The Elmer A. Sperry Award

1983

for advancing the art of transportation

The Elmer A. Sperry Medal

The Elmer A. Sperry Award

☐ The Elmer A. Sperry Award shall be given in recognition of a distinguished engineering contribution which, through application, proved in actual service, has advanced the art of transportation whether by land, sea or air.

In the words of Edmondo Quattrocchi, the sculptor of the Elmer A. Sperry Medal:

"This Sperry medal symbolizes the struggle of man's mind against the forces of nature. The horse represents the primitive state of uncontrolled power. This, as suggested by the clouds and celestial fragments, is essentially the same in all the elements. The Gyroscope, superimposed on these, represents the bringing of this power under control for man's purposes."

Presentation of

THE ELMER A. SPERRY AWARD FOR 1983

to

Sir George Edwards, *OM, CBE, FRS*
General Henri Ziegler, *CBE, CVO, LM, CG*
Sir Stanley Hooker, *CBE, FRS* (in memoriam)
Sir Archibald Russell, *CBE, FRS*
M. Andre Turcat, *Ld'H, CG*

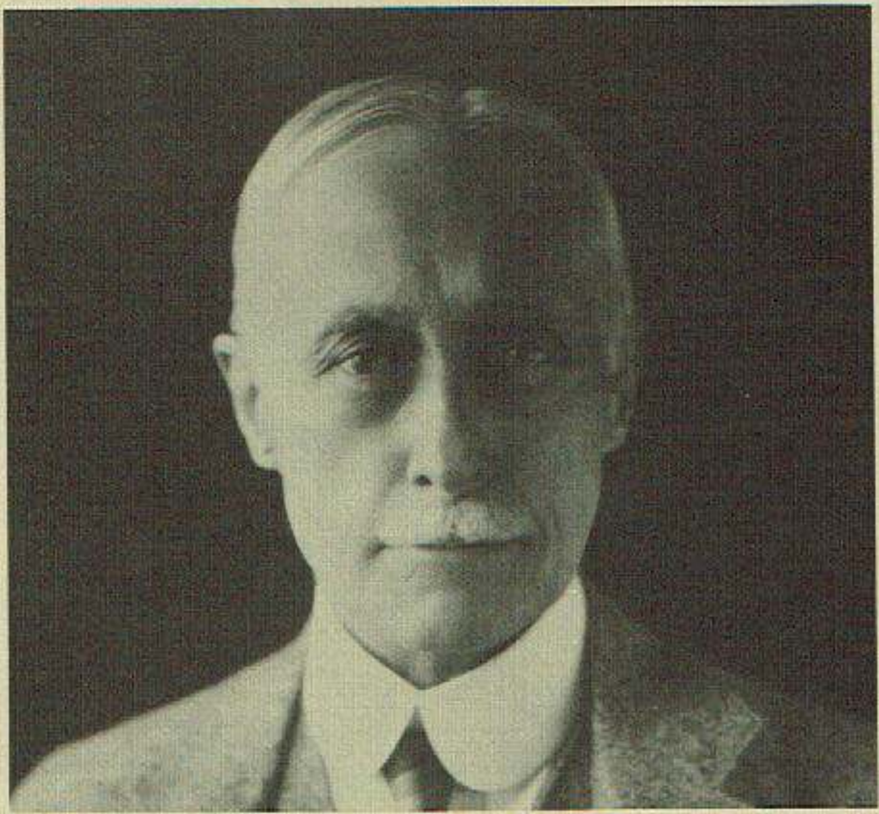
by

The Board of Award under the sponsorship of

The American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers
Society of Automotive Engineers
The Society of Naval Architects and Marine Engineers
American Institute of Aeronautics and Astronautics

At the Banquet during the XIV Congress of the
International Council of the Aeronautical Sciences

Thursday, September 13, 1984 – Toulouse, France



Elmer Ambrose Sperry 1860 – 1930

Founding of the Award

The Elmer A. Sperry Award commemorates the life and achievements of Dr. Elmer A. Sperry (1860-1930) by seeking to encourage progress in the engineering of transportation. Much of the great scope of the inventiveness of Dr. Sperry contributed either directly or indirectly to advancement of the art of transportation. His contributions have been factors of improvement of movement of men and goods by land, sea and air.

The award was established in 1955 by Dr. Sperry's daughter, Mrs. Robert Brooke Lea, and his son, Elmer A. Sperry, Jr.

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AWARD CITATION

To Sir George Edwards, OM, CBE, FRS, General Henri Ziegler, CBE, CVO, LM, CG; Sir Stanley Hooker, CBE, FRS (in memoriam)*; Sir Archibald Russell, CBE, FRS; and M. Andre Turcat, Ld'H, CG; commemorating their outstanding international contributions to the successful introduction and subsequent safe service of commercial supersonic aircraft exemplified by the Concorde.

*Sir Stanley Hooker passed away on May 23, 1984 after his selection as an awardee.

THE ANGLO-FRENCH CONCORDE SUPERSONIC AIRLINER

THE BREAKTHROUGH GENERATION

The Anglo-French Concorde supersonic airliner (Fig. 1) is undeniably a supreme technological achievement by any measure.

Concorde has pioneered international technological innovation and industrial collaboration on a grand scale and has given Europe undisputed leadership in the most advanced field of commercial aircraft development.

It has introduced the biggest step forward in the history of air transport in three principal respects:

1. Concorde is the only form of commercial passenger transport in regular international service capable of sustained cruising at Mach 2 (1300 mph—2092 kph).
2. Concorde more than doubles normal airliner cruise speed and is the first form of transport capable of bringing journey times between the major cities of the world within the compass of 12 hours travel—man's natural day and normal working hours.
3. Concorde incorporates and demonstrates unique technological solutions to unique aeronautical design problems.

As with any endeavor contesting the frontiers of Man's knowledge, Concorde has also created a vital new plateau of aerospace technology—together with a significant reservoir of technological "spin-off" benefits to industry at large.

In gestation as a feasible technical concept since the mid-1950's, Concorde became a formal international collaborative venture by the British and French Governments through their now historic Agreement of November 1962 . . . with the physical Aircraft Program responsibility split between the British Aircraft Corporation (now part of British Aerospace) and Sud-Aviation (now part of Societe Nationale Industrelle Aerospatiale of France) and the engine portions split between Bristol Siddeley (now part of Rolls Royce) in the U.K. and Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA) in France. The agreement specified "on the basis of equal responsibility" which was carried out by alternating leadership in management on a yearly basis (e.g. French leadership one year followed by British leadership the next year followed by French . . . etc.).

Concorde was intended to exploit the benefits of speed and time-saving in the supersonic regime.

In reality, its ability to cruise at twice the speed of sound—faster than

Figure 1: *The Anglo-French Concorde Supersonic airliner*

a rifle bullet—means that long-distance air journey times are halved, thereby setting it in a class apart from all other airliners cruising at a subsonic 600 mph (966 kph). It thus appeals to the "time priority" traveler and complements the much greater number of high-capacity subsonic jets, notably on the key North Atlantic air link, its principal operating mission.

VISION AND ADVENT

Concorde itself stemmed from an emerging belief in the mid-1950's—simultaneously in Britain and France—that the next major advance in international air travel could, and should, be at speeds beyond the so-called "sound barrier". Overcome by the imperatives of military technology in the battle for aerial combat supremacy fostered by the contemporary "Cold War" in Europe, this barrier was no longer considered an impassable obstacle to further significant advances in the prime asset of air transport—speed. The "12 hour world" envisioned in 1958 is shown (Fig. 2).

