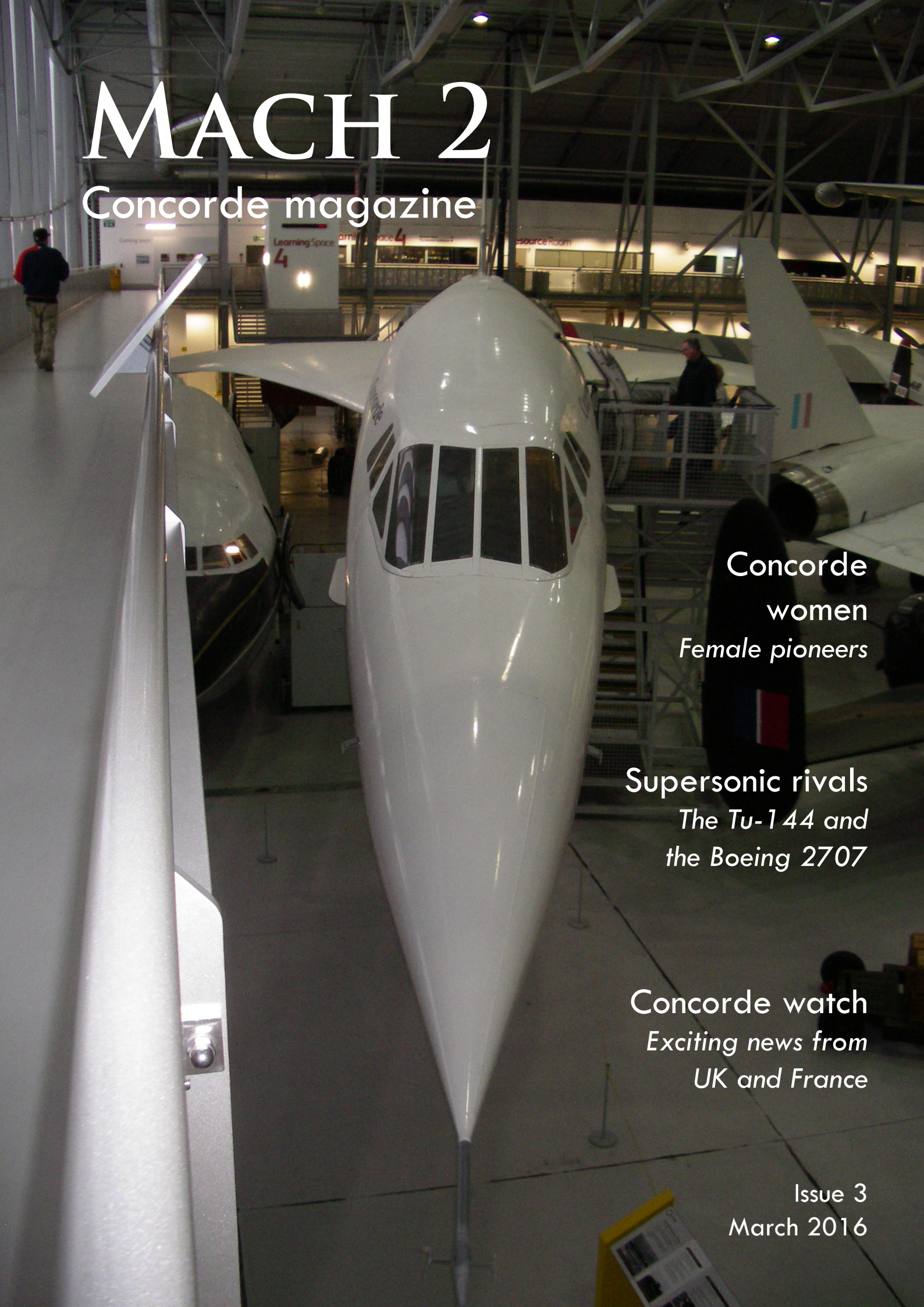
Mach 2

Concorde magazine



Concorde women

Female pioneers

Supersonic rivals

The Tu-144 and the Boeing 2707

Concorde watch

Exciting news from UK and France

Issue 3
March 2016

Introduction

This edition of Mach 2 magazine is slightly different from usual – we are giving most of it over to the women whose work over the decades helped to make the Concorde services possible. Our special series of articles commemorates the female pilots and engineers, and even one of the first Concorde test pilots, and includes an account from our regular writer GIlly Pratt.

This issue also reveals an insight into the navigation systems on Concorde, from former Captain Christopher Orlebar, and a bumper crop of exciting news from around the Concorde museums.

In addition, co-editor Nigel Ferris looks back at Concorde's two great rivals – the Soviet Union's Tu-144 and the USA's planned supersonic Boeing 2707. He assesses their strengths and weaknesses and considers what might have been if these two aircraft had shared the sky with Concorde.

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Editors: Katie John, Nigel Ferris

Cover: Concorde G-AXDN at the Imperial War Museum, Duxford (Photo: Katie John)

Fascinating facts

Nigel Ferris *looks at some of the features that made Concorde uniquely fitted to fly faster and higher than any other airliner.*

