RAeS Loughborough Branch

Lecture synopses - 2009/10 Season

13th Oct. 2009 - One of the Few by John Shipman

This lecture told the story of John Shipman's father Ted "Shippy" Shipman who flew with 41 Squadron in the Battle of Britain. The story was made possible by the copious notes "Shippy" prepared detailing all the events of his life in the RAF.

"Shippy" left the Lincolnshire farm where he had grown up in 1930 and enlisted as an RAF driver. His real enthusiasm was flying and, by a combination of good luck and tenacity, he succeeded in obtaining flying training which eventually led to his becoming a fighter pilot during WW2. He encountered his first enemy aircraft, a Heinkel 111K, on 17th October 1939. Later operational duties included defending the warships at Scapa Flow and providing air cover over Dunkirk.

During the latter part of WW2 he became a senior flying instructor at the flying training school, Montrose, and the Central Flying School, Upavon. He ended the War as a flying instructor in Rhodesia.

After the War he did tours in Germany and Cyprus. He was Commanding Officer RAF Sopley and RAF Boulmer until his retirement from the RAF in 1959. He retired with the rank of Wing Commander.

Joint lecture with Loughborough Students' Flying Club (one of the societies attached to Loughborough University Students Union).

3rd Nov 2009 - Bristow Helicopters-Southern North Sea Operations by Captain David Higgins, Bristow Helicopters

Bristow Helicopters was founded in 1953 by the late Alan Bristow, and is now a US-owned global helicopter company, one of the largest in the world, with over one thousand aircraft. Its headquarters are in Houston, Texas. It operations include those in the US, UK, South Africa and Australia. In addition it has a contract to train pilots for the UK Army Air Corps.

This lecture was concerned mainly with Bristow Helicopter operations out of Norwich Airport and relating to the gas fields of the southern north sea located up to 130 nm off the Norfolk coast. The specific difficulties of flying over the North Sea were considered together with the techniques for landing on gas platforms. Flying is a mixture of instrument and manual flying. During daylight helicopters are permitted to land on a rig helicopter landing pad provided that the wind speed is less than 60 knots. This limit is halved for night time operations. All helicopters are required to carry sufficient fuel to enable them to return to a land base if it is not possible to land on a rig.

Both the helicopter crew and all the passengers are required to wear survival suits. The crew undertake regular training courses in survival procedures.

In the UK Bristows trains its own pilots at its Instrument Rating Training School which is also located at Norwich Airport.

The lecture concluded with a look into the future in the form of the new Eurocopter 155 helicopter which features an all-composite structure, a “silent” fenestron, i.e a semi-enclosed rear rotor, two FEDECs on each of its two engines. It also features a sophisticated flight control computer allowing fully automated flying from just after take-off until the final approach to a gas rig landing pad.

17th Nov 2009 - The Future Aircraft Carrier by Tony Graham, Director Capital Ships, UK Ministry of Defence DE&S

A detailed report on this lecture is not available.

This lecture discussed the roles, design, configuration and operation of future aircraft carriers including the aircraft to be used on those carriers. There was special emphasis on the two new carriers, HMS Queen Elizabeth and HMS Prince of Wales, to be built for the Royal Navy.

29th Jan 2010 - Secret British Fighter and Interceptor Projects by Tony Buttler

The lecture covered the design and development of British interceptors and fighters since 1945, but instead of concentrating on the aircraft that were built and flown it also included a great number of rejected proposals. In the days of the biplane it was easy to build a prototype, so if the Air Ministry wanted a new fighter you might get half a dozen designs competing in a fly-off competition. After the war the much higher cost of new military aircraft prohibited such events, and the solution was a paper plane competition where the interested companies would submit brochures detailing their proposals. After assessment by Farnborough, etc, the most promising design would be selected for construction as a prototype. However, the rejected designs were still Top Secret and so it has only been possible to research these unbuilt studies from 1945 to the 1970s during the last few years. Pieced together, they show how the state of the art of interceptor and fighter design has advanced over the period from the slide rule to the computer.