The diligent pursuance of this concept over the intervening 20 years in the Concorde program, and the massive technical and industrial in-

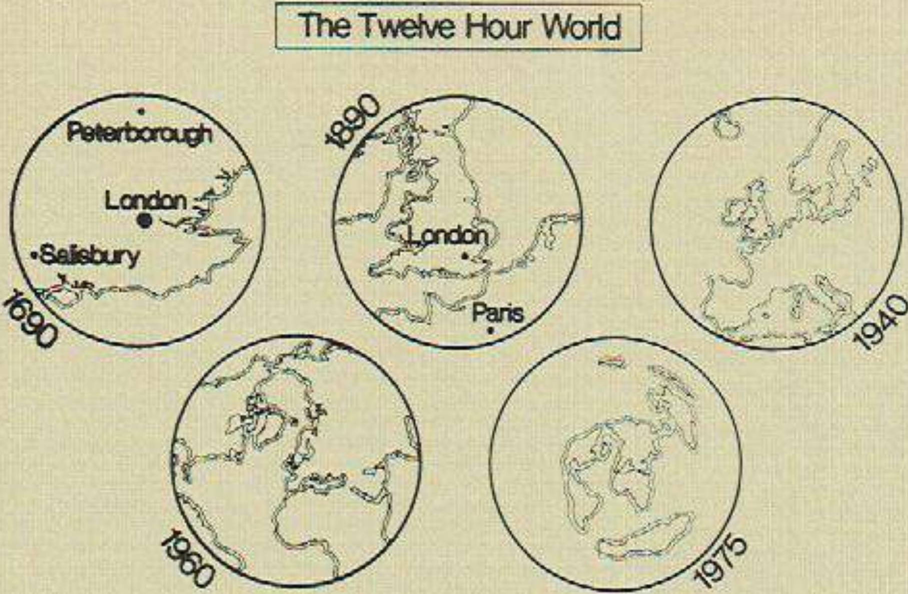

Figure 2: *The 'Twelve-Hour' World. (Sir George Edwards 1958)*

novation that has necessarily resulted, is second only to that of the American Apollo Moon-landing program.

Supersonic research was going forward in Britain, France, the U.S., and the U.S.S.R. in the late 1950's. Some, including that in Britain and in France was specifically aimed toward a supersonic transport aircraft. Numerous technical feasibility studies were made, employing a range of swept, compound-swept, and delta-wing planform shapes. The evolution, in Britain, of the slender ogival delta shape ultimately adopted in Concorde was probably the most significant result of this wide-ranging research and development.

THE MACH TWO DECISION

From the very beginning of all of this work it became increasingly clear that a radical step in virtually all aspects of the design was inevitable and that the first basic decision to be clarified was that of the design cruise speed. Moreover, in any event, three distinct physical design (and verification testing) domains would be involved:

1. Subsonic
2. Transonic
3. Supersonic

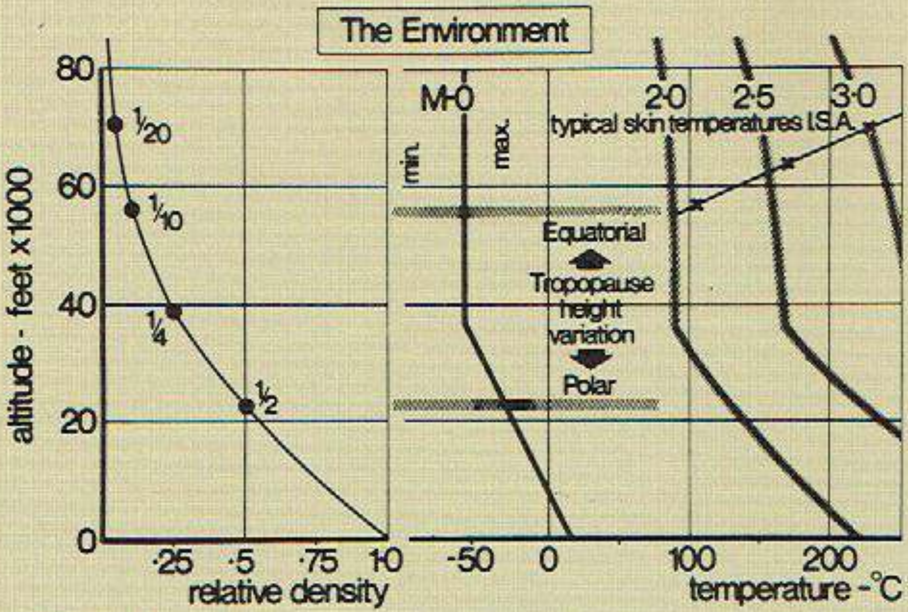

Figure 3: *The physical characteristics of the International Standard Atmosphere—together with the variations in relative density and aircraft skin temperature with altitude and Mach number.*

While much was already known in the late-1950's about military aircraft designed for speeds of Mach 2, nothing at all was known about the Mach 3 regime. Moreover, the cost and development time needed for a Mach 3 airliner study were found to be very much greater than those for the Mach 2 design, principally because of the considerably more exotic materials that would have been involved. Close study of vehicle efficiency, together with the properties of structural materials at the greatly elevated temperatures engendered by the kinetic heating phenomenon (Fig. 3) at these supersonic flight speeds—a completely new factor in commercial airliner design and operation—strongly pointed towards the Mach 2 regime wherein known conventional aluminum—alloy materials could still be used.

It is appropriate to consider each of these interrelated factors in more detail. The dominant aerodynamic characteristic of an SST is its delta wing shape—which had its origins in the pioneering research in Germany towards the end of World War II.

The potential aerodynamic efficiency that could be achieved with the delta wing across the speed range involved indicated that the operating costs of a supersonic airlines could be brought down to a commercially realistic level (considering the low price of kerosene fuel at that time).

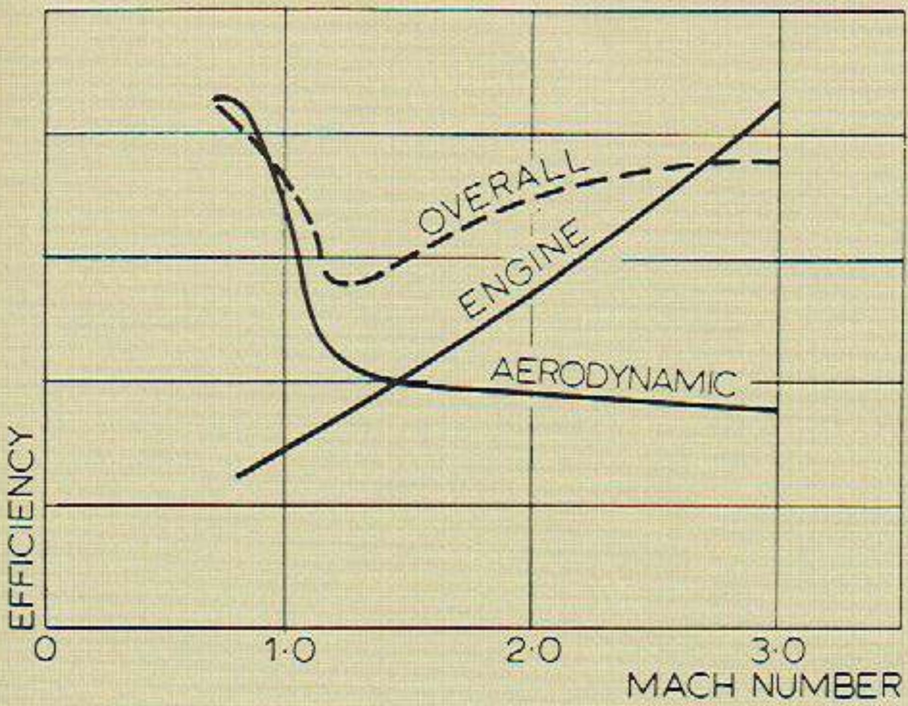

Figure 4: *The Variation of Vehicle Efficiency with Mach Number.*

Overall aircraft efficiency is essentially a function of the aerodynamic Lift/Draft (L/D) ratio of the wing in combination with the propulsive efficiency of the engine (Fig. 4).

If the configuration is optimized for each speed range, the L/D ratio falls sharply from about 18, typical of today's jets cruising at Mach 0.8, to around 10 in the transonic region and then moves slowly to about 8 to 7 in the Mach 2 to Mach 3 speed band. On the other hand, the propulsive efficiency of jet engines increases steadily from around 25 percent at today's subsonic cruise speeds to around 40 percent between Mach 2 and 3.

Combining these two factors, the overall efficiency that was available in the transonic region was recovered by the time Mach 2 was reached, indicating that between Mach 2 and Mach 3, it should be possible from aerodynamic and thermodynamic considerations to produce a vehicle with efficiency approaching that of the subsonic jets of that time period. Hence, attention was focused on this range of speeds.