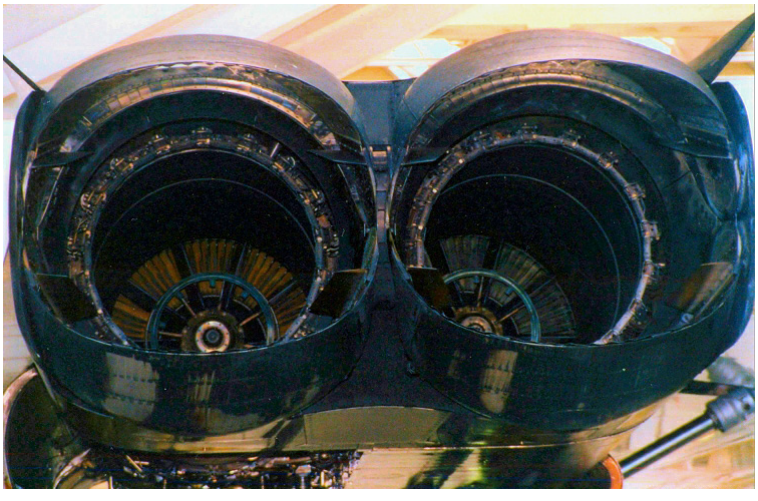
1 **Over 5000 hours** of wind tunnel testing was carried out to optimise the complex compound curvatures and cambers of the wings, resulting in the final shape, which was ideally suited to high-speed flight. There was some compromise in the design to cater for low-speed handling – a delta wing has to adopt a fairly high pitch up attitude to generate the lift. (In Concorde's case this was vortex lift.) This does mean that there is also a large amount of drag induced. Concorde therefore had to make what is called a 'powered approach' compared with a conventional aircraft – i.e. the engines had to have a fairly high power setting, maintaining the speed. This power setting would normally cause the aircraft to climb, so a small amount of down elevon was selected to counter this tendency. It had an added bonus of creating a small amount of flap effect to assist in maintaining the lift.

Stages of development
Some of the models used for wind tunnel testing to define the optimum shape for Concorde's wings. These models are now on display at the Farnborough Air Sciences Trust.
Photo: Katie John

2 **Concorde could use** reverse idle thrust on the inner engines (numbers 2 and 3), if the aircraft needed to lose speed and height at a quicker rate, to fit into landing patterns when instructed to do so by Air Traffic Control.

3 **Each engine** had 6 electronic control boxes – 2 for the intakes, 2 for the engine and primary nozzles, 1 for the reheat and 1 for the secondary nozzles and reverse thrust buckets. The control laws for the intakes started off at AA, then AB, AC etc., going to TT and beyond, all updated during testing.

4 **The reverse thrust buckets** were operated by compressed air – hydraulic rams and fluid, electric motors and wiring would not have been able to withstand the high exhaust temperatures. Compressed air was more suitable, as the pressure could be controlled to take into account the effects of temperature on a compressed gas.



Reverse thrust buckets
Close-up view of the reverse thrust buckets, with the engine reheats visible beyond them.
Photo: Jetinder Sira

5 **The cabin floor** was mounted on rollers to allow the airframe to expand around it in supercruise.

6 **The constant heating** of the airframe during transonic acceleration and supercruise ensured that any moisture or water that collected in the structure would evaporate. This helped to eliminate corrosion, thereby ensuring a long service life. In effect, Concorde was a self-healing aircraft.

Concorde ladies

To follow International Women's Day on 8 March, this series of articles features the women involved with Concorde – not the supermodels and film stars who travelled as passengers, but the pilots, engineers and designers who worked to create and fly the aircraft. Co-Editor Katie John *revisits their achievements, and we hear from some of these pioneers themselves, as well as from those who knew them well.*

The mathematician: Johanna Weber

8 August 1910 – 24 October 2014

One of the foremost scientists who helped to bring Concorde into being was a German-born woman, Dr Johanna Weber. Her work led to the development of the "slender delta" wing concept, which made supersonic transport aircraft possible and was used on Concorde.

Despite being a "war orphan" from a poor family, Johanna Weber excelled as a student, gaining a first-class honours degree from Göttingen University, which was globally renowned as a centre for mathematics and science. She trained to become a teacher, but was denied a post as she was not a member of the Nazi party, so in 1937, to help provide for her family she began mathematical and computational work in the Krupp ammunition and armaments factory.

In 1939 she moved to the Aerodynamische Versuchsanstalt (AVA) in Göttingen, where she met aerodynamicist Dietrich Küchemann. The two of them worked closely together, with Dr Weber carrying out the mathematical calculations and working on wind tunnel testing while Dr Küchemann developed and guided the research. Their work was presented in the textbook *Aerodynamics of Propulsion*.

After the end of the Second World War, Drs Küchemann and Weber were brought to England to work at the Royal Aircraft Establishment (RAE) at Farnborough, and both took up British citizenship in 1953. The two provided vital information for the design of the crescent-shaped swept wings on the Handley Page Victor; Dr Weber led a team of female "computors" who performed the necessary calculations by hand. Her theoretical methods were also applied by Vickers in designing the wings for the VC10 (as well as being used on the DH121 Trident and the BAC 1-11).

Dr Weber was also involved in the research into supersonic transport aircraft. In 1955 her work at the RAE, with colleague Eric Maskell, demonstrated that a slender delta wing would perform well both during take-off and landing and during supersonic flight, with no need for variable geometry. Dr Küchemann's support for this idea made possible the establishment of the Supersonic Transport Advisory Committee (STAC) in 1956. During the development of Concorde, Dr Weber's work on drag during supersonic conditions and on the shaping of the wing led to the creation of the unique "warped" shape seen in Concorde's wings.

Form following function
Air condenses over Concorde's wings as the vortices form during take-off.
Photo: courtesy of British Airways

Following Concorde, Dr Weber returned to her work on design methods for swept-wing subsonic transport aircraft – notably the first Airbus wide-body jet, the A300B. Her work therefore played a key role in the early success of Airbus.

Johanna Weber finally retired in 1975. She remained friends with Dr Küchemann and his family for the rest of her life. She never married, but lived next door to them until she entered a nursing home at the age of 100.