The aircraft described included:

Vickers VS508 (Prototype), Vickers VS525, Scimitar, DH110 Sea Vixen (naval night fighter), Blackburn B-89 (twin jet naval night fighter), Westland W-37, DH116 (super Venom), Hawker P1057, Hawker P1067 (which evolved into the Hawker Hunter), Gloster Javelin, VS Swift, Hawker P1083, VS545, Thin-Wing Javelin (i.e. a supersonic version of the Javelin), Hawker P1091 (i.e. a swept wing supersonic version of the Hawker Hunter), English Electric P1 (which evolved into the English Electric Lightning), Fairey Delta 2, Armstrong Whitworth AW51, English Electric P6-1, Vickers VS553, Bristol T188, Armstrong Whitworth AW169, Fairet Delta 3, Hawker P1103, Vickers VS559, Hawker P1151, Vickers VS543, Saro P177, BAC VG Lightning (i.e. a variable wing geometry version of the Lightning with a low speed landing capability specifically for use on aircraft carriers), Hawker P1154, Panavia Tornado, BAC P96 and P103, Hawker Siddeley Aviation HS1202, BAe P1214, BAe P1216, European Combat Aircraft, Agile Combat Aircraft, BAe Experimental Aircraft Project(EAP) to prove Eurofighter technology, BAe P106, Eurofighter.

It was noted that the 1957 Duncan Sandys White Paper, which favoured ground-to-air missiles in favour of air defence fighters, had a very significant impact on fighter aircraft procurement right up to the 1980's.

9th Feb 2009 - Formula One Aerodynamics by Geoff Richards, ex. McLaren F1

The lecture commenced with an introduction into the theory of airflow as expounded by Euler and Bernoulli in the eighteenth century. The differences in air pressure across the surfaces of a body in an air stream results in a force which can be resolved as lift, which acts at right angles to the airflow direction, and drag which acts along the airflow. The effects are made more complex by the boundary layer close to the body surface.

Drag slows a car down. Downforce, i.e. negative lift, increases the grip between tyres and road. There is a correlation between drag and downforce; downforce helps on the corners but slows the car down on the straights. This means that for any given circuit there is an optimum downforce level. A further aerodynamic effect is that the wake of the car in front affects the ability to overtake. The first team to use downforce was the US Chaparral sports-car racers. The idea was picked up by Formula 1 teams in 1968. The next development was the ground-effect car, the first being the Lotus 78.

The use of aerodynamics to improve racing car performance led to an “aerodynamics war” between the teams trying to make cars go faster and the governing body trying to slow them down for safety reasons This war started in 1981, with a skirt ban and a 60 mm gap specified between the car and the ground.

In 1983 a new rule specified flat floors for the cars between the front and back wheels. One immediate effect of this was a return to shorter side-pods. The next major development came from Tyrell. This was the raised nose. By getting more air between the front wheels and using a shorter floor, it improved the floor downforce and reduced the ride-height sensitivity.

The rules were changed in response to Ayrton Senna's fatal crash at Imola, which was caused by his car bottoming out on cold tyres and thus losing downforce in the middle of a high-speed corner. Ride heights were forcibly increased by specifying a plank under the centre of the car and the outer parts of the floor were raised. It was from about this time that a whole slew of new aerodynamic devices were developed by the teams. 2009 saw one of the biggest changes in the aerodynamic rules. The intention was to reduce downforce by approximately 50%, which also resulted in the cars having less drag. .

In practice, a major flaw in the new regulations undermined their intent. There was supposed to be a reduction in diffuser size, but a loophole in the regulations allowed a double-decker diffuser, effectively higher than intended, provided the upper part drew in air from a vertical intake in the floor step.

Primary Aerodynamic Elements of a Modern Formula 1 Car

The main downforce element is the floor. The rear wing assembly produces about a third of the downforce. The front wing acts something like an aircraft canard.

Any fairing around a suspension element must have a minimum thickness to chord ratio of 28%, no camber and a maximum incidence of 5 degrees.

Diverters, deflectors, barge-boards are fairly prominent aerodynamic components mounted on the body sides behind the front wheels.

A forward facing duct is often used to bring cooling air to the wheel hub. Further air ducts are used to cool the brake callipers.

The Aerodynamics Design Process

Designers produce a new car geometry and a Computational Fluid Dynamics (CFD) team conducts an initial evaluation. CFD involves dividing the air around the car geometry into lots of small cells, forming a mesh, and then using the Navier-Stokes equations of viscous flow and a turbulence model to calculate how the physical properties of the air change in moving from one cell to the next. This can be a very computationally demanding process and some of the world’s largest computers have been used for this work

A wind-tunnel team carries out a rapid evaluation over a broad range of conditions. Formula 1 wind tunnels are similar to low speed aviation wind tunnels. Two things that are different are the rolling road and adaptive walls. The rolling road moves the tunnel floor along at the same speed as the air.