The possibility of artificially induced fuel price increases, such as those experienced after 1973, was not considered in the program, nor on either side of the Atlantic. The economically damaging results of such artificial escalation (now significantly decreasing) must not be allowed to diminish the technological accomplishments of the Concorde.

On the question of airframe materials, whereas at subsonic speeds the stagnation temperature during cruising flight is of the order of minus 35°C, at Mach 2 the kinetic heating effect raises this temperature to around 120°C; at higher speeds it continues to rise rapidly so that at Mach 3 it exceeds 250°C.

While 120°C could still be tolerated by known and available aluminum alloys, the substantially higher temperatures at Mach 2.5 to 3 would have demanded exclusive use of steel and titanium.

Apart from the much higher cost and more difficult fabrication techniques required, these materials are so strong that relatively small thicknesses would have been required to carry the loads encountered and hence further weight would have to be expended in stabilizing the structure against buckling. This meant that the resulting airframe would have been very much heavier and more expensive.

In addition to the choice of structural materials, the kinetic heating effect also influenced the design of the systems. Weight and complexity—and hence cost—increases sharply in both areas with increasing design temperature. With the payload function of an SST being only about one-twentieth of the fully laden weight, the paramount importance of weight-saving and avoidance of complexity were obvious.

Moreover, the massive extra outlay that would have been involved in the higher speed design band would still have only reduced the trans-Atlantic journey time by around 30 minutes—from three and one-half to three hours—whereas the entire feasible Mach 2 design would halve the subsonic seven-hour journey time.

All these factors pointed to a cruise speed of Mach 2 for a practical long-range SST. Below this speed, overall vehicle efficiencies tended to be too low and above it the additional weight, cost and complexity combined completely to invalidate economic viability within the prevailing state of knowledge.

THE CONCEPTION AND BIRTH OF CONCORDE

Although working from quite distinct backgrounds of supersonic and commercial aircraft experience through the 1950's, there was a remarkable similarity between the approach of the British design team led by Dr. (now Sir) Archibald Russell and the French design team led by Pierre Satre (now deceased).*

*The covenants of the Sperry Board of Award prevent its presentation to a person deceased at the time of selection.

Closer cooperation between British Aircraft Corporation (formed the previous year by a merger of the aviation interests of Bristol, English-Electric and Vickers) and Sud-Aviation was agreed in mid-1961 to study the possibility of adopting a single design.

The first joint BAC/Sud meetings were held in Paris and at Weybridge in June/July 1961 and the formal collaborative agreement came 14 months later. It was entitled:

> "Agreement between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the French Republic regarding the development and production of a civil supersonic transport aircraft."

Signed at Lancaster House in London on November 29, 1962, this formative agreement was not only the first major international collaborative venture in advanced technology to be started in Europe, but also was the precursor of the impressive range of international collaborative aerospace ventures now in being throughout Europe, involving virtually all aspects of the business. British Aircraft Corporation in the U.K. and Sud-Aviation in France were charged with the responsibility for the airframe and Bristol Siddeley of the U.K. and SNECMA of France were to be responsible for the powerplant.

Soon afterwards, the eminently appropriate name "Concorde" was officially adopted by both Governments (although it was to take another five years before the spelling of the name—with a final "e" as in French or without as in English—was clarified; this was on December 11, 1967, when the first prototype Concorde 001 was ceremoniously rolled out at the Sud factory at Toulouse). Andre Turcat, Sud's Flight Test Director, made the epic first flight on March 2, 1969.

ANATOMY OF A CLASSIC SHAPE

The development of the characteristic shape of Concorde (Fig. 5), the choice of engine and powerplant installation, and of the airframe materials were each of considerable significance and interest, especially in the fundamentally new technological concepts which they were to embody.

Wing Design

The primary objective in the design of the Concorde wing was the achievement of maximum aerodynamic efficiency consistent with the conflicting requirements of the speed range involved. Hence the ultimate configuration had to be a compromise, but largely determined by the design Mach number. The higher the Mach number, the higher the angle of sweep-

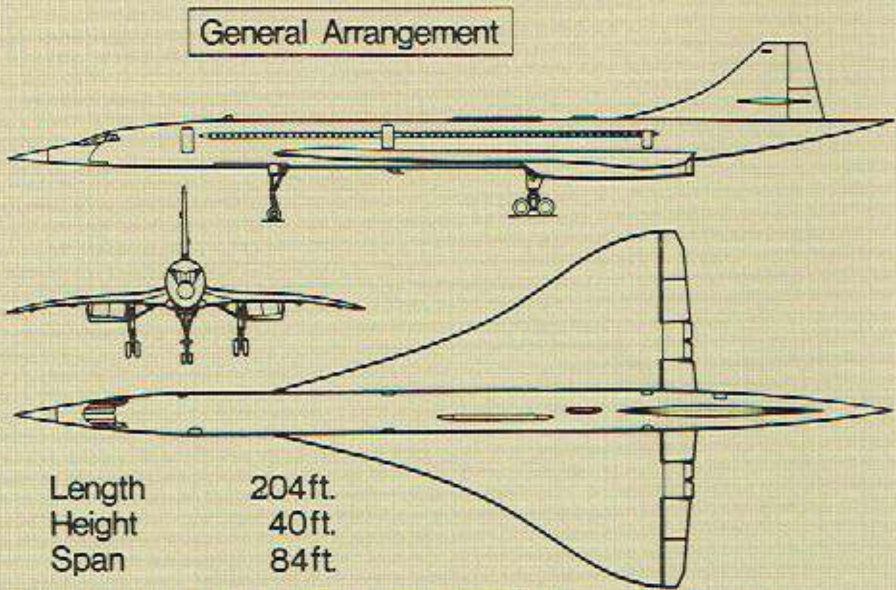

Figure 5: *Three-View General Arrangement Drawing of Concorde.*

back required, and because of the spanwise drift of the boundary layer, the aspect ratio had to be kept small to prevent a large buildup at the wing tip.

In considering the ideal planform for supersonic flight, the point is reached where it is possible to lengthen the root chord of a highly swept wing and straighten the trailing edge for lateral and pitch control placement and thus eliminate the need for a horizontal stabilizer. The result is the "Delta" planform.

A major advantage of this shape is that the greatly lengthened root chord means that the enclosed volume of the wing, and hence the fuel capacity, are considerably increased for a given thickness/chord ratio. The large root chord also means that the delta wing can overcome the disadvantages of lack of structural stiffness and lack of wing volume associated with thin, highly swept wings and yet remain aerodynamically thin.

The sudden drop in Lift/Drag ratio that occurs at around Mach 1.0, as mentioned earlier, is associated with a rearward shift in the Aerodynamic Centre. Experience at speeds beyond Mach 1.2 showed that the fore and aft control problem could be solved by provision of adequate trimming and that the rapid fall in L/D in the transonic regime was checked at around Mach 1.15 and thereafter decreased quite gradually if a suitable delta shape were chosen. The optimum theoretical shape for cruise performance for Mach 2 was found to be a slender delta about three times as long as its semi-span.

For the Concorde mission so far described, the simple "triangle" had unsatisfactory characteristics at low speed and also required further development to meet a number of conflicting requirements implicit in that mission, which can be broadly summarized in four main respects:

- Supersonic wave drag—due to lift and volume—minimized by the use of large wing chord.
- Vortex drag—at all speeds but particularly subsonic—minimized by the use of large wing span.
- Skin friction drag and wing structure weight—each minimized by minimum area and by scrupulous adherence to close tolerance engineering and assembly standards.
- Acceptable control characteristics over the very wide speed range from normal takeoff and landing speeds to Mach 2 cruise.

Satisfying these conflicting requirements led to the development of the now familiar ogival delta wing planform shape and it was found possible to achieve the required L/D with a moderately long fuselage nose.

At the same time, a position for the Centre of Gravity (CG) could be obtained with realistic location of payload and fuel which had to be forward of the subsonic aerodynamic center in low speed flight and coincident with the center of lift in supersonic cruise. It was also found that the distance between these centers could be substantially reduced by suitably shaping the triangle to a curved ogival shape, with increased sweep-back at the root and tip. By using curved "streamwise" tips, and extending the root fillets forward, it became possible to ensure attachment of the leading edge vortex sheet—which is formed naturally on this type of wing—right down to and below the "stall" (Fig. 6).