Further information about Johanna Weber can be found in her obituary on the Royal Aeronautical Society website:

http://aerosociety.com/News/Society-News/2742/OBITUARY-DR-JOHANNA-WEBER

The test pilot: Jacqueline Auriol

(5 November 1917 – 11 February 2000)

The foremost female test pilot in France, and one of the most renowned in the world, Jacqueline Auriol was one of the first pilots ever to take command of Concorde.

Jacqueline Auriol (born Jacqueline Marie-Thérèse Suzanne Douet) was born into a wealthy family. She had her first flight at the age of 16, but her primary passion was art; after graduating from the University of Nantes, she studied art at the École du Louvre in Paris. In 1938 she married Paul Auriol, and the pair were active in the French Resistance during the Second World War. In 1947 Paul Auriol's father was elected President of France. Jacqueline helped to decorate some of the rooms in the Élysée Palace. She was known as one of the most elegant women in Paris.

A new life in the air

Then, in 1948, she changed course radically and learned to fly, becoming a highly proficient aerobatic pilot. The next year, however, she suffered serious injuries as a passenger in a seaplane crash on the Seine, and endured 22 operations to rebuild her face. Nevertheless, she continued flying; she earned her helicopter pilot's licence in just 4 weeks and gained her licence as a military pilot in 1950, then was accepted as a test pilot at the Flight Test Centre in Brétigny.

In 1951 Mme Auriol set a new world speed record for a woman, attaining 828 km/h (515 mph) in a Vampire jet. For this feat she was awarded the French Légion d'Honneur and the American Harmon trophy. She went on to achieve the world speed record for women five times between 1951 and 1964.

As a test pilot, Mme Auriol flew more than 100 aircraft types. She was only the second woman pilot ever to break the sound barrier, in 1953. Significantly, she was one of the first test pilots ever to fly Concorde, working with the late André Turcat to take the prototype 001 through its development programme.

In 2015 a new training centre for aerospace engineers at the University of Toulouse was named in her honour, as a way to inspire the female pilots and engineers of the future. (See http://www.univ-toulouse.fr/universite/presentation/aerocampus#mfja)

Living to fly
Jacqueline Auriol in the cockpit of a Mirage IIIC, the aircraft in which she set one of her world air speed records for female pilots, in 1962.
Photo: source unknown

The British first officer: Barbara Harmer

14 September 1953 – 20 February 2011

The first woman to fly Concorde in commercial service, Barbara Harmer worked her way to this pinnacle of aviation from a very different point in life.

Growing up in Bognor Regis, Barbara left school at just 15 to train as a hairdresser. After five years, though, she changed course and took a place as a trainee air traffic controller at Gatwick Airport.

During her time at Gatwick, Barbara put herself through A-levels and also gained her private pilot's licence. To help build her flying hours she worked as an instructor at Goodwood Flying School, and took a correspondence course for her commercial pilot's licence, finally gaining the licence in 1982.

After more than 100 job applications, Barbara gained her first flying job with a small commuter airline, then joined British Caledonian in 1984 , where she flew the BAC 1-11 and DC-10. When British Caledonian merged with British Airways in 1987, she became one of only 60 female BA pilots at the time.

In 1992, Barbara was the first woman selected by BA to undergo the intensive 6-month conversion course to fly Concorde. Then, on 25 March 1993, she made her first flight as First Officer on Concorde, from Heathrow to JFK, and in so doing earned a place in history as the first, and only British, female Concorde airline pilot.

After Concorde flights were suspended in 2000, following the crash at Gonesse, Barbara moved on to become a captain on Boeing 777s. She also became known as a public speaker, as well as a fully qualified yacht master, often commanding the Concorde crew in international yachting events. She finally left BA in 2009.

Barbara succumbed to cancer in 2011, but she is still widely respected and fondly remembered in the aviation world.

The French first officer: Béatrice Vialle

The only woman to pilot Concorde for Air France, Béatrice Vialle has spent a life on the flight deck and is still working today.

After training at the French École Nationale d'Aviation Civile, Béatrice Vialle began her career as a pilot in 1984, at just 23 years old. Two years later she moved to Air France. She flew first the Boeing 727, then the Airbus A320, and the Boeing 747; during this time she also married a fellow 747 captain and had two children.

In 2000 Mme Vialle gained her qualification to fly Concorde – on 24 July, just one day before the horrific crash at Gonesse. Nevertheless, she continued her training flights. One of these flights, on Concorde F-BVFB, took place on 11 September 2001; Mme Vialle only found out about the tragedy in New York once she had landed.

Béatrice Vialle made her first commercial flight with Concorde on 19 November 2001. She completed 45 supersonic round trips from Paris to New York.

When Air France retired its Concorde fleet in May 2003, Mme Vialle was one of the flight crew for the last commercial flight, again with Concorde F-BVFB, on 31 May. She continues to fly for Air France today, as Captain on the Boeing 747.

Final flight
First officer Béatrice Vialle, with Captain Jean-Louis Châtelain, bring Fox Bravo home after his last commercial flight.
Photo: Source unknown

The lady Concorde pilot

Captain Dave Rowland, former Concorde Flight Manager for British Airways, looks back at the career of his remarkable colleague.

I joined the Concorde fleet as a co-pilot in 1976, and after getting my command on the BAC 1-11 (the rules at the time meant that you couldn't get your first command on Concorde or other long-haul aircraft) I was appointed back to Concorde as Flight Manager (Technical), later also being appointed Commercial Manager of the fleet. I retired in 1999.

I first met Barbara when she joined the fleet in 1992, on day one of her 6-week Concorde ground-school course. I remember meeting a pilot who knew she had been given a wonderful chance to fly and be involved with such a unique aircraft, and a woman determined to be treated equally and to succeed on merit without any concession to her gender.

