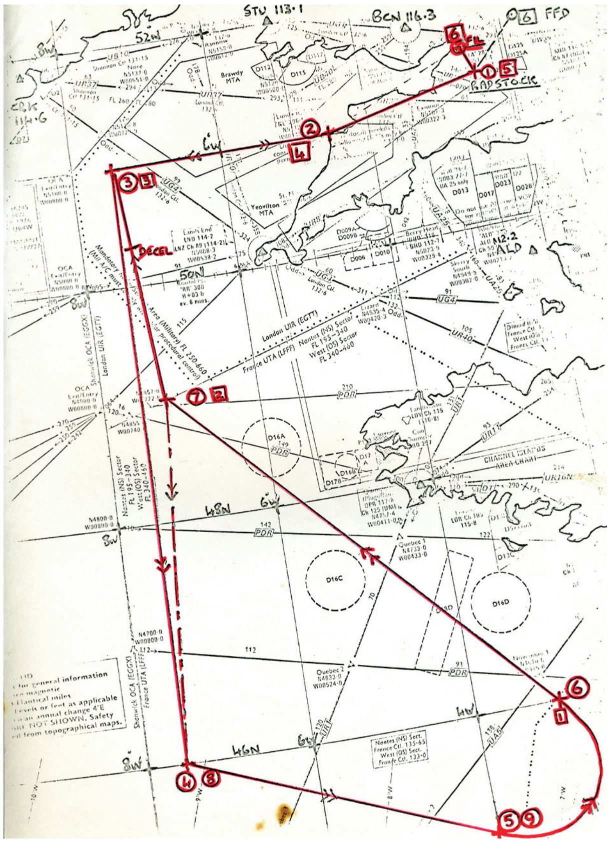
Route plan
The latitude and longitude for each waypoint (marked WPT) are shown under the heading 'NEXT POSITION' and sub-heading 'WAYPOINT'.
Image: David Macdonald

Flight map
The numbers in red on the map below correspond to the waypoint numbers on the flight plan (see left).
Image: David Macdonald

The day of the flight

We flew from Filton to Radstock and on to waypoint (wpt) 2, Hartland Point in north Devon, then to 73West in the Irish Sea, to facilitate a supersonic run down to wpt 4; into the Bay of Biscay to wpts 5 and 6; then north-west to 7 and back south to 8, which is the same geographic location as wpt 4. Similarly, wpt 9 is the same as wpt.5.

The INS display 'memory' can only hold nine waypoints at a time; so, having got to wpt. 9 we have to re-program the INSs, so new wpt 1 is the same as old wpt 6; 2 the same as 7; but new 3 is the same as old 3.



G-BOAE after delivery
18 August 1977: G-BOAE at the start of her life in service.
Photo: AirTeamImages.com

Going to Extremes

In this feature we look at the rigorous test programme carried out with Concorde G-AXDN, which took place over a period of about 15 months. Concorde avionics engineer John Dunlevy *shares his recollections of his involvement with this programme.*

G-AXDN flight test programme 1974–75

8–13 Jan 74	Flight from Fairford to Tangier for engine intake performance trials
26 Mar 74	Second flight to Fairford following modifications to the air intake control systems; setting of speed and altitude records
June 74	Flight to Toulouse to be used for taxy trials to test different water deflectors on the main landing gear
7 Nov 74	Flight from Fairford to Bangor, Maine, USA, for trials of the de-icing system; at 2 hours 56 mins, this sets a speed record for the fastest east-west crossing of the Atlantic Ocean by a commercial airliner
7 Nov 74	Flight from Bangor to Moses Lake in Washington State, at 4 hours 53 mins, sets another record, for fastest east-west crossing of USA
11 Dec 74	Return flight from Moses Lake to Bangor sets another record time for crossing the USA, at 3 hours 50 mins
13 Dec 74	Return from Bangor to Fairford; this flight also takes 2 hours 56 mins
26 Feb–12 Mar 75	Flight from Fairford to Nairobi via Cairo for tropical icing trials