Finally a track test team conducts trials on a test car. Track testing for aerodynamic data is carried out in conjunction with the normal testing of car performance. The main purpose is to obtain a definitive aero map; measuring downforce as a function of ride height by using suspension load measurement and laser height gauges. Drag can be calculated either from a roll-down test, measuring deceleration with the car in neutral, or instrumenting the drive system for torque.

Joint lecture with I. Mech. E

23rd Feb 2010 - Towards a Silent Aircraft by Dr Tom Hynes, Cambridge University

The Silent Aircraft Initiative (SAI) was launched with the aim of developing a conceptual design for an aircraft whose noise would be almost imperceptible outside the perimeter of an urban airport. The project has been carried out through collaboration between about 40 researchers at the University of Cambridge, MIT and a 'Knowledge Integration Community' which includes many different stakeholders, including industry, government and academia.

The human ear perceives sound on a logarithmic basis. As a result it is necessary to make very significant reductions in aircraft noise before there is a perception that there has been a significant reduction. Typically this means a reduction of approximately 25 PNdB.

The aircraft requirement was taken to be a 250 seater passenger aircraft with a range in excess of 5,000 nm. It had to be significantly quieter than the generation of aircraft currently coming into service and also significantly more economical.

SAX40 Conceptual Design

The major sources of aircraft noise are the engines, the aircraft surfaces (especially the control surfaces), and the landing gear. The former is the dominant noise source on take off and the latter two on landing.

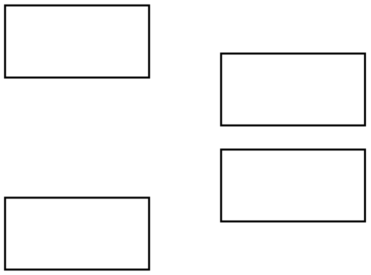
Much of the engine noise is produced in the vortices behind the engine; hence the use of acoustic noise prevention techniques within the engine are of limited value. Instead it is necessary to maintain the mass flow of the air though the engine whilst reducing its velocity. Many modern jet engines do just this by using a high bypass ratio turbofan design. In these engines approximately 10% of the air passes through the rear turbine whilst the remaining 90% passes only through the large fan mounted on the front of the engine. This 10:1 bypass ratio must be increased to about 20:1 if a meaningful engine noise reduction is to be achieved.

The turbofan in such an engine would be too large to be acceptable for most aircraft designs. In addition the engine nacelle would be massive and induce too much aerodynamic drag. The solution was to adopt an engine design in which the single coaxially-driven turbofan was replaced by a single turbine driving three separate turbofans arranged in parallel. In this arrangement the central turbofan remains coaxially mounted with the turbine whilst the two outer turbofans are driven by crown wheel and pinion gear chains off the turbine. The result is an engine with a bypass ratio of 20:1. Three such engines are necessary to power the aircraft (see picture).

Avoiding aerodynamically generated noise from the aircraft surfaces requires a major rethink about the aircraft configuration. An all-lifting design (see picture) has many benefits, enabling a closer integration of airframe and engine than the traditional 'tube and wing' design. The disadvantage of such a design is that a tube fuselage design is most structurally efficient for withstanding the pressure difference between inside and outside the pressurised aircraft. The outside air pressure changes during ascent and descent are sources of fatigue failure. The solution here is to incorporate three or more separate tubes into the width of the flying wing. Indeed increasing the passenger carrying capability of the aircraft will be achieved by increasing its width and inserting more tubes rather than by increasing its length or the diameter of any given tube.

The aircraft control surfaces are located all along the rear of the wings outboard of the engines. Relatively large and long control surfaces are necessary because the length of the fore and aft moment arm of the control surfaces about the aircraft centre of gravity is relatively small. By the same token large forces are required to operate these control surfaces, and can represent a take of up to 1 MW from the main engines.

Such an aircraft is too heavy to be landed on a landing gear using just two side by side mounted wheels on each oleo; instead a four wheel arrangement is necessary with one pair of wheels trailing the other. The vortices produced immediately behind the front pair of wheels are a significant source of noise. This noise may be greatly reduced by mounting the wheels in the manner shown below.



Low Noise Wheel Arrangement

The conceptual design, SAX40, is predicted to achieve a radical reduction in noise and to use 25% less fuel per passenger mile than the best of current aircraft.