Her route to becoming an airline pilot in the first place was what was often described in the aviation world as that of the "self-improver" – a journey requiring ability, determination, commitment and self-discipline; training in stages, at their own expense, as and when time and money permitted and all without any certainty or even prospect of employment as a commercial pilot at the end of the day. She wrote over 100 job applications and even took to signing herself "B Harmer" as she felt her gender was preventing her getting an interview.

A year or so of flying a Shorts 330 for a commuter airline led to her joining British Caledonian and then transferring to the DC-10 with the merger of BCal into British Airways. In 1992 she successfully applied for one of 2 co-pilot vacancies on Concorde.

The course itself was enough of a challenge for anyone, but there was the media to deal with; hers was a story that they wanted to tell. At first reluctant and uncomfortable with being the centre of attention, she soon became very accomplished at dealing with media questions and demands. And so, in parallel with her professional job on the fleet, there began a career as a celebrity and role model – speaking engagements and invitations to high-profile events, and in a lower-key vein, speaking at schools, especially to the girls, about ambition, determination and not limiting their horizons. She would get letters later thanking her for inspiring them to set out to achieve their ambition through the example she set. In November 1993, The British Women Pilots' Association awarded Barbara the Brabazon Cup – an annual award to a British woman pilot who has achieved one particularly outstanding performance in aviation in the current year.

She was a pleasure to fly with; thoroughly professional and relaxed but quietly obstinate when she needed to be! Barbara fitted into the Concorde "family" with ease. Her unique contribution is easier to define than most – in Britain, Barbara, will always be "the lady Concorde pilot".

Pre-flight planning
Barbara Harmer, seen here in April 1993, in discussion with colleagues as they prepare for a flight. Barbara would go on to fly Concorde for 7 years.
Photo © Corbis Images

The British ground engineer: Emma Daniel

Hydraulics Engineer Emma Daniel was one of only a few female engineers working on Concorde for British Airways – but was passionate about her job and about the aircraft.

Safety modifications
Emma Daniel is seen here fitting the Kevlar linings to Concorde's fuel tanks after the crash in 2000. *Photo: Emma Daniel*

Emma had been fascinated by engineering since she was a child. She left school at 16 and qualified as a machine apprentice. While working with a firm in West Drayton, she saw a British Airways advertisement in a local paper, for a job as a pneumatics and hydraulics engineer. She didn't expect to get it, but applied anyway – and was accepted.

Emma tells the rest of the story herself:

"I started working on Concorde as part of the team based in the hydraulics workshops. I loved it from day 1 – they were a great team to work with. Although I worked on many components, my main involvement was with ramp actuators, artificial feeljacks, swivels, and selectors. We also carried out work to the aircraft itself in the hangers on AOGs if needed; it was an even bigger joy to work on the gorgeous aircraft herself.

When she was grounded after the Air France crash I was one of the volunteers who carried out some of the fuel tank modifications. This would be my biggest career achievement to date. Working as part of another team of engineers preparing her to fly again was amazing. The workspace was limited, as you can imagine, and involved crawling inside some tiny tanks in the wings, but it was thrilling!

I was lucky enough to get a flight on board her; its just a sad shame that won't happen again. Sad days when she was taken out of service, but she will always be remembered."

The French ground engineer: Alex Jolivet

An aircraft maintenance engineer for Air France, Alexandra Jolivet worked on Concorde in service and still helps to maintain F-BTSD and 001 today, at Le Bourget.

Alexandra Jolivet worked on Concorde for Air France as an aircraft maintenance engineer; she held this position for 18 months, between Concorde's return to flight in late 2000 and the final grounding of both fleets in 2003.

In addition, Alex has been a volunteer at the Musée de l'Air et de l'Espace (MAE), at Le Bourget, since 1987. She participated in the restoration of 001 (F-WTSS), the French prototype Concorde, between 1994 and 1997. Since Concorde F-BTSD (Sierra Delta) arrived at Le Bourget in 2003, she has formed part of the team who maintain this aircraft as well.

"Other jets are for kids!"

Regarding her feelings for Concorde, Alex says, "Even 13 years after Concorde's last flight, it is still my passion. Nothing will replace Concorde – not the latest Boeing or the latest Airbus, for all that these are masterpieces of technology."

Her personal motto – which she gave us in English – is: "Other jets are for kids!"

Alex's charges
Concordes F-WTSS (001) and F-BTSD on display in the Concorde Hall at the MAE, Le Bourget. *Photo: ignis / Wikimedia Commons*

The cabin crew member: Gilly Pratt

Our regular contributor Gilly Pratt, Concorde cabin crew member for British Airways, recalls the finely tuned "people skills" that she and her colleagues needed in their work.

At work
Gilly seen during a flight.
Photo: Gilly Pratt

I am extremely grateful to the wonderful women who, in the 1950s and 1960s, took on their airlines' management and won. By the mid 1970s, when I started flying, the awful restrictions once forced on stewardesses had mainly been removed. We were no longer required to "retire" in our early thirties, and we could apply for promotion, get married and have children. At last our profession was regarded as a career.

Rising to challenges

During my career I met some wonderfully strong and successful women. Some flights we operated, however, could really test our skills. One particular Concorde flight from New York came into that category.

We had boarded most of the passengers (98 of them) and suddenly there was a commotion at the front door – an elderly lady had collapsed. She came round and said she was fine, but we were very dubious as three and a half hours with someone unwell could be catastrophic. The ground staff insisted that she should travel, so she was duly assisted to her seat in the front cabin.