A work-horse on display
September 1974: G-AXDN takes a few days away from the test programme to perform displays at the Farnborough International Air Show. The test markings for the forthcoming ice trials are visible under the canard and the wing, and around the camera mounted under the forward cabin door. *Photo: Steve Fitzgerald / Wikimedia Commons (GFDL 1.2)*

Joining the digital age

The air intake control system is vital to Concorde's functioning, as it slows the air from supersonic to subsonic speed so the engines can ingest it safely. John Dunlevy *was one of the test team working to assess the specially developed digital system during a series of flights from Tangier in Morocco.*

Concorde G-AXDN is a very special airframe indeed. She was built and initially flown minus any intake control system.

The preceding prototype airframes, 001 and 002, were launched with an analogue control system, manufactured by Ultra (a radio valve, transistor and TV company); although the electronic control units were heavy and cumbersome at that time, the aircraft could fly up to Mach 2. However, the system was drastically unrefined in many respects, sometimes requiring close attention when Concorde was flown above Mach 2.

After much deliberation, and with the incoming digital age in sight (plus the realisation that some aircraft manufacturers were already introducing digital equipment), the manufacturers deemed it possible to devise a completely new digital control system that would be less weight and give a more responsive control (see box, page 11).

The system was designed and manufactured in house by the Guided Weapons Department of the British Aircraft Corporation, Filton, Bristol. G-AXDN was flown back from the Fairford Flight Test Centre to Filton during August 1972 for installation of this digital system, together with the new version of the Olympus engine (593 Mk 602), which would be the production engine. In March 1973 she returned to Fairford and re-joined the test programme.

The test base at Tangier

G-AXDN flew to Tangier on two occasions for evaluation and testing of the digital intake control system: first in January 1974 and then, following some further enhancing modifications to the system, returning in March 1974.

Tangier was chosen for its superb long runway, which enabled a direct take-off and unrestricted climb out and over the sea, allowing supersonic flight to commence early. Also, the intake tests needed to be carried out in the fairly cold high-altitude atmospheric conditions that exist near the equator.

However, there were no suitable hangars or engineering facilities available. To get around the lack of facilities, we constructed a tented village of sorts, with any technical information required being relayed from Fairford and spare parts delivered by a Canberra chase aircraft. Our impressive but dodgy-looking facility and G-AXDN were constantly protected by numerous armed guards. Being careful at night was essential in case someone became a little trigger happy.

Flight crew

Pilots: John Cochrane, Eddie McNamara, Gordon Corps (CAA Test Pilot)
Flight Engineer: D F B (Dennis) Ackary
Navigator: George Wood

Curing the surges

The intake control system had to be able to deal with a series of engine surges (large burps), which would be deliberately induced during test flights, and to recover the situation at various speeds above Mach 1.3. It was also crucial to discover the maximum sustainable Mach number

Engines on G-AXDN
1970: An engineer performs a boroscope examination of an engine prior to XDN's maiden flight. Before the 1974 test programmes began, the aircraft was fitted with the new Olympus 593 Mk 602 engine, which would be used on the production aircraft.
Photo: AirTeamImages.com

(within airframe limits) that could be set for commercial service.

Burps were induced by the flight engineer, using the MANUAL intake control switches to slowly inch the intake ramp doors open until the engine surged. On several occasions this would alarmingly induce a sympathetic surge in the adjacent engine. The digital control system would then be switched to AUTO and would hopefully recover the engine condition and the ramp and spill door positions. The surges were induced at various speeds and altitudes until the required criteria were reached.

Some upgrades were needed to the AICU's read-only memory (control laws) and were carried out on site to basically fine-tune the system. I had the privilege of modifying these units in a flooding tent at night in pouring rain. Certainly not the 'clean room' conditions that are normally associated with this kind of work!

Performance tests

The next series of tests were purely performance related. During these flights, G-AXDN achieved Mach 2.23 at an altitude of 63,700ft, making her the fastest test airframe ever. Although these are the official figures, from various recorded read-outs the aircraft appeared to have touched Mach 2.25 momentarily, at a slightly higher altitude.