The resulting "separated flow" wing has a very important additional aerodynamic characteristic in that it does not have a stall in the generally accepted sense; the development of these vortices means that the stall angle is so large that it is impossible to reach a stalled condition in any reasonable condition of flight. At the minimum control speed, the attached vortex increases lift by as much as 30 percent in free air and twice as much in the "ground cushion". It thus acts as a "variable area wing" without the attendant problems of a mechanical system—other than the need for an automatic throttle control to cope with speed instability.

The flow development is smooth with increase in incidence and so is the lift and pitching moment. The flow also changes smoothly with Mach number. There are therefore no abrupt changes in aerodynamic characteristics through the operating range of incidence and Mach number.

However, because of the rearward shift of aerodynamic center of pressure as the aircraft passes through the transonic acceleration phase, sub-

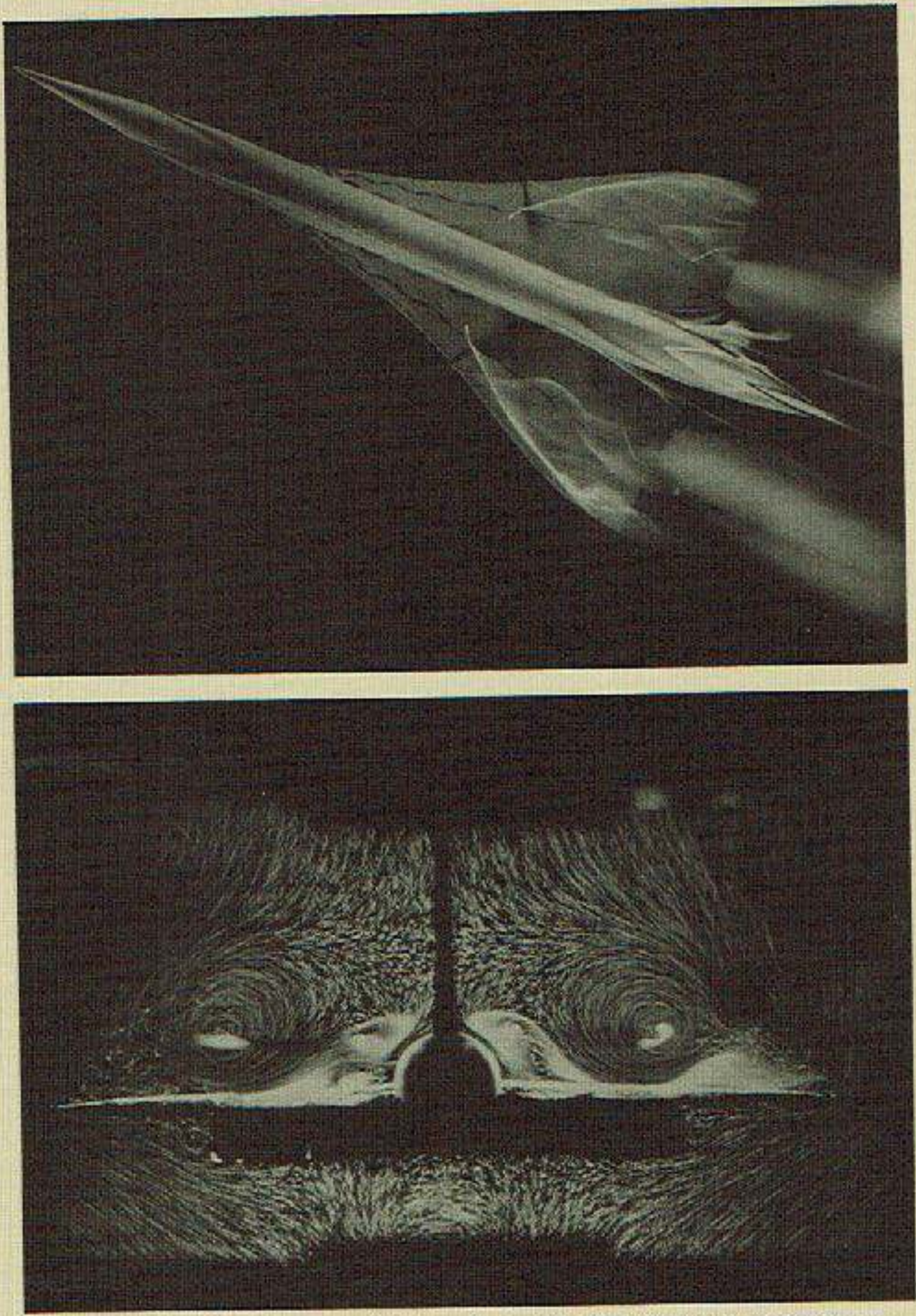

Figure 6: *The Characteristic Low-Speed 'Rolling Vortices' of the 'Separated Flow' Pattern over the Concorde Wing as Visualised in a water tunnel.*

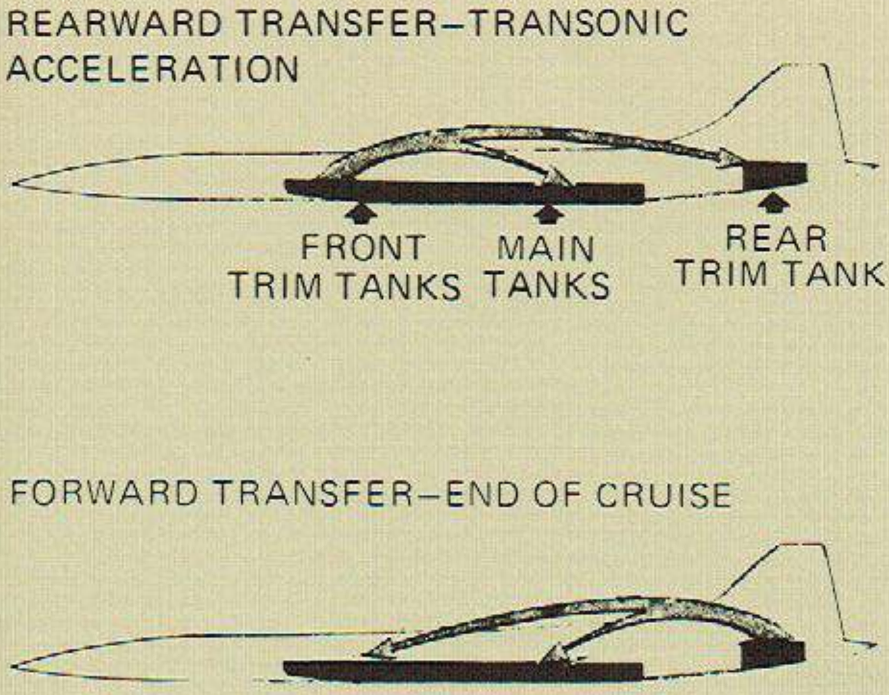

Figure 7: *Concorde's Special Fuel Transfer System Used to Control the Aerodynamic Trim Change that Occurs During Transonic Acceleration and Deceleration.*

stantial retrimming becomes necessary. Retrimming by use of the aerodynamic controls has to be avoided to minimize drag.

This is achieved on Concorde by transferring fuel from a group of tanks forward of the center of gravity to a tank in the rear fuselage (Fig. 7). After supersonic cruise, the fuel is transferred forward again to restore the subsonic CG position. All the trim fuel is usable, being part of the total fuel load.

In the necessity to optimize the fuel load—taking into account both supersonic and subsonic performance—the low speed regime is especially significant in the Concorde mission. The final shape of the aircraft has also resulted in a pattern of holding and approach performance that is comparable to current subsonic jets. Hence, as its now extensive service flying has shown, Concorde is readily integrated with existing air traffic control and airport procedures.