After take-off we realised a catastrophe had happened – the poor lady had emptied her bowels where she sat! The aroma was frightful. We had a full flight of passengers who needed serving. Luckily we had an angel on the crew named Sharon who assisted the lady to the mid-ships and proceeded to clean her up, bag her clothes and wrap her in blankets – all behind the galley curtains. Unfortunately they could not mask the smell! In the meantime we were rushing around serving drinks and canapés, including to Sharon's passengers. We then had to prepare for a meal service and we had to ensure that no contamination had occurred (thank goodness for black bags and used hot towels). We all made sure everything was scrubbed clean and then carried on with the service.

On arrival at Heathrow, the lady was assisted from the aircraft by wheelchair as she was only wearing blankets. Happily she was fine and extremely grateful.

Every member of the crew put in a recommendation that Sharon should receive a Customer Service Award. This was declined by Management (not Concorde's management, I might add) as she was "only doing what she was employed to do"!

Emotional labour

The work of a flight attendant – performing a practical service, and also giving passengers a sense of calm and reassurance – has been described as "emotional labour".

There is no manual for emotional labour. Experience teaches you most of what you need to operate as a good cabin crew member. No-one can tell you how to handle a passenger who is travelling home, desperately hoping to get there before someone dies. All you can do is observe them and be ready to act if needed. You know there will be anger if there is a delay, there may be tears being held back, and most of all the desperation of fighting "Time". It is not taught you in the Training School – that is for learning the skills to cope with evacuation, fire, medical emergencies, etc. You may be grieving yourself and what you are witnessing brings it to the fore, but you have to be professional and hide your personal feelings.

"There is no manual for emotional labour."

We used to check in for a flight, then spend the journey to the aircraft bemoaning the management, discussing union fights, or thinking of personal problems. On arrival at the aircraft, however, we all shrugged off our moaning and said "OK, let's go and do this flight and have fun". Ninety-nine percent of the time that worked. I really enjoyed my flying career – there were good and bad days but overall the wonderful crew and passengers you flew with gave you a life that most people couldn't even dream of.

Concorde navigation

Christopher Orlebar, former Concorde pilot with British Airways

Christopher Orlebar explains how navigation was carried out on earlier jet airliners, and how significantly Concorde differed from the first aircraft types he flew commercially.

I joined BOAC in March 1969 from Hamble College of Air Training (top of my course!). As the summer schedule of 1969 was going to use all the VC10s, none would be available for pilot training. In the meantime those in my group we were trained in navigation. In the autumn of 1969 I started on the VC10 pilot conversion course. I left the VC10 at the end of 1975 to start the Concorde course in 1976.

Early devices

In 1962 airliners were not equipped with sophisticated devices such as "Inertial" or "Global" positioning. Even when I started with BOAC in 1969 I had to learn how to use a sextant, a short wave radio and a host of other devices. Three position lines would be drawn on the chart to make a triangle, which by choosing the most suitable sources was as near equilateral as possible. The aircraft's position was assumed to be in the middle of the triangle, where a dot was inscribed.

The sextant was good at night provided there were no cloud cover or turbulence; but in daylight it could only be used with the sun, the moon and maybe Venus. There was an orifice with a door in the roof of the cockpit. To maintain pressurisation the door could only be opened once the sextant was pushed up. It then protruded into the slipstream.

The Doppler radar fitted to BOAC's VC10s and Boeing 707s was good for measuring distance covered; but due to small inaccuracies in the compasses the distance to right or left of the desired track could not be measured accurately. So the law required that a flight navigator was active when crossing regions with sparse radio aids outside further than 200 nms (nautical miles) of pilot interpretable radio navigation aids.

Even at the leisurely pace of a mile every eight seconds (Mach 0.8, 80% of the speed of sound) accurate track-keeping out of radar coverage was not perfect. I well remember a Los Angeles radar controller asking us "Speedbird 123, where the **** do you think you are? Turn left immediately onto a heading of 350". However, flying at Mach 2 – therefore covering a nautical mile every three seconds – in the wrong direction would be serious at best or catastrophic at worst.

Inertial navigation systems

In the early 70s, and due especially to the US Apollo lunar missions, Inertial Navigation Systems (INS) were becoming available for commercial airliners. After being switched on and fed with its initial present position, an INS took about 10 minutes to stabilise. When switched to "navigation mode" it would sum up the accelerations it had detected in any of the three dimensions and for how long. This gave the velocity of its movement and hence, at a given time, its new position.

A view of the stars
A BOAC VC10 (below), and a view of a VC10's flight deck (left). The sextant descended from the ceiling; the cover for the sextant is visible at the top centre of the picture. *Photos: Bahnfriend / Wikimedia Commons (left); Katie John (below)*

On Concorde there were three INS sets. The position due to gyroscopic inaccuracies of each set would be different, but the position appearing on the three coupled together was the median or middle latitude and longitude. This diminished the error; nevertheless after three hours each set could be 10 nms astray.

Avoiding the sonic boom

It was essential not to deposit a sonic boom on the United States. The boom could be heard ten miles either side of a straight track and twenty on the side of a turning track. As the North American coast was approached, accurate navigation became essential.

To this end it was possible to update the position shown by the combined INS sets by use of DME (Distance Measuring Equipment), a radio navigation aid which gave such an accurate measurement that if flown over at a certain altitude it would show that altitude in nautical miles. So when a DME radio was tuned and identified, its distance information could be fed into its INS and used to refine the INS to show a more accurate position. The INSs checked the rate of change in the DME distance indicated. One beacon dead ahead would decrease at the ground speed of the aircraft and vice versa. A DME to the side of the track would decrease until the aircraft was at right angles to that track. Once passed it would increase its reading. This rate of change of distance would be pre-calculated by the INS and rejected for updates if it fell outside certain parameters.