On completion of the trials, Mach 2.20 was determined to be the boundary of the safe flight envelope. Therefore, after much discussion between various departments, Mach 2.02 would be set as the in-service max speed and the limit that would also maximise airframe life.

An incredible series of tests and a lot of fun for all of us lucky enough to be involved.

Test team at Tangier
Members of the flight test crew, engineers and observers, including navigator George Wood (top left) and Rolls-Royce engineer Chris Powell (top right). John Dunlevy is in the third row down, on the right.
Photo: John Dunlevy

The clockwork tangerine!

During the intake testing trials carried out in Tangier, any spare parts required were delivered by the Concorde chase aircraft, a Canberra PR.7 bomber registered as WH793.

The Canberra's rather long, formidable bomb bay held a friendly cargo container (a long, black-painted, locking wooden box, suspended securely within the bay) rather than the explosive devices previously carried. Unserviceable parts from Concorde were loaded on to the Canberra and flown back to the Fairford Flight Test Centre.

On loading the spares, there appeared to be plenty of available space in the cargo container. This seemed to us to be rather wasteful and needed filling a little, perhaps with something that would even help to hold the spares in place.

With an abundance of tangerines available at the local markets, we decided to send a few bags back to the rest of flight test team back at the Fairford base. These were received most gratefully – and, like Oliver Twist in the film, the "can we have some more please" message came to us with the next spare parts delivery flight.

The next couple of returning flights eventually carried more tangerines than spare parts!

This enterprise deserved some form of recognition. As the Canberra was already carrying various logos, an additional one was created. The film *A Clockwork Orange*, showing in cinemas at the time, inspired the design of the logo – and given the fact that tangerines and oranges almost look alike, well, it just had to be done.

The Canberra was duly hand-painted with the fabulous design, "The Clockwork Tangerine".

G-AXDN was not to be left out and was later adorned with her own "tangerine" logo; after all, our eventual return flight to Fairford carried a further cargo of the juicy fruit.

Fruits of creativity
Left: The original "tangerine", seen here on the salvaged fuselage skin of Canberra WH793. This skin segment is now on display at the South Yorkshire Aircraft Museum.
Right: The "tangerine" painted on G-AXDN; have a look for it if you visit the aircraft at IWM Duxford.
Photos: John Dunlevy

Concorde's air intake system

Unless you have a rocket fitted, the normal commercial aircraft jet engine is classified as subsonic. This means that it has limitations as to the amount of air it can gulp in – the air must not enter the engine at too great a speed.

Depending upon the design of the intake, just over Mach 1 (supersonic) may be possible for the engines to manage; however, increasing airspeeds above and beyond Mach 1 will introduce supersonic air along with tremendous pressure into the front of the engine, totally overwhelming its capacity to swallow or gulp in any more. The result will be one big burp, technically known as a surge when related to jet engines. Therefore, we have to have some way to deal with the problem and keep control of the air intake (digestion).

For Concorde, this is the air intake control system. The control would commence at Mach 1.3 and continue up to and beyond Mach 2.

Control of the incoming air is maintained by a pair of hydraulically powered, linked, wedge-shaped moving doors (ramps) located at the front of each intake, which have the task of slowing the air down to subsonic speed for engine consumption, with any excess unmanageable air being dispelled out of a lower door (spill door). The ramp doors will get increasingly lower as airspeed increases, and vice versa as the airspeed decreases. Because we can change the effective shape of the intake internally, it is known as a Variable Geometry Intake.

These ramp doors create and hold a shock wave within the intake, which effectively slows the incoming air and allows the engine to carry on breathing without surging.

External view of air intakes
The ramps inside the intakes are clearly visible; in this case they have been set at different positions for display.
Photo: Tim Sheerman-Chase / Wikimedia Commons (CC BY-SA 2.0)

The positioning of the shock wave is critical at all times at supersonic speed and must be maintained within a specific band. The action of the ramps is controlled digitally by eight Air Intake Control Units (AICUs). On G-AXDN these were stand-alone units installed in the cabin. By the time the production aircraft had been built, though, the AICUs had been incorporated into the flight-deck controls – two for each intake.

