RAeS Loughborough Branch

Lecture synopses - 2006/07 Season

24 October 2006 - AEW Nimrod and Vulcan Tanker - Test flying the AEW Nimrod, development of Nimrod in-flight refuelling capability for the Falklands Campaign, Vulcan tanker development, by Wg Cdr Robby Robinson, ex Chief Test Flying Instructor, ETPS, ex Chief Test Pilot BAE Woodford and author of 'Avro One'

Robby joined the RAF in 1950 and during his RAF career and flew with Meteor, Canberra and Valiant squadrons. In 1963 he joined A&AEE Boscombe Down where he tested Victors, Vulcans, Argosies, Beverleys and Andovers.

He retired from the RAF in 1978 to become a Test Pilot and later Chief Test Pilot at BAe Systems, Woodford. His first task was to flight test the AEW Nimrod. The aircraft was configured with two radomes: one at the front and one at the rear with each covering an azimuth field of 180°. The advantage of this solution was to eliminate the shadow effects of the fuselage, wings and tail as experienced with the Boeing E-3 Sentry which has a single radome mounted above the fuselage.

The aerodynamics of the AEW Nimrod were such that the wing lift caused a slight bend in the fuselage. This necessitated the use of correcting software with the radar. In February 1981 the aircraft was tested at it maximum Mach No. of 0.82 for the first time. The result was very significant overheating of the jet pipes on the two inboard engines followed by the stalling of both engine compressors. Examination of these engines after landing showed that both the turbines had virtually disintegrated. Wind tunnel tests showed the cause to be the development of high velocity vortices in the vicinity of the in board air intakes at Mach 0.82. This caused both engines to surge. The solution was to add vortex generators on both sides of the forward radome.

Electronic trials commenced in 1981. Each trial consisted of a 10-12 hour sortie with the RSAF providing the targets. Problems with the radar lead to the programme being cancelled in November 1986 in favour of the US AWACS aircraft.

The Falklands War meant that, in April 1982, BAe Systems, Woodford was asked to provide the MR2 Nimrods with a capability to be refuelled in flight. This was to increase their range from 1,000 miles + patrol time to in excess of 12,000 miles + patrol time. The modifications were achieved in record time and the first modified aircraft (XV229) was delivered in advance of the required delivery date of 1st May. The refuelling probe was located immediately above the cockpit and significantly increased cockpit noise. It also degraded the already poor directional stability. After the Falkland War the refuelling system was designed as a “proper” system although several years were to elapse before all MR2 Nimrods were upgraded.

May 1985 also saw the Nimrod MR2s given an air-to-air attack capability by fitting Sidewinder missiles. This was in addition to its anti surface vessel and submarine capability based on the Harpoon missile.

The need to refuel the Nimrod MR2s placed a heavy strain on the RAF’s Victor tanker fleet. The VC10 tankers were yet to come into service, hence BAE Systems, Woodford were asked to convert some of the RAF’s surplus Vulcans to a tanker role. A rapid development programme was initiated and it was decided to install the refuelling unit into the empty space of the rear EMC bulge. The programme was highly successful and Vulcan XH560 , the first modified Vulcan, flew out of Woodford on 15th June 1982. The airflow behind the aircraft was smooth and the hose completely steady. The Falklands War ended in September 1982.

7 November 2006 - Training pilots to fly the Shuttleworth Collection Aircraft by Roger Bailey, Chief Test Pilot Cranfield University and Chief Flying Instructor Shuttleworth

Teaching pilots to fly the Shuttleworth aircraft takes many years and is intended to provide manageable steps in operating difficulty so that by the time the pilots is asked to fly the worst of the early aircraft he/she will have few if any unpleasant surprises. For this reason Shuttleworth are not interested in pilots who simply wish to add more types to their logbook; once a pilot is trained he is expected to remain with Shuttleworth until he retires. The aim of the training is to achieve a safe and effective flying display involving more than 30 different aircraft.

The essential starting requirements for any potential pilot are a valid Private Pilot's Licence (PPL), an above average piloting ability and a demonstrated capability to fly many different aircraft types. The course starts with one year on the ground. This is followed flying training on a series of different aircraft groups, starting with the "easiest".

Group 1 comprises aircraft with in line air cooled engines and a tail wheel or tail skid. The latter can be steerable, fixed or free. First in this group is the Chipmunk. Here the main problem for jet pilots is to accept that it is necessary to stall the aircraft before landing. Second in this group is the DH 82a Tiger Moth which has a steerable tail skid, no brakes and no flaps. Its huge tail fin/rudder is to provide directional stability whilst taxiing. The DH 60X Moth is similar. Others in Group 1 are the Desouter Mk 1 and the Bucker Jungmann. Typically 3 years have elapsed by the time training on Group 1 is complete.

Group 2 is subdivided into 3 sub-groups; 2a, 2b and 2c. Group 2a comprises aircraft with radial/geared air cooled engines, tail wheels with brakes or a tail skid which can be either steerable or fixed. The Avro Tutor falls into this group. For many years it was used as an RAF training aircraft. It is the easiest aircraft in the Shuttleworth collection to land. Its magneto operates in synchronism with the turning propeller. The other aircraft in this group are the Percival Provost, Hawker Tomtit, Southern Martlet and the Cowper Swift. The latter was specifically built to fly like a Sopworth Camel which had the unenviable reputation of killing more pilots during the First World War in flying accidents than from enemy action.