However, on one occasion one of two DME beacons not far apart but over 200 nms ahead was used to refine position. To begin with the INS accepted the rate of distance change and started the process of calculating. As Concorde approached the beacon confident that the updating was valid, the aircraft drifted towards the coast. The crew did not realise they had updated their INSs on the more inland of the two DMEs. This resulted in a sonic boom landing somewhere in the vicinity of Cape Cod.

The American authorities made a fuss; however, although regular loud sonic booms would be unacceptable, one boom is no more harmful than the occasional thunderclap. So the storm died down and a cautionary tale was learnt.

Concorde firsts

Nigel Ferris *looks at some of the ways in which Concorde set or exceeded the standards for commercial aircraft.*

First commercial aircraft to use 'fly by wire' for flying controls. Admittedly not the sophisticated systems of today where the pilot's input to the controls are interpreted by computers, which then decide whether to act on the pilot's instruction, and move the flying control surfaces. Concorde's controls were linked to computers, which then sent electrical signals to the hydraulic units on the PFCs to make the movements. The controls, however, had two safety features: cables were linked from the controls to the PFCs and signalled the electrics to operate the hydraulics; and, should the controls become jammed, sensors would monitor the pilot's pressure input into the controls and send signals accordingly.

First commercial aircraft to use computer-controlled intake ramps, primary nozzles and secondary nozzles to match LP and HP compressor spools, for maximum percentage RPM (according to ambient conditions) for take-off, transonic acceleration and supercruise. This match of intakes, engines, primary and secondary nozzles, with throttle amplifiers and computer-controlled throttles ensured maximum power for all conditions, plus the very efficient use of fuel at high Mach numbers.

First commercial airliner to use the Michelin NZG tyres, as a result of modifications required following the Air France crash at Gonesse. NZG stands for 'Near Zero Growth', where if a tyre is punctured explosions would not result which could send large lumps of rubber into the aircraft structure. These tyres are now an industry standard.

First commercial airliner to use carbon fibre disc brakes (5 in each wheel, 20 per bogie, 40 in total). Better heat resistance, less likely to suffer from fade, far more efficient.

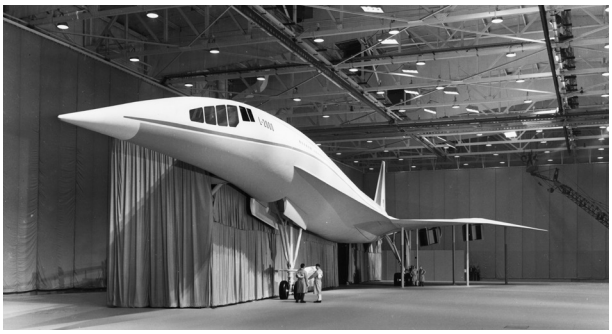
First commercial airliner to use thrust augmentation (reheat, afterburners) for rapid take-off acceleration to rotate speed, and for transonic acceleration to high Mach numbers.

First commercial airliner to fly passengers at Mach 2, 58–60,000 feet, for sustained periods, with passengers able to enjoy fine wines and cuisine during the flight. The only other people likely to be flying higher or faster would be fighter pilots – and they would have to be supplied with oxygen under pressure through a mask – and the NASA shuttle astronauts.

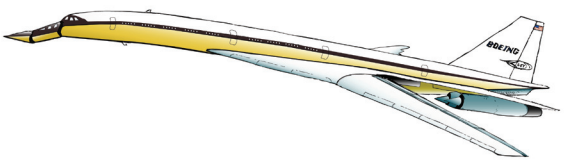
Supersonic rivals

During her life in service Concorde reigned supreme in the sky – but at the start she faced competitors from both the USA and the Soviet Union. Nigel Ferris *takes a look at these rival aircraft.*

The Anglo-French Government agreement between Sud Aviation and the British Aircraft Corporation to build a supersonic transport (SST) was signed on the 29th November 1962. At about the same time, the Russians and Americans both decided to proceed with their own SSTs, and design contracts were issued for these proposals. Tupolev in Russia gained this authority, while in the USA Boeing and Lockheed began their studies, namely the Boeing 2707 and Lockheed L-2000.



Lockheed L-2000
A full-size mock-up of the L-2000-7. This aircraft would have carried at least 230 passengers. *Photo courtesy of the San Diego Air and Space Museum*



Boeing 2707
Early versions of the Boeing 2707 SST concept had swing wings and a double-jointed droop snoot. *Artwork: Katie John*

The Boeing 2707

The victor in the USA was Boeing. Their original design was for a Mach 3 swing-wing aircraft, for 250-300 passengers. This was considerably bigger than Concorde, would have been the longest aircraft ever produced, and as envisaged would have been able to supercruise at Mach 3.

In order to achieve this last feat, the aircraft would have had to be made primarily of titanium. This metal would have been able to withstand the high temperatures over the airframe (as a result of the airflow over the structure undergoing compression). By contrast, the maximum temperature allowed for Concorde at Mach 2 at the pitot tube on the nose was 127 degrees centigrade. Titanium, however, is more difficult to machine than Concorde's aluminium alloy, and much more expensive. (Concorde did use some titanium, as a firewall in each nacelle between the paired engines.) The Boeing aircraft would have had full-length leading edge slats and trailing edge flaps.

The complexity of designing and manufacturing hinge and pivot points for the swing wings, their ability to withstand supersonic cruise, and their strength (and cost) led Boeing to revert to a more conventional fixed-wing design. However, due to cost and other factors, the project was cancelled in 1971.

Swing-wing designs

The swing wing concept is not uncommon. Examples of aircraft with swing wings include the Panavia Tornado, the Rockwell B1a and B1b Lancer, and the Tupolev Tu-160 (NATO codename Blackjack).