Test flight units
The bulky cabinets holding the first digital Air Intake Control Units, installed in G-AXDN's cabin; these units are still in place today, and have been restored to show how they would have looked while in operation.
Photo: John Dunlevy

Flight-deck controls
The controls for the AICUs on the production aircraft. These instruments are part of the flight engineer's control panel. They enable the flight engineer to monitor the activity of the AICUs and the movement of the ramps and spill doors.
Photo: Heritage Concorde

Breaking the ice

From the sultry air of Tangier, Concorde flew to the snowy north-west of the United States at the end of 1974, to carry out trials of the de-icing system. John Dunlevy recalls the challenges of this test programme.

As part of aircraft certification, the ability to fly in all icing conditions has to be thoroughly tested and the means of dissipating ice accretions judged to be satisfactory.

Concorde has two systems for dissipating ice – continuous heating and cyclic heating – both in the form of heating elements built into the relevant structures prone to possible ice build-up. Although in-flight water spray trials (simulating heavy rain and hail) had been successfully carried out on both G-BSST and G-AXDN, no constant and naturally occurring heavy icing conditions had yet been encountered.

One notable area in the world where such icing conditions occur is Washington State, in the north-west of the USA, where significant ice-bearing clouds are encountered daily from late autumn until early spring. Moses Lake (Grant County), Washington State, about 285 km (177 miles) east of Seattle, was chosen as a suitable base for the test flights due to these weather conditions, along with its proximity to Seattle's Tacoma International Airport.

Preparing for the tests

Once the final decisions had been made, G-AXDN had her port side underwing and leading-edge surfaces painted matt black, complete with roman numerals identifying the various sections for the benefit of the cameras, to be added later, which would photograph the ice build-up.

Flight crew

Pilots: John Cochrane, Eddie McNamara
Flight Engineer: Dennis Ackary
Navigator: George Wood

Areas marked for observation
G-AXDN on arrival at Moses Lake; the black paint can be seen on the underside of the port canard, beside the forward cabin door, around the camera (under the yellow steps), and on the underside of the port wing.
Photo: John Dunlevy

The lower lip leading edges and sidewalls of numbers 1 and 2 intakes were also painted, together with the leading edges of the forward ramp doors. Any of these areas can seriously affect flight or engine performance if not kept free of ice.

Black squares also appeared on the fuselage forward of the left-hand wing, again for camera placement.

The paint, which is similar to that used on the Lockheed SR-71 (Blackbird), is able to withstand supersonic flight temperatures – and, apart from a few bits peeling from the leading edges, it was still intact on arrival at Moses Lake.

Unseasonal warmth

On 7 November 1974, G-AXDN departed Fairford on route to Bangor, Maine, USA. An astounding 'no holds barred' flight, with the aircraft achieving a record Atlantic crossing in 2 hours 56 minutes. A few hours later, the flight from Bangor to Moses Lake (hugging the USA's border with Canada) set another record, for east to west crossing of the USA; G-AXDN completed it at a maximum speed of Mach 0.99, in a time of 4 hours 43 minutes.

The weather on arrival at Moses Lake was a balmy 24°C (75°F) – not what we were anticipating. Our cold-weather clothing went back in the suitcases. A local farmer smilingly informed us that the weather would probably not change for at least a week or two! He was correct, and everyone had a lot of down time to explore beautiful Washington State, with an abundance of autumn colours to appreciate.

Setting up the cameras

Fitting the cameras was the first task. One was installed on the forward fuselage, together with its heated cowling, and one in each of numbers 1 and 2 engine intakes, located above the forward ramp doors. In addition, a camera was installed onto the under-belly viewing scope (hyposcope). All of the heavy cabling and connectors for the

Flight test observer
Alan Radford seated at the Ice Station.
Photo: John Dunlevy

cameras had already been installed back at base.