Joint lecture with Chartered Institute of Logistics and Transport

9th March 2010 - Gas Turbine Combustor Developments for Lower NO_x Emissions by Prof Jim McGuirk, Director of University Technology Centre in Combustion Aerodynamics, Loughborough University

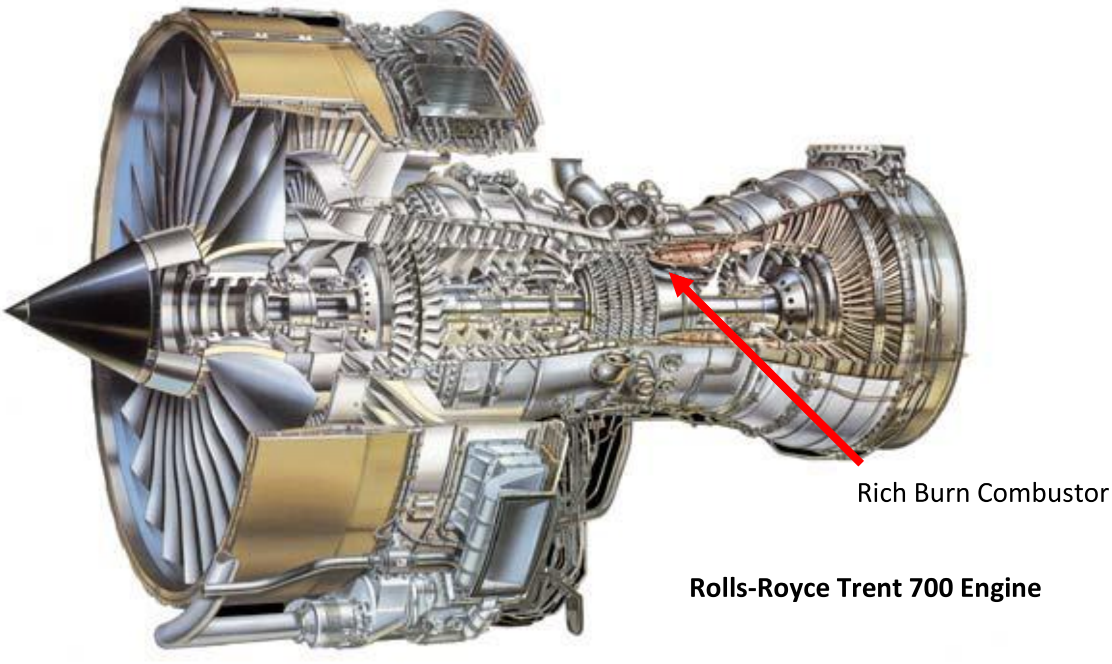
The Advisory Council for Aeronautics Research in Europe (ACARE) has set targets to reduce passenger aircraft fuel consumption and CO_2 emissions by 50% and NO_X emissions by 80%. These targets are relative to the year 2000 and aim is to achieve these targets by 2020. This follows concerns about local air quality around airports and climate changes.

The highest level of NO_X emissions occurs during Take-Off followed, in decreasing order, by Climb, Approach and Idle. International Civil Aviation Organisation (ICAO) has produced the CAEP Emissions Regulations based around a defined Landing and Take-Off (LTO) Cycle. Jet engine emissions requirements are now referenced to these regulations which sets limits to the pollutants produced..

Since 1986 the limits have decreased by approximately 50%. Engines such as the Rolls-Royce RB211-524H meet the ICAO 1986 standard. The CFM56-5B2/2 and the RB211-524H-T meet the 2008 standards.

Increasing the engine pressure and bypass ratios improve fuel efficiency and thereby decrease the engine's CO_2 emissions. Increasing the bypass ratio decreases the air mass flow velocity and thereby decreases the engine noise. Conversely a higher pressure ratio requires a higher flame temperature which in turn increases the rate at which NO_X is produced although this trend can be off-set by changes to the engine combustor design.

Maximum NO_X emissions occur when fuel is burnt in a stoichiometric mixture, i.e. when the fuel supply is matched to the available oxygen. Thus NO_X can be minimised by using either Rich or Lean burning. Rolls-Royce is implementing this combination in its Trent 900/1000 series engines. These engines have the world's lowest single angular large turbofan emissions. The combustors in these engines incorporate a Rich Burning Primary Zone followed by a Rapid Mixing Intermediate Zone and finally, a Lean Dilution Zone.



Rolls-Royce Trent 700 Engine

For further reductions in NO_X emissions it will be necessary to avoid high temperatures by using Lean Burn at high power. Rich Burn will continue to be required at low power because the reduced air flow rate does not permit the use of Lean Burn. The result is a two stage combustor. Both Rolls-Royce and Pratt and Witney have developed such combustors. The design of these combustors is being aided by new gas flow design and analysis mathematical models which can be run on today's fast computers. These models permit an eddy, swirl and hence mixing analysis to be carried out on the air/fuel burning process within the combustor, although such an analysis can still take up to 5 weeks of continuous computer use.