The Tu-160 is still in service with the Russian Air Force, regularly getting close to British controlled airspace (prompting the Royal Air Force to send up a couple of Typhoons, and politely telling the Tu-160 to "go away"). This aircraft is capable of Mach 2.05, and has an endurance of 15 hours at Mach 0.77 at 30,000 feet. She employs full-length leading edge slats, and full-length trailing edge flaps for low-speed handling control.

Swing wing in action
A Tu-160 at a display in Moscow, 2013. *Photo © Vitaly Kuzmin / Wikimedia Commons*

The Tupolev Tu-144

The Tu-144 (NATO codename "Charger") first flew on 31st December 1968 – beating Concorde's first flight on 2nd March 1969. It is well documented that this was a lesser design than Concorde, however; at the time there were stories of industrial espionage whereby the English and French allowed 'doctored' blueprints to be passed on, resulting in this flawed design.

Various differences from Concorde were readily observable. The wing shape did not include the complex curves and cambers of Concorde's design. The main undercarriage had 6 main wheels per bogie, as opposed to just 4 on Concorde – this was due to superior tyre and brake technology on the part of Britain and France. The Tu-144 prototypes utilised afterburning turbofans – which meant, due to the size, higher induced nacelle aerodynamic drag. Later models (after much redesign) featured efficient 'canards' on the nose behind the cockpit to improve low-speed handling characteristics, re-positioned engine nacelles, and undercarriage retraction.

The Tu-144 had to employ partial reheat to maintain supersonic cruise (supercruise is defined as maintaining supersonic speed without reheat). Concorde employed twin spool axial flow turbo-jets, with computer-controlled intakes, throttle amplifiers, primary and secondary nozzles, without the need for continued reheat.

Noise in the cabin was a major factor (with passengers sitting relatively close to each other having to pass notes rather than conversing) – due to the engines, air conditioning and the skin cooling system.

The aircraft went into service, but only completed 102 flights in total: 55 as passenger-carrying, the rest as cargo. Whether her non-success was due to design, or the 'espionage' will never be known.

Strikingly different
This front view of the Tu-144 shows the extended canards and the rather simpler delta wing shape that made it so different from Concorde.
Photo © Christian Volpati / Wikimedia Commons

A stretch too far: the Tu-144 tragedy

There has been some conversation on our Mach 2 magazine site regarding the ability of Concorde to execute an 180° turn at Mach 2. Concorde in fact achieved this feat during her last test flight post-Gonesse modifications, while travelling across the big pond with a full complement of passengers (non-paying). It was well within the flight envelope, and not exceeding the aerodynamic restraints or structural integrity of the aircraft – a testament to her design and construction.

This manoeuvre proved to be too much for the Tu-144. At the Paris Air Show in 1973, when Concorde and the Tu-144 were both displaying, the display time of the Tu-144 was cut by half. I am reliably informed that the French sent up one of their fighters to photograph the aircraft showing the canards that had been added as a design feature, aft of the cockpit, to enhance the admittedly poor low-speed handling characteristics. As a result of the French fighter flying too close to the Tu-144, the Soviet pilot had to take emergency action to avoid collision – putting the aircraft into a pitch down attitude. This resulted in a surge in all four engines, leading to flame-out, so the pilot initiated a further downward pitch attitude in an attempt to windmill-start the engines. This failed, and as a result the Tu-144 went into a 1g negative dive. This overloaded the structural integrity of the aircraft, and the left outer wing broke off, causing the aircraft to crash. It is worth noting that Concorde would have survived a 1g negative pitch down attitude.

On display
Tupolev Tu-144S CCCP-77102 displaying at the 1973 Paris Air Show at Le Bourget.
Photo: RuthAS / Wikimedia Commons

An official description of the accident was that a cameraman was present on the flight deck, and dropped his camera into the well at the bottom of the control columns, thereby jamming the controls – so denying the pilot the chance of employing any amount of back stick. Concorde had a system whereby the pilot's input as pressure into the controls (even if they could not be physically moved) would be measured and converted into signals to the PFCs, allowing aircraft control.

The Tu-144 occupies a special place in aviation, as does the Boeing design (although the latter was only ever seen as a wooden mock-up).

Missed opportunities

The purpose of this article is to highlight the technological achievements of Concorde, and serve as a testament to her design and construction, and the unsurpassed contribution she made to British aviation and passenger carrying.

A typical Boeing 747 Jumbo could be expected to achieve a service life of around 25 years – Concorde amassed 27. It is agreed that the hourly usage was far less than for an average mass people carrier, but that contributed to the longevity of the aircraft. Surely Concorde's life in service could have continued for 10-15 years more.

I do not wish, however, to denigrate the Russian or American efforts. Unusually in an article which is a tribute to Concorde, I lament the fact that neither the Russian or American efforts came to offer any real competition. Why? Had the Russians produced an aircraft that could have competed in the global market for SST passenger transport, it is my belief that the Americans would not have allowed the Russians to overtake them in terms of world-beating aircraft production. (Think of the 'Space Race' – America had to beat the Russians to the moon.) They therefore would have pressed on with their project. And if the US SST had gone into production, with subsequent sales to airlines, Concorde and her US and Russian counterparts would not necessarily have been in direct competition with each other. The Russian aircraft would have served the large distances then encompassed by the Soviet Union, with the US aircraft serving the longer worldwide routes, and Concorde serving the (admittedly highly lucrative) trans-Atlantic route (which she did anyway).

So to sum up, this should be taken as a comparison, again highlighting the superb achievement that was Concorde in its own right.