Fuselage

The technical demands of the operating domain of Concorde have also resulted in a slim and sleek payload carrier. Since frontal area is very

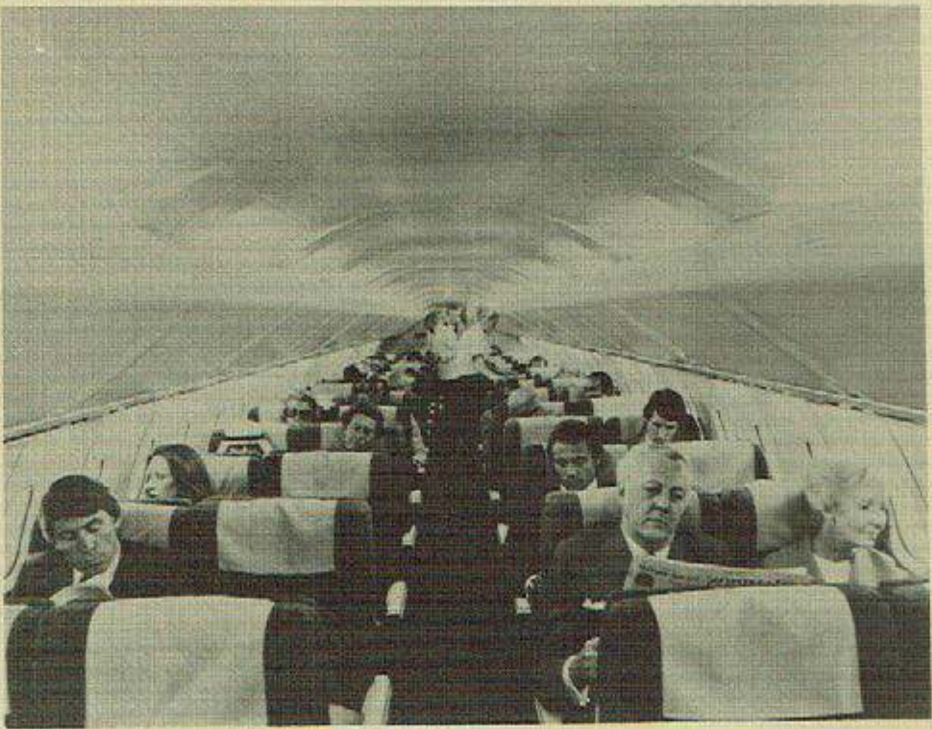

Figure 8: *Concorde's Passenger Cabin*

expensive in terms of supersonic drag, the fuselage cross-section is a minimum consistent with four-abreast seating.

Sized to provide a natural growth in productivity compared to first generation intercontinental jets, Concorde carries between 100 and 108 passengers.

Despite the severe technical and operational restraints, and the inability fully to exploit "sculpturing" techniques in the design of the fixed furnishings, a most attractive and space-efficient interior concept was evolved (Fig. 8).

The external stagnation temperature of the air at cruise of around 120°C has to be reduced to around 20°C inside the passenger cabin. Hitherto, only super-fit and highly trained military aircrew provided with sophisticated flight clothing, life-support equipment and survival apparatus could fly supersonically. Hence the creation of a normal "lounge suit" passenger environment was a completely new problem in commercial airliner design.

Because Concorde cruises about one and one-half times as high as today's intercontinental jets—at 50,000 to 60,000 feet (15,240 to 18,290 m)—

a maximum cabin working differential pressure of 10.7 lb./sq.in. (0.75 kg./sq. cm.) became necessary.

While all of these factors greatly accentuated the physical problems of the design of the interior, the drastically reduced journey times effectively equate Concorde operation to that of a short-haul jet. However, this has not resulted in significant relaxation in comfort or environmental standards.

All delta wing aircraft have a relatively high angle of incidence at slow speeds, including approach and landing. Improvement of pilot visibility for Concorde was achieved by hinging the nose section downwards and by lowering the transparent visor—another completely new requirement for a commercial aircraft. For landing, the nose is in the fully drooped position ($-12½°$) and for taxiing and takeoff, it is in the intermediate ($-5°$) drooped position. The visor is fully raised for high speed flight to give a clean aerodynamic shape by covering, and hence "fairing off", the windshield. It also protects the windshield from the effects of kinetic heating.

The Propulsion System

The choice of engines for Concorde also involved the resolution of many conflicting requirements.

Essentially these were that it should have a high specific thrust for takeoff, transonic acceleration and supersonic cruise, together with low fuel consumption in both supersonic and subsonic conditions. A very high pressure ratio would have given a low powerplant weight, but would have resulted in an excessive turbine entry temperature. A high bypass ratio engine could have shown improved fuel consumption at subsonic speeds, but with its lower specific thrust and large frontal area would have been very inefficient at supersonic cruise speeds.

Consequently, a moderate pressure-ratio turbojet with a cooled turbine was chosen because at supersonic speeds a substantial compression occurs in the nacelle intake and therefore the pressure ratio required from the engine itself is much lower.

Such an engine could be made available in the required size by development of the Bristol Siddeley "Olympus" military turbojet for supersonic operation. This was already in production for the BAC TSR-2 supersonic bomber under the direction of Sir Stanley Hooker.

The commercial version of this engine—the Olympus 593—with a compressor pressure ratio of 11.3:1 at the design cruise condition of Mach 2 at 60,000 ft. ISA $+5°C$, combined with a small frontal area and low overall powerplant weight, has proved to be an excellent choice for Concorde. Nevertheless, it was a major development. Its thrust was increased partly by modifying the compressors and partly by using the high turbine entry temperature permitted by the cooled turbine essential for sustained cruis-

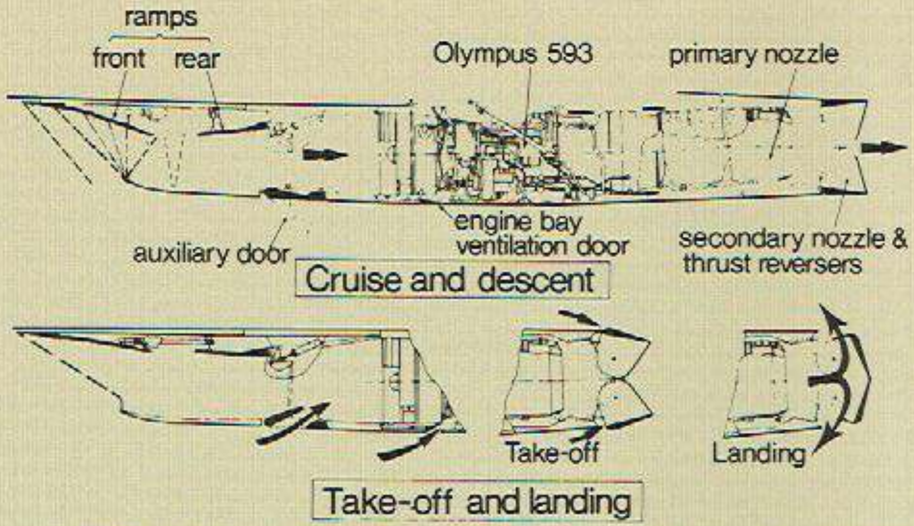

Figure 9: *Powerplant Arrangement and Sequence of Operation of Variable Geometry Air Intake and Exhaust Systems.*

ing at supersonic speeds. A prevaporization type annular combustor virtually eliminates all smoke emission by ensuring more complete combustion of the fuel/oxidant mixture.

As well as this major development in the engine itself, the need to present ambient air to the engine at around half the speed of sound at all conditions of flight meant the development of a sophisticated variable geometry intake system ahead of the engine—plus a variable operation exhaust system behind (Fig. 9). Here again was a design situation completely new for a commercial airliner.

The location of Concorde's powerplant under the wing ensured that the intakes were in a region of minimum-thickness boundary layer and favorable pressure fields, and changes in intake flow direction during takeoff and final approach were minimized. Additionally, it made for ready accessibility for ground servicing.

A sophisticated, reliable and compact electronic intake control system had to be developed to match intake, engine and aircraft operating conditions.

Due to the wide operating speed range, the intake/exhaust systems had to be carefully matched to the engine. To meet the engine air demands, variable area intakes were required to enable the engine compressor inlet to be presented with a subsonic airflow and to ensure maximum pressure recovery at all flight speeds. Thus the engines were arranged in pairs in rectangular cross-section nacelles giving substantially two-dimensional flow in the intake ducts, and to simplify the mechanical control. At the same time, the now widely fashionable "Fly-by-Wire" (FBW) control technique was also introduced.