All film would be recorded in black and white, and live images would also be viewable on three monitors located in the rear cabin. This area was nicknamed "The Ice Station" (after the Alistair MacLean book and film *Ice Station Zebra*).

In addition to the cameras, a basic visual ice detecting probe (hand-made on site at the request of test pilot John Cochrane) was installed below the captain's DV window.

Daily morning checks were carried out all the same to keep G-AXDN in readiness for any change in weather conditions. Finally the weather changed, the air temperature well below freezing and snow showers prevalent. Time to fly.

A chilly start

On arriving at the airfield early that morning, we applied electrical ground power and began the pre-flight checks. Problems soon became apparent due to a flight deck temperature well below freezing. Many instruments refused to co-operate and remained flagged and dormant.

I had the idea of putting the instrument lighting on full to try and warm things up. After around an hour things looked more promising, except that the warning flags on the exhaust gas temperature (EGT) gauges failed to clear.

Must be ice on the probes? No, hang on – they cannot read below zero; that's the reason. Wait until engine start; perhaps the flags will clear. Hope I'm correct!

Then I pulled the control column and found it almost immovable. On investigation, to our horror, we found ice around the bell-cranks in the dry bays due to moisture condensing there overnight. This necessitated the use of a ground air start truck to blow hot air around.

Below freezing
The weather finally became cold enough to provide the icy conditions for the test flights – but the freezing temperatures rendered many instruments and controls immovable. *Photo: John Dunlevy*

Finally everything appeared to be fully free. Ice Encounter or not.

Into the icy air

Engines started and EGT indicators working. (Thought so.)

Seattle tower receiving messages from incoming aircraft of heavy icing conditions.

XDN airborne and following the same approach patterns – but although the ice master warning light illuminated and some slight ice appeared on the hand-made probe, there was no recordable accumulation of ice.

The de-ice heaters were deliberately switched off at this time to allow any ice to accumulate; they would then be selected 'on' after any build-up.

Several ensuing flights produced similar results. It was deemed that the aircraft shape was too slippery to allow significant ice accretions.

Testing is all about 'what if', and it was decided that maybe reducing airspeed a little and increasing attitude and climbing into the clouds might produce a result.

The resulting manoeuvre produced expletives from the crew as substantial accumulations of ice were caught on the monitor screens. The hyposcope and other cameras recorded almost 1 inch or more of ice on the intake lower leading edges, together with a substantial coating on the underwing surface. There was very little prominent on the wing leading edges, though.

Time to test the de-ice system.

As mentioned above, cyclic and continuous de-icing heating elements are installed within the critical structures that are known to be susceptible to ice accretion.

Time to shed the ice; it's switch-on time!

Wow! The resulting avalanches of ice heading towards the numbers 1 and 2 engines, captured via the recording devices, was spectacular but amazingly was not accompanied by any surging of the engines.

After-flight Inspection

The after-effects of the ice encounter were a shock to us. All four engines had suffered damage to the low-pressure (LP) compressor stage, consisting of numerous dents and chips. Boroscope checks of the engine internals indicated that they had lucky escapes.

The worst scenario involved all four engines needing to be changed, and as December was closing in that could not be achieved until after Christmas.

I was one of the volunteers elected to stay and take care of the aircraft if that was to be the case. However, our hero Rolls-Royce engineer, Mervyn Scull, concluded that it might be possible to save the day and dress out the blade damage to give the engines a serviceable status.

The local hardware store was invaded, and all manner of cutting, sawing and grinding tools were purchased. After days of trimming and balancing, the LP compressors were declared once again fit for purpose.

Returning home.

G-AXDN, now adorned with the name of 'Miss Moses Lake' (painted on using a tin of the ubiquitous black paint), departed for Bangor on 11 December 1974. There were no apparent engine problems apart from a short-lived vibration from number 3 engine. On this flight the aircraft made another record crossing of the USA, this time from west to east.

On arrival at Bangor the upper rudder actuator was found to have developed a substantial hydraulic leak. Spare seals had to be flown in from Virginia via a light aircraft, but due to fog the arrival of this aircraft was delayed by 24 hours.