The overall reduction in environmental impact is illustrated by the new Rolls-Royce Trent XWB type engines. These reduce CO_2 emissions by 14% (ACARE target 20%), NO_X emissions by 40% (ACARE target 80%) and noise by 4PNdB (ACARE target 10 PNdB).

23rd March 2010 - Past, Present and Future Engine Trends by Nick Howarth, Civil Future Programmes Engineering Dept., Rolls-Royce plc

Rolls-Royce was started as a company in 1904 by Henry Royce who ran an engineering business and by Charles Rolls who ran a car sales business and was also an aviation pioneer. Charles Rolls was later killed in a flying accident with a Wright Flyer.

During WW11, Rolls-Royce was famous for its Merlin engines which powered aircraft like the Spitfire. Towards the end of WW11 and after, Rolls-Royce supported Frank Whittle and his Power Jets company in the development of some of the first jet engines. This included the Welland engine which was a development of Whittle's W2B engine.

Early engines after WW11 included the Derwent (jet) and the Dart (turboprop). Bypass jet engines were developed in order to improve efficiency. The first of these was the Conway with a bypass ratio of 0.7 in the early 1950s. This engine was used to power the Boeing 707.

Later Rolls-Royce acquired Bristol Siddeley and with that the Pegasus vertical take-off engine, later to be used in the Harrier aircraft. Further engine developments included the Adour, RB211, Olympus, 535E4, RB199, Trent 800, EJ200 and the Trent 900.

The 3 shaft RB178-51 was developed in the 1960s. This design permitted a far more rigid structure than before and allowed the HP and LP turbine spools to be run at different speeds thereby allowing each to be operated at its optimum aerodynamic design point. In parallel with this Rolls-Royce realised the need to get into the US aircraft engine market. For that they needed engines powerful enough to be used on wide body aircraft. The result was the RB211, a 3 shaft engine based on the RB178-51 and the Conway but with an increased bypass ratio. The development costs of this engine caused the company to become bankrupt in 1971 but their US customer, Lockheed with their Tri-Star aircraft, maintained faith in Rolls-Royce and the company was saved as a result of a UK government intervention. The RB211 was the origin of today's Trent series engines. The final development of the RB211 was the RB211-524G/H which develops 60,000 lb thrust and was used to power the Boeing 747 Jumbo Jet.

The RB211 evolved into the Trent series of engines which have been used on the Airbus A330/340 series aircraft and on later versions of the Boeing 747. The Trent 900 was the first engine to use contra-rotating HP and LP turbine spools and also the first to use swept fan technology to reduce the onset of drag. The Trent 1000 incorporates a relatively high electrical power take off capability. This means that the aircraft cabin air can be sourced via electric circulation pumps taking outside air rather than via the aircraft engine bypass air. In the next development, the Trent XWB, the turbine blades will be machined directly on to the disc. This will further improve strength and reliability.

Rolls-Royce's current policy is to produce jet engines which together meet the needs of every area of the jet engine market. The market over the next 20 years includes engines for 13,500 130-180 seat aircraft together with further markets for engines suitable for both larger and smaller aircraft.

For the future the targets to be met are:

a. Reduce external noise by 50% (30PNdB cumulative);

b. Reduce both fuel consumption and CO_2 emissions by 50%;

c. Reduce NO_X emissions by 80%.

Associated with the above there are three Vision Statements:

a. Vision 5 – In the near term to apply the latest state of the art technology to present products.

b. Vision 10 – This relates to the next generation of engines which will incorporate improved noise absorption screening, “on aircraft power optimisation”, reduced operating temperatures and higher pressure ratios.

c. Vision 20 – This will involve further work with airframe manufacturers to optimise the performance of the aircraft-engine combination.

These targets can only be met by optimising both thermal and propulsive efficiency. The specific fuel consumption (SFC) is inversely proportional to the air velocity in the engine. Hence a high bypass ratio engine will be more efficient. Theoretically a 30% reduction in SFC is possible compared with present day engines. Conversely decreasing the SFC can increase both the engine drag weight and noise.

Conventional turboprop engines tail off in efficiency as the aircraft speed increases beyond about Mach 0.7. Conversely open rotor jet engines with contra-rotating fan blades may be used at Mach 0.85 (the speed of most passenger jet aircraft). These are also high bypass ratio engines. Hence they are one option for future engine design. Further improvements may be achieved by designing engines to operate at constant pressure rather than constant volume.