The convergent/divergent intake duct was formed by means of movable ramps in the roof of the duct and a spill door, incorporating intake flaps, in the floor of the system. The front ramp causes the formation of a shock-system to reduce the speed of the inlet air with respect to the aircraft to just below the speed of sound. The air is further decelerated in the divergent duct formed by the rear ramp. During takeoff, the ramps are fully raised and the flaps in the spill door automatically open inwards to provide maximum airflow to the engine. At speeds above Mach 1.3, the ramps start to lower automatically to control the position of the shock waves and achieve the required reduction of air velocity at the engine face. During Mach 2 cruise, Mach 0.45 conditions thus prevail at the compressor inlet with a pressure equivalent to about seven times ambient.

A variable convergent/divergent exhaust system was also essential for thrust and performance optimization at all conditions, and a reheat system was used to provide thrust boost at takeoff and during transonic acceleration.

The exhaust assembly comprised a variable area primary nozzle and a combined secondary nozzle with reverser buckets and retractable "spade" type silencers inside. This assembly forms a monobloc structure for each pair of engines. The two "clamshell buckets" at the rear of the unit perform the dual function of variable secondary nozzle and thrust reverser. This latter is also used to reduce airport noise by the action of the secondary nozzle on the exhaust jet stream.

The Thermal Problem and Materials

For reasons already discussed, the primary airframe constructional material for Concorde is aluminum alloy.

However, the thermal problem is a complex one. Because the creep-resistance of these materials falls rapidly with increasing temperature, the strongest types were not suitable. Hence it was decided to adopt the more conservative aluminum/copper alloys of a type long used for engine components—since become known as "Hiduminium RR 58" in Britain and "AU2GN" in France.

In addition to these considerations of basic material choice, exceptional care was taken in the structural design process to take account of thermal stresses.

While the external skin temperature of Concorde's wing at the hottest point is raised to around 120°C at supersonic cruise, the internal structure only picks up heat by conduction, thus putting the skin into compression and the internal structure into tension. Special provisions, such as pin-

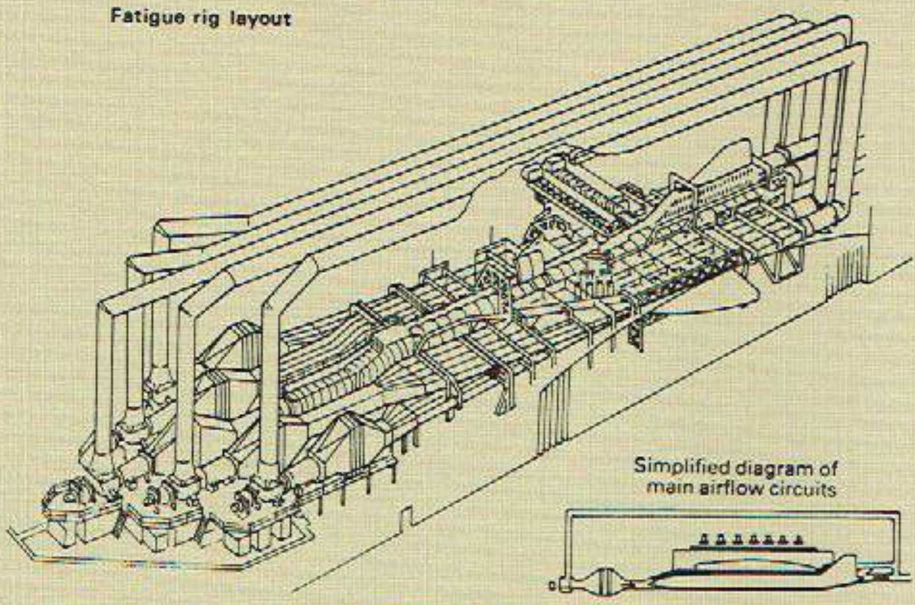

Figure 10: *The Full-Scale Concorde Airframe Thermal Test Rig Facility at the Royal Aircraft*

jointed attachments and fluted webs, were used to relieve the resultant strains.

All these problems of thermal fatigue have been studied by carefully simulated tests in which a complete Concorde airframe, located in a major thermal test facility at the Royal Aircraft Establishment (RAE) Farnborough (Fig. 10), was subjected to alternate heating and cooling cycles to represent flight conditions in conjunction with the more usual mechanical loadings. This complemented the static loading test airframe at the Centre d'Essais Aeronautique de Toulouse (CEAT) facility.

Analogous considerations and provisions were also made in the design of the systems, all of which have also been subjected to rigorous full-scale facsimile testing.

ENVIRONMENTAL EFFECTS

The difficulties of designing a supersonic transport largely result from the characteristics of the physical environment—the atmosphere up to an altitude of about 20 km (65,616 feet)—on the airplane, rather than what is more popularly discussed the other way around, and this had already been discussed in the context of the principal design features involved (Fig. 3).

However, concern about the possible impact of the SST on the environment has been widely expressed in three main areas:

- High Altitude Effects
- Pollution
- Noise and the Sonic Boom

It was suggested that supersonic operations in the stratosphere could cause serious disturbance to the natural balance and structure of the atmosphere and so produce considerable changes in the Earth's climate—most notably damaging effects on the ozone layer which protects the Earth against ultraviolet light. The great volume of aircraft operation, both supersonic and subsonic, already in the stratosphere has produced no discernible adverse effects on the climate. Moreover, scientific and mathematical rather than emotional analysis has revealed little evidence to support the forecasts of these alleged effects in the stratosphere and monitoring does, in any event, provide an absolute safeguard.

Concorde has demonstrated that it can operate into and out of existing airports without special attention.

The "sonic boom" phenomenon is the principal new problem associated with supersonic transport operation. The intensity of the boom depends mainly on two factors: the weight at which the aircraft is flying and its altitude. The heavier the aircraft, the greater the intensity of the boom that it is capable of generating. The higher it is flying, the more the boom will be attenuated by the time the sound pressure wave reaches the ground.

Evidence so far is that Concorde's sonic boom is unlikely to cause physical damage, nor does it cause material damage to any reasonably well-maintained structure. Whether or not the boom is socially acceptable has to be a decision by governments, taken in light of public opinion. Concorde's manufacturers have always assumed that supersonic flight would only be permitted over the oceans and overland by national governments over areas of sparse population and the large and uninhabited deserts which form a considerable element of the Earth's surface. In this context, it is significant that between 75 and 80 percent of today's intercontinental seat-miles are, in fact, flown over the sea.

THE INDUSTRIAL BENEFITS

As well as the very significant technological innovations already discussed, the scope of the benefits of the Concorde program in terms of new manufacturing techniques and processes and technological advance throughout industry generally have also been considerable.

In this respect, there is clear evidence that the great advances in the use of numerically controlled machine tools and in electrochemical machining have been stimulated by work on Concorde. There are also comparable advances in manufacturing techniques, such as electron-beam welding and the use of laser beams in the working of titanium.

Again, the materials and precision and medical equipment industries have benefited substantially from research and development initiated specifically for Concorde—such as titanium, plastics, glass, lubricants, paints, seals and plumbing techniques, miniaturization, electric motors and actuators, brakes and antiskid devices, and thermal controls.

THE GREAT COLLABORATION

The task of organization and management that stemmed from the Anglo-French agreement of 1962 was unprecedented in the aerospace business, not only because the aircraft was to be developed on a collaborative basis, but also because of its sheer advance and complexity.

Grappling with the problems of working with two frequently changing national governments and policies, two languages, monetary and measurement systems; two design, assembly and flight test centers separated by physical and national barriers 600 miles apart; and the coordination of around 800 subcontractors and suppliers—were the principal challenges of collaboration and program management. The coordination of activity on this scale was clearly a formidable management task.

In addition to specifying the allocation of development and manufacture, the 1962 Treaty also laid down the principles of the basic organizational structure for the program.

This meant that, whereas the day-to-day management was necessarily the responsibility of the manufacturers, officials of the two governments played a complementary supervisory role. Hence appropriate boards of management were established at both government and industrial levels. In addition, as previously noted, the agreement of 1962 was "on the basis of equal responsibility" which led to alternating leadership roles.

The progress of the program from conception to hardware was strongly influenced by the interplay of the personal characteristics of its industrial leaders.