Finally everything was good to go and on 13 December 1974 XDN departed Bangor for Fairford, which would be only 3hrs 50 mins away.

What a fabulous trial and adventure for us all; I was lucky to be involved.

Test crew
G-AXDN, now adorned with commemorative “Miss Moses Lake” logo, with the crew, including John Dunlevy (fourth down on left) and Alan Radford (white overalls).
Photo: John Dunlevy

Badges of honour
By the end of the test programme, G-AXDN bore the logos from Tangier, Moses Lake, and Nairobi.
Photo: Nickbeer / iStockphoto.com

The need for aircraft de-icing

Ice forming on aircraft structures will create serious drag and loss of lift, critically affecting both take-off and flight performance. In-flight icing will form when supercooled water freezes on impacting the structures. This can eventually overwhelm the aircraft’s ability to maintain altitude and airspeed, which can lead to a stall and finally total loss of control.

In the trials, G-AXDN followed preceding aircraft on finals flying into Seattle that were encountering and reporting severe icing conditions in cloud – but XDN, even with the de-icing systems switched off, could not get any ice to adhere.

Concorde Watch

Concorde G-AXDN British pre-production aircraft

Location: Imperial War Museum, Duxford, UK
Reporter: Graham Cahill **Date:** 13 April 2021

We were so glad to be working again after this current lockdown. The team were Peter Ugle, John Dunlevy, James Cullingham and myself.

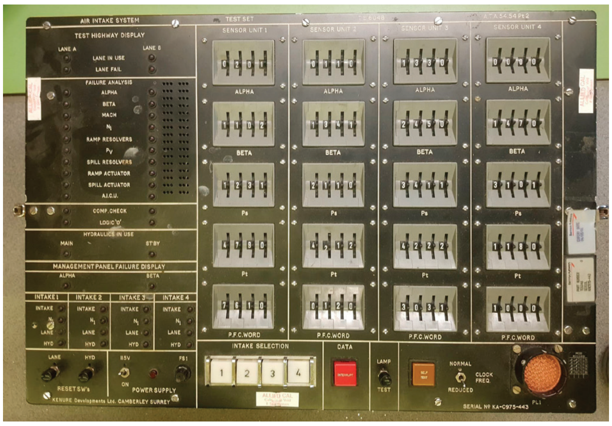
We started by inspecting and cleaning the nose; a small leak had occurred on the pipes so we needed to pay it some attention. We have not inspected the nose for well over a year due to COVID-19 so this was long overdue. We tested the nose and it works fine. Concorde always did have small leaks on the hydraulic system so this minor drip is nothing to worry about.

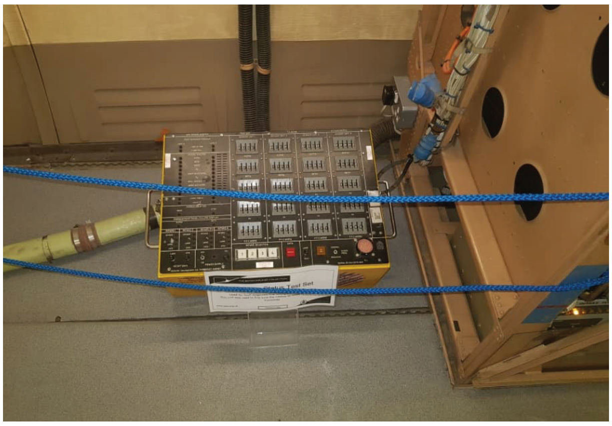
James Cullingham very kindly brought an intake test box from Brooklands and this is now on display on board the aircraft. Many thanks to Brooklands for helping improve the DAS displays. The test box is highly relevant to Duxford because G-AXDN was used to develop the intakes that made Concorde so successful and able to fly at over twice the speed of sound without continuous use of afterburners (see pages 9–11).

We made some small changes to the engine noise demo that the Duxford Aviation Society (DAS) use each time they show the nose moving. The demo was triggering at random times, which is annoying, so we ordered a small part, which we will fit on our next visit to fix the problem completely.