Concorde Watch

Concorde G-BOAB — British production aircraft

Location: Heathrow Airport, London, UK
Reporter: Katie John **Date:** 25 March 2016

Following British Airways' recent engineering open days, at which G-BOAB has been a centrepiece, the airline has recently employed a group of apprentices and graduate engineers to clean and overhaul the aircraft.

As reported in the January 2016 edition of BA's magazine "Up to Speed", the team carried out much-needed refurbishments and repairs; the works included draining water from inside the cabin windows, repainting the landing gear, and removing the old, damp magazines that were formerly stored in the empty cabin.

Further refurbishments and display features have been proposed for the future, including a plan to fit lighting to look like the reheats in action. Best of all, G-BOAB will now remain at Heathrow, to be used to train the next generation of BA engineers in maintenance and repair work, under the guidance of senior engineers and former Concorde specialists. So the future looks bright!

Recent maintenance
G-BOAB in the hangar, having the nose landing gear area painted and the magazines that were used as ballast removed from the cabin (top); back in her usual site (bottom).
Photos: Heritage Concorde

Concorde G-AXDN

British pre-production aircraft

Location: Imperial War Museum, Duxford, UK
Reporter: Graham Cahill **Date:** 25 March 2016

The work being done by Heritage Concorde (HC) and the Duxford Aviation Society (DAS) is due to be completed this year.

Most strikingly, the nose and visor systems are now fully working, and are run from an external power pack supplied by Hydraulics Online (http://www.hydraulicsonline.com). HC have been carrying out 6-monthly inspections of the nose system and have found no major problems. They foresee "many years of trouble-free service" ahead.

The cockpit lighting and audio cockpit warning systems are functioning again. HC found the wiring and systems inside the cockpit area to be in excellent condition.

The landing lights are working, and the navigation lights (now converted to LED) will be functional again soon.

HC plan to restore the appearance of the intakes as far as possible, and to get one set of intake ramps moving for future technical tours.

HC have closed reverse thrust buckets 1 and 4; nos. 2 and 3 remain open, with dummy engine prints inside. HC plan to have bucket no. 3 moving for future Tech tours.

HC are working with DAS to refurbish the cabin so it looks as much as possible as it would have done during the testing programme.

Live displays

- Members of the Duxford Aviation Society carry out demonstrations with G-AXDN on the last Sunday of each month (apart from December), in which they activate the landing lights and then lower the visor and nose, showing the different positions, with a commentary.
- Donations to DAS for work on G-AXDN can be accepted on the aircraft, or made direct to the Society (http://das.org.uk).

Graham Cahill of HC says: "DAS have shown great skill with this sort of project on the rest of the collection, and this work will make Concorde at Duxford one of the most attractive displays. Significant cost is being spent on the new displays, and any donations towards the cost will help with the end result.

I have to say DAS have supported this work now for 3 years; the background work involved has been substantial both for Heritage Concorde and for DAS. The end of the project will see a much improved display of Concorde that will ensure the future of the aircraft.

We would like to thank DAS and the Imperial War Museum (IWM) for the support they have given here."

Access all areas
Clockwise from right: ex-BA engineer John Dunlevy shows off a working navigation light; ex-BA engineer Phil Cairns works on the reverse thrust buckets; the finished buckets (one open and one closed) on display; lighting activated on the flight deck.
Photos: Heritage Concorde

Concorde G-BOAA

British production aircraft

Location: East Fortune, Scotland
Reporter: Katie John **Date:** 25 March 2016

The National Museum of Flight held a ceremony to mark the 40th anniversary of G-BOAA's historic flight to inaugurate Concorde passenger services, on 21 January 1976.

One of Alpha Alpha's tasks on that day had been to carry a haggis from the UK to Bahrain to help the expat community celebrate Burns Night. The museum therefore had a haggis, made by former BBC Professional Masterchef winner Derek Johnstone, piped aboard. Museum General Manager Steve McLean also read out a specially adapted version of Robert Burns' "Address to a Haggis", in honour of the aircraft.

Burns Night tribute
The haggis is piped aboard Alpha Alpha. *Newspaper clipping supplied by the National Museum of Flight*

Concorde F-WTSA

French pre-production aircraft

Location: Musée Delta, near Orly Airport, Paris
Reporter: Graham Cahill **Date:** 25 March 2016

Last year on 14 October representatives from Brooklands, Heritage Concorde, Duxford, and Manchester visited F-WTSA and found that he was in good shape. (For details, see the Heritage Concorde site: http://www.heritageconcorde.com/#!paris-visit-blog/ze07p) Since that visit the enthusiastic team of restorers at the museum have made great strides to improve and restore the aircraft.

The big news is that work has started on the cockpit instrument and panel lighting. So far the team have restored 28v and 5v power to some of the engineer's panel and some of the overhead panel, with more to come soon.

In the cockpit, the fitting of the 14 instruments Brooklands provided for the cockpit restoration last year is moving ahead. In addition Heritage Concorde have provided pre-production dummy Machmeters, and the restoration team are working on other dummy instruments to fill more gaps.

Work is also progressing well to restore the cabin windows, which were allowing water to ingress between the glass panels. The cabin interior panelling is being refreshed and repaired. Cabin lighting is being upgraded and improved, and a full engineers' inspection of the interior structure of the aircraft has been carried out.

The team truly love the aircraft; if you visit you will get a warm reception from some lovely people who are proud to be the custodians of this beautiful aeroplane.

The Musée Delta is currently open on Wednesdays and Saturdays, 2pm to 6pm.

Further details of the work are available on the museum website: http://museedelta.wix.com/musee-delta#!home/c1bc3

Work in progress
A volunteer activates lighting on the overhead panel in the cockpit (left); dummy machmeters ready to fill the holes in the dash panels. *Photos © Musée Delta*