The two principal industrial leaders—Sir George Edwards of BAC and General Henri Ziegler of Aerospatiale—built on the long working relationship which they had had since they first worked together in 1952 when Sir George was head of Vickers-Armstrongs (Aircraft) and selling Viscount prop-jets to Air France which General Ziegler headed at that time. Later they worked closely together again on the BAC-Breguet Jaguar miltary strike/trainer aircraft program when General Ziegler was in charge of Breguet Aviation. He became President of Aerospatiale in 1968 and made a major impact on the Concorde program during the critical period from prototype first flight to the initiation of the customer contracts.

NEW HORIZONS

The spearheading concept of Concorde has lifted transport aircraft technology to a new plateau. In turn, it will undoubtedly stimulate new horizons in future generations of air transport development in the 21st Century.

As has been repeatedly emphasized, Concorde involved large extrapolations from existing knowledge in numerous areas simultaneously—with no large-size long-range military predecessor to pave the way.

This Elmer A. Sperry Award recognizes that, of the several teams that investigated the possibility of supersonic air transport, only the one represented by the recipients succeeded in bringing the aircraft through development into production and sustained international passenger service (Fig. 11).

Figure 11: *The British Airways and Air France Concordes Seen Together at Washington DC at the Inauguration of Trans-Atlantic Concorde Services (from London and Paris) on May 24, 1976.*

SIR GEORGE EDWARDS, O.M., C.B.E., F.R.S.

Sir George, born on July 9, 1908, joined Vickers-Armstrongs at Weybridge at the age of 27, working in the Experimental Design and Drawing Offices until the outbreak of war in 1939, when he was appointed Chief Designer and was head of the design team responsible for the Viking, Valetta, Varsity, Viscount, and the Valiant bomber.

On being appointed Managing Director of Vickers-Armstrongs (Aircraft) Ltd. in 1953, he continued to be responsible for the overall technical direction of the company, and for the Vanguard, VC 10 and TSR 2. He was awarded the MBE in 1945, the CBE in 1952, and was knighted in 1957.

In May 1961, Sir George, as Executive Director (Aircraft) of British Aircraft Corporation, and overall technical leader of the aircraft design teams, initiated the BAC One-Eleven short-haul jet airliner—the first product of the new corporation. Sir George took a prominent part in the negotiations which led, in November 1962, to the Concorde supersonic airliner (with Aerospatiale of France), and has since played a continuing and leading role in its vast program. More recently, he has also been prominent in the Anglo-French Jaguar aircraft program and the Anglo-German-Italian Panavia MRCA (Multi-Role Combat Aircraft).

In November 1963, Sir George was appointed Chairman of British Aircraft Corporation Limited. He relinquished the post of Managing Director of the Company in November 1972.

In 1971, Her Majesty the Queen bestowed upon Sir George the Order of Merit. This honor is the personal gift of the Queen, and the Order is limited to 24 members.

Other honors bestowed upon Sir George include Fellowships of the Royal Society, Hon. Fellowships of the Royal Aeronautical Society and of the American Institute of Aeronautics and Astronautics, the Guggenheim Gold Medal for Pioneering in Aviation, the George Taylor Medal, the Gold Medal of the Royal Aeronautical Society, and the Air League Founders Medal. He was awarded the Albert Gold Medal by the Royal Society of Arts in 1972. In July 1974, the Institute of Sheet Metal Engineering awarded him its first Silver Jubilee Medal.

In November 1974, Sir George Edwards was honored by the award to him of one of the three Royal Medals of the Royal Society for that year.

Sir George has also been President of the Royal Aeronautical Society, Vice President and Council Member of the Royal Society of Arts and he has been Pro Chancellor of the University of Surrey since 1966. He is an Honorary Doctor of Science of Southampton, Salford, London, and City Universities and Cranfield Institute of Technology. He is an Hon. Fellow of the Manchester Institute of Science and Technology and received an Honorary Doctorate of Law from Bristol University in July 1973.

HENRI ZIEGLER, C.B.E., C.V.O., GRAND OFF. LEG. D'HONNEUR, OFF. LEG. OF MERIT, CROIX DE GUERRE

Born on November 18, 1906 at Limoges, Henri Ziegler, after graduation from Ecole Polytechnique in 1926 and Ecole Superieure de l'Aeronautique in 1931, rose to become one of the best known French aviation executives. During his early career he qualified as an airplane and seaplane pilot and also as a test pilot.

In 1938, he was appointed Deputy Director, Centre d'Essaies en Val and a year later he became Assistant Director of the French Purchasing Mission in America, in charge of the purchase of U.S. aircraft for the French Forces.

During World War II, 1941-1944, in Europe, he was active in the underground resistance in French occupied territory, and in April 1944, was named Chief of Staff of the French Forces of the Interior in London.

After the war, he was appointed Dir.-Gen. Air France from 1946 until 1954, and then Chief of Cabinet to three French Government Ministers. A number of senior industrial appointments followed, including Dir.-Gen. Breguet Aviation, 1957-1967, Pres. Dir.-Gen. Sud-Aviation and Aerospatiale, 1968-1973, and Founder and Admin., Gerant Airbus Industrie, 1970-1975. During this period, he did much to promote European collaboration and played a leading role in the development of aircraft, such as Atlantique, Jaguar, Concorde, and Airbus, in addition to his contributions to the development of helicopters, missiles, and space systems.

Henri Ziegler was elected President of Groupement des Industries Francaises Aeronautiques et Spatiales, 1971-1973, and throughout a very busy life has maintained his interest in mountaineering. For his achievements, he has been awarded many French and foreign decorations including Grand Officier Legion d'Honneur, Croix de Guerre, Rosette de la Resistance, Legion of Merit, C.B.E., and C.V.O. He also is an Honorary Fellow of the Royal Aeronautical Society, and the Society of Experimental Test Pilots.

SIR STANLEY HOOKER, C.B.E., F.R.S., FRAeS

Born in 1907, Sir Stanley Hooker was one of Britain's most respected aero-engine designers. He joined Rolls-Royce Ltd. in 1938 after graduation at London and Oxford and a period of research in fluid mechanics and rockets with the Admiralty. As a key member of the pioneering design and development team responsible for the Whittle and early Rolls-Royce centrifugal compressor jet engines, his contributions culminated in the Nene in the early 1940's.

Upon moving to the Aero Engine Division of the Bristol Aeroplane Company in 1948, he became Chief Engineer in 1951; Technical Director of Bristol Siddeley Engines on its formation in 1959; Technical Director of Rolls-Royce, Bristol Engine Division, after the merger between Bristol Siddeley and Rolls-Royce; and ultimately Group Technical Director of Rolls-Royce Ltd. from 1971 until 1977. During this period, he was associated with many British engines used worldwide and, in particular, the Olympus jet engine for the Concorde, and the Pegasus vectored thrust turbofan for the Harrier.

He has received many awards from European countries, from China, and the Goddard Medal from the American Institute of Aeronautics and Astronautics in 1969. He is a Fellow of the American Academy of Engineering and an Honorary member of the American Society of Mechanical Engineers. He was awarded the CBE in 1964, knighted in 1974, and elected a Fellow of the Royal Society in 1962.

SIR ARCHIBALD RUSSELL C.B.E., F.R.S., F.ENG., HON. F.R.Ae.S.

Sir Archibald, born in Wotton-under-Edge, Gloucestershire, in 1904, subsequently graduated from Bristol University in 1924. A peak in his career was reached when he became a British leader in the Concorde program.

He joined the Bristol Airplane Company, Ltd. in 1925 and progressed to successively more responsible positions until assuming the post of Technical Director. He also carried several technical and engineering executive responsibilities before becoming Chairman of the Filton Division of British Aircraft Corporation in 1969. During these years, he was accepted as a leading authority on airframe structural engineering and was centrally involved in the design of a long line of Bristol aircraft from the famous wartime Blenheim and Beaufighter through to the post-war Britannia airliner. His contributions to the pre-war Bristol high altitude record-breaking monoplanes and the post-war Bristol Brabazon, a large experimental eight-engined airliner, were also substantial.