Peter Ugle started to remove a panel at the rear of the aircraft that showed staining from wax oil. We did not complete the job but will do next visit; the screws are full of paint and take a long time to remove. Once the panel is removed we will find the cause of the stain.

Landing gear lights
The four landing gear lights now correctly show as 'down'; the tail bumper light is the small one third from the left. The red light indicates that the nose gear bay doors are open.
Photo: Graham Cahill





Intake test box
Top: Detail of the controls on the box.
Above: The unit restored to its former location near the intake computers at the rear of the aircraft.
Photos: Graham Cahill

James repaired the tail bumper indicator, which was showing as 'up' but was actually down. This issue originally arose because when G-AXDN arrived at Duxford she was stored outside, so bird nets were fitted; the only way to fit the net was to cut a wire loom to the tail bumper, which caused a false indication of 'tail bumper up' on the flight deck. This has been resolved, but the wiring loom has not been reinstated.

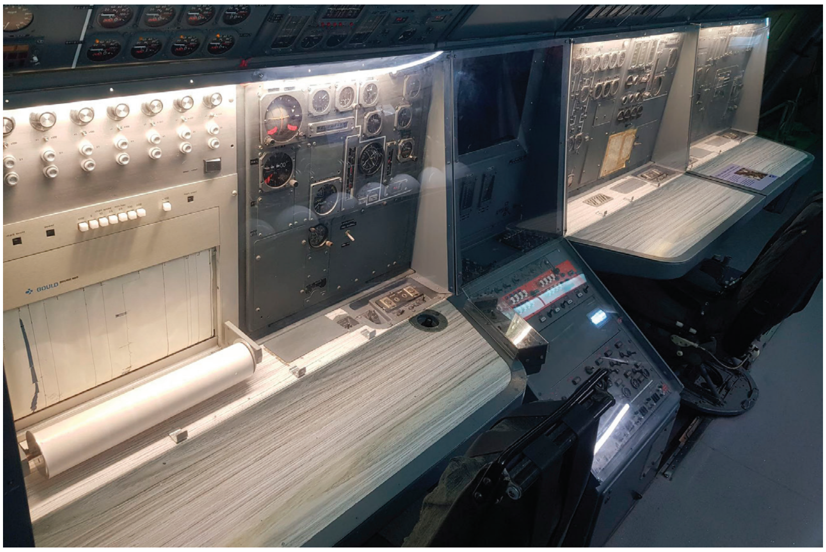
We investigated the landing gear ground switch and nose landing gear (NLG) bay for a future project: we intend to move the hydraulic pump that operates the nose into this area and also make the gear bay doors move. This is a long-term project, but initial inspection shows the hydraulics to be in good condition.

The LED lighting above the observers' desks was replaced with warm white LEDs instead of bright white (the LED strips were faulty so needed replacing anyway); we prefer the warm white light as it is in keeping with the rest of the aircraft.

We replaced some blown filaments inside the aircraft, mostly on captions. This is a standard job for each visit, but this time we found only a few had failed because of the aircraft being closed for most of the year due to COVID-19.

In all a very productive day from a great team, and it was lovely to see our colleagues at DAS.

An ongoing job
Peter Ugle works on the stained panel at the rear of the aircraft.
Photo: James Cullingham (www.concorde-photos.co.uk)



Observers' stations
The stations with the new warm white LEDs fitted.
Photo: Graham Cahill

Supporting the DAS collection

I cannot stress enough how much COVID-19 has affected museums. IWM Duxford will be re-opening fully on Monday 19 May. It is extremely important that, when you visit, if you can afford a small donation then it will be gratefully received.

DAS are doing a great job of maintaining a high profile, and in my opinion they are leading the way in terms of helping visitors enjoy their visit.

So far DAS have been first to use 'tap and donate' pads so people can easily donate, the first to publish a Concorde app for mobile devices, the first to display a QR code at the steps of the aircraft so visitors can still see inside even if the aircraft is closed, and the first to release 360° images of the entire collection.