In 1956 interest was stimulated by an official investigation organized to establish the feasibility of supersonic airliners. Work was to be shared between the official establishments and industry. In the subsequent design competition, Bristol submitted a M2 airliner with trans-Atlantic range and it was selected as a base for possible international competition. The time coincided with the formation of the British Aircraft Corporation.

Arrangements then made for joint Anglo-French control of the Concorde were inevitably complicated, formalized and duplicated and with hindsight seen to be necessarily so. But circumstances changed when the potential airlines, with options, played a direct part in determining the detail specifications and arrangements of the final version.

When Concorde was at last ready for those airlines to operate the guaranteed payload, speed and range had been demonstrated, but the intervening rise in fuel costs and general inflation had distorted the economics.

As one of Britains most notable aircraft designers, Sir Archibald has received numerous awards, including the Daniel Guggenheim Medal in 1971, and delivered major papers in the USA, beginning with the Wright Brothers Lecture in Washington in 1949, as well as many others in U.K. He was knighted in 1972 and elected a Fellow of the Royal Society (FRS) in 1970.

ANDRE TURCAT, OFFICER LEGION D'HONNEUR, CROIX DE GUERRE

Born in Marseilles on October 21, 1921, Andre Turcat inherited the Turcat car family name, his father having produced the Turcat-Mery cars. He is best known as the Vice President of Flight Test and Chief Test Pilot of Sud-Aviation (now Aerospatiale) of France, who commanded the first flight of the first Anglo-French Concorde supersonic airliner 001 at Toulouse in Southern France on March 2, 1969, thereafter playing a major role in the flight development of Concorde throughout the world.

An engineering graduate of the Ecole Polytechnique in 1942, he began his pilot training in September 1945, qualifying as a navigator and a pilot in 1947. He served in the French Air Force from 1945-1953, with his last position being Director of the French Test Pilots School. He retired from the service with the rank of Colonel.

In 1953 he joined SFECMAS, later absorbed by Nord-Aviation, where in 1954 as Chief Test Pilot, he became the first Frenchman to reach Mach 1 in level flight in the "Gerfaut" experimental delta-winged jet.

On February 25, 1959, he set an international speed record of 1,018 miles per hour (1,638 Km/hr) over a 100 Km closed circuit in the Nord "Griffon" 60-degree delta with a novel turbo-ramjet powerplant, reaching Mach 2.19 (1,448 mph—2,330 Km/hr) in the same aircraft. Eight months later these achievements earned him the Harmon Trophy presented in Washington.

In 1962, he joined Sud-Aviation where he led the flight development of the Sud-Lear automatic landing system in a Caravelle airliner. Appointed Flight Test Director of Sud-Aviation in September 1964, he thus became involved in the Concorde development program from the outset.

Andre Turcat's logbook details almost 5,000 flying hours on 90 aircraft types. He is an officer of the Legion of Honour (1962) and holder of the Croix de Guerre, the Gold Medal of the Aero-Club of France and the Academy of Sports.

Andre Turcat retired from flying on March 31, 1976. He was Deputy Mayor of Toulouse from 1971 to 1977 and a Member of the European Parliament in 1980 and 1981.

Previous Elmer A. Sperry Awards

1955 to *William Francis Gibbs* and his Associates for development of the S.S. United States.

1956 to *Donald W. Douglas* and his Associates for the DC series of air transport planes.

1957 to *Harold L. Hamilton, Richard M. Dilworth and Eugene W. Kettering* and Citation to their Associates for the diesel-electric locomotive.

1958 to *Ferdinand Porsche* (in memorian) and *Heinz Nordhoff* and Citation to their Associates for development of the Volkswagen automobile.

1959 to *Sir Geoffrey De Havilland, Major Frank B. Halford* (in memoriam) and *Charles C. Walker* and Citation to their Associates for the first jet-powered aircraft and engines.

1960 to *Frederick Darcy Braddon* and Citation to the Engineering Department of the Marine Division, *Sperry Gyroscope Company*, for the three-axis gyroscopic navigational reference.

1961 to *Robert Gilmore Letourneau* and Citation to the Research and Development Division, *Firestone Tire and Rubber Company*, for high speed, large capacity, earth moving equipment and giant size tires.

1962 to *Lloyd J. Hibbard* for application of the ignitron rectifier to railroad motive power.

1963 to *Earl A. Thompson* and Citation to his Associates for design and development of the first notably successful automobile transmission.

1964 to *Igor Sikorsky* and *Michael E. Gluhareff* and Citation to the Engineering Depártmet of the Sikorsky Aircraft Division, *United Aircraft Corporation*, for the invention and development of the high-lift helicopter leading to the Skycrane.

1965 to *Maynard L. Pennell, Richard L. Rouzie, John E. Steiner, William H. Cook* and *Richard L. Loesch, Jr.* and Citation to the Commercial Airplane Division, *The Boeing Company*, for the concept, design, development, production and practical application of the family of jet transports exemplified by the 707, 720, and 727.

1966 to *Hideo Shima, Matsutaro Fujii* and *Shigenari Oishi* and Citation to the *Japanese National Railways* for the design, development and construction of the New Tokaido Line with its many important advances in railroad transportation.

1967 to *Edward R. Dye* (in memoriam), *Hugh DeHaven* and *Robert A. Wolf* and Citation to the research engineers of *Cornell Aeronautical Laboratory* and the staff of the Crash Injury Research projects of the *Cornell University Medical College*.

1968 to *Christopher S. Cockerell* and *Richard Stanton-Jones* and Citation to the men and women of the *British Hovercraft Corporation* for the design, construction and application of a family of commercially useful Hovercraft.

1969 to *Douglas C. MacMillan, M. Neilsen* and *Edward L. Teale, Jr.* and Citations to Wilbert C. Gumprich and the organizations of *George G. Sharp, Inc., Babcock and Wilcox Company*, and the *New York Shipbuilding Corporation*, for the design and construction of the N.S. Savannah, the first nuclear ship with reactor, to be operated for commercial purposes.

1970 to *Charles Stark Draper* and Citations to the personnel of the *MIT Instrumentation Laboratories*: Delco Electronics Division, *General Motors Corporation*, and Aero Products Division, *Litton Systems*, for the successful application of inertial guidance systems to commercial air navigation.

1971 to *Sedgwick N. Wight* (in memoriam), and *George W. Baughman* and Citations to William D. Hailes, Lloyd V. Lewis, Clarence S. Snavely, Herbert A. Wallace, and the employees of *General Railway Signal Company*, and the Signal & Communications Division, *Westinghouse Air Brake Company*, for development of Centralized Traffic Control on railways.

1972 to *Leonard S. Hobbs* and *Perry W. Pratt* and the dedicated engineers of the Pratt & Whitney Aircraft Division of *United Aircraft Corporation* for the design and development of the JT-3 turbo jet engine.

1975 to *Jerome L. Goldman, Frank A. Nemec* and *James J. Henry* and Citations to the naval architects and marine engineers of *Friede and Goldman, Inc.,* and *Alfred W. Schwendtner* for revolutionizing marine cargo transport through the design and development of barge carrying general cargo vessels.

1977 to *Clifford L. Eastburg* and *Harley J. Urbach* and Citations to the Railroad Engineering Department of *The Timken Company* for the development, subsequent improvement, manufacture and application of tapered roller bearings for railroad and industrial uses.

1978 to *Robert Puiseux* and Citations to the employees of the *Manufacture Francais des Pneumatiques Michelin* for the design, development and application of the radial tire.

1979 to *Leslie J. Clark* for his contributions to the conceptualization and initial development of the sea transport of liquefied natural gas.

1980 to *William M. Allen, Malcolm T. Stamper, Joseph F. Sutter* and *Everette L. Webb* and Citations to the employees of *Boeing Commercial Airplane Company* for their leadership in the development, successful introduction and acceptance of wide-body jet aircraft for commercial service.

1981 to *Edward J. Wasp* for his contributions toward the development and application of long distance pipeline slurry transport of coal and other finely divided solid materials.

1982 to *Jörg Brenneisen, Ehrhard Futterlieb, Joachim Körber, Edmund Müller, G. Reiner Nill, Manfred Schulz, Herbert Stemmler* and *Werner Teich* for their contributions to the development and application of solid state adjustable frequency induction motor transmission to diesel and electric motor locomotives in heavy freight and passenger service.