They are currently working on several exciting projects, which they will announce shortly. As soon as they do so we will share the information. Well done DAS and the British Airliner Collection. For further details, see:
DAS: www.duxfordaviationsociety.org
British Airliner Collection: www.britairliners.org

Perfect condition
G-AXDN's condition is a tribute to the care given by DAS.
Photo: James Cullingham (www.concorde-photos.co.uk)

Concorde G-BOAC

British production aircraft

Location: Runway Visitor Park (RVP), Manchester, UK
Reporter: Graham Cahill **Date:** 23 April 2021

The team attending were Graham Cahill and John Hepple. This was the first visit to G-BOAC since lockdown. It is always a pleasure to visit my local Concorde; she is in great condition. On this occasion we continued some work that was started before this lockdown.

Cockpit door strike panel
The unit fitted in its proper place (just beneath the four dials).
Photo: Graham Cahill

Headset unit
The unit restored to its original place (above the row of switches).
Photo: Graham Cahill

Planned work for the day

1. Cockpit door panel
Replacement of cockpit door strike panel missing from engineer's panel, and replaced by a previous engineer with a headset unit moved from the 5th position. The RVP very kindly obtained the correct unit for us; they are extremely keen to see OAC in tip-top condition and made real efforts to get this part for us.

The unit was removed from all five serviceable Concordes on decommissioning by British Airways, because they are used on some of the Airbus fleet including the A319 and A320. This left a nasty gap in the flight engineer's panel, which was filled with a headset unit from the opposite side in position 5 supernumerary. The cockpit door unit had arrived the day before our visit, so we fitted it. The original connectors were plugged in and the headset unit returned to position 5.

2. Replacement of light bulbs
We had wanted to add a little life to the aircraft for technical tour visitors to see, so re-commissioned some of the ground service lights, but unfortunately almost all of the dual filament bulbs were blown or broken. The ex-Concorde engineers did say the bulbs used to be rattled around so much that the solder used to wear down on them; on removing the blown lights this was clearly the case, so we have replaced all the bulbs with glass LED filament bulbs that retain the correct colour. The job is mostly complete, with just the nose leg gear (NLG) and rear equipment bay to do. At night this will look great and they can be powered without the need to power the cockpit up, thus prolonging filament life in the cockpit.

3. Inspection of nose
I completed a full inspection of the nose. A small leak is still apparent near the swivel units; this is a seal on a bobbin through a bulkhead rather than the swivels themselves, which is a relief. The leak is so small we will just monitor it. There are no issues visually. The nose was tested

Internal inspection of nose
A view of the nose interior, with the service bay lights switched on. Despite a small leak, the nose is performing normally.
Photo: Graham Cahill

A hidden message
Right: John Hepple lifts the cover on one of the flight deck seats, to reveal this message from the engineers who worked on it just before the Concorde fleet's retirement.
Photo: Graham Cahill

during the following week and performed admirably, as expected.

4. Repair of the First Officer's seat
The seat was stuck in the 'fully in' position due to lack of use during lockdown; the rails were cleaned and lubricated and it works fine now.

5. Cleaning of flight deck seats
The flight deck seats required a little attention. John Hepple removed all the covers and cleaned them. We found a small message from some of the last engineers to work on the aircraft (see photo, right) – a nice touch and goes to show the passion of the people who looked after her.

6. Main landing gear bays
I inspected the main landing gear bays. It was nice to see untouched parts of the aircraft. I was replacing filaments in there anyway so took a full look around. All was OK and in great condition.

7. Toilet service hatches
We opened the mid toilet service hatches to replace the ground service filaments. They were not in too bad condition but had clearly not been opened since retirement; the hinges were oiled and filaments replaced.

In all, considering there were only two of us, it was a very productive day and as always most enjoyable.

The Runway Visitor Park is now open for visitors. For further information on tours and other events, visit the RVP website:
www.runwayvisitorpark.co.uk

Main landing gear bay
A view inside one of the landing gear bays, with one of the struts for the leg visible. The interiors were in good condition.
Photo: Graham Cahill