The Group 2b aircraft have twin cylinder air cooled engines, a tail skid (fixed or free) and very low performance. The group comprises the 30 hp DH 53 Humming Bird, the 30 hp A NEC ll, the E E Wren and the Hawk Cygnet. Group 2c includes the 120 hp DH51 Moth which has poor landing and directional stability and the Parnell Elf with poor lateral stability.

Group 3 is military aircraft with "V" or in line liquid cooled engines, ignition retard/advance and a pilot controlled radiator. First in this group is the Bristol F2b Fighter. This is followed by the RAF SE5a which has similar flying characteristics to a Tiger Moth. Next is the Hawker Hind with its 640 hp engine followed by the 840 hp Gloster Gladiator. The power of the Gladiator results in significant precession, especially when the aircraft is on the ground hence it is essential to start the aircraft with its tail down. Its angle of approach on landing results in poor landing visibility. The Westland Lysander is also in this group. It has pilot controlled cooling gills, a trimmable tailplane, a dual pitch propeller and leading edge flaps. This is followed by the Hawker Sea Hurricane 1b which has a constant speed propeller and retractable landing gear. In flight it has poor longitudinal stability. Its partner is the Supermarine Spitfire LE Vc. This overheats on the ground hence take-off must be within 7-8 minutes of starting its engine. It has the reputation of having the second most pleasing set of curves known to man. The final aircraft in this group is the DH88 Comet which has the worst engine obscured landing approach of all the aircraft in the collection, thus necessitating a curved/sideslip approach.

Group 4 is aircraft with rotary engines. The first in this group is the Avro 504 which, in addition to its rotary engine, has a steerable tail skid, no brakes and an all flying fin. The 80 hp Sopwith Pup is also in this group.

Its is ground loop prone and hence must be landed on all three points, i.e. both wheels and the tail skid. The Sopwith Triplane and Bristol M1c complete this group.

Group 5 contains the “Edwardian” aircraft. It is only after some nine years training that Shuttleworth pilots commence their training on these aircraft. The first of these aircraft is the A V Roe IV Triplane which has a warping wing, a fixed trial skid and no brakes. Its longitudinal stability is satisfactory but its lateral and directional stability are poor. The Bristol Boxkite has a fixed tail skid and no brakes. It has poor performance poor lateral and directional stability and poor longitudinal stability. Also in this group is the Deperdussen, which has similarly poor characteristics, and finally the wing warping Bleriot XI.

21 November 2006 - Fighter and Test Flying Reminiscences by Gp Capt Wally Bainbridge, Loughborough Branch Chairman

Wally joined the RAF in 1945 and his early training was in Southern Rhodesia on Tiger Moths and Harvards.

His first squadron in the UK was at Swinderby where he flew Wellingtons. His first night solo on this aircraft was memorable for a port engine fire on final approach. This was followed by Lynham where he flew Hastings transport aircraft. These are notable for their need for high stick forces on landing and the gyroscopic effects produced by the four engines. It was during this time that Hastings took part in the Berlin Airlift.

Duxford saw his first encounter with jet aircraft in the form of the Meteors of 65 Squadron. In the 1950s the Meteor was the UK's only day fighter. It is interesting to note that the engines on the Meteor were each rated at 3,500 lbs thrust compared with the 25,000 lbs thrust of each of the Eurofighter/Typhoon engines.

The Meteor was power limited but a stable instrument flying platform. Touchdown was at 105 knots and stall at 95 knots leaving little margin for error. At Mach 0.78 it suffered from high buffeting and at Mach 0.82 pronounced wing droop. The latter could result in a rolling dive over 15,000 ft at which point the denser air reduced the Mach No. and control could be regained. Other problems with the Meteor included the dinghy which was located on top of the ejection seat. The dinghy had a habit of inflating at high altitude which forced the stick forwards and put the aircraft into a vertical dive. The solution was to issue pilots with a sharp knife for puncturing the dinghy.

The Meteor 7 was a conversion of the Meteor 4 to accommodate a crew of two. The conversion resulted in the length of the aircraft being increased by 30 inches when its directional stability became exceedingly marginal especially as it retained the small fin of the Meteor 4.

There was 6.5% annual loss rate of Meteor aircraft which resulted in an overall loss of 900 aircraft and 460 pilots over the 10 years it was operational. In part the losses were due to the use of inexperienced pilots. The Meteor was superseded by the Hunter, probably Wally's favourite aircraft.

In the late 50's Wally moved to the Empire Test Pilots' School (ETPS) at Farnborough where he flew 13 aircraft types in his first month.

He was then assigned to the Structures and Mechanical Engineering Department, also at Farnborough, where he participated in wing flutter and low level high speed gust research. After a one hour conversion on to the Lincoln he piloted it on a series of braking parachute trials. This was followed by trials with the Prone Meteor to investigate the potential for reducing the G loads on pilots. The Prone Meteor was a two seater aircraft in which the forward crew member was required to lie in a prone position whilst the rearward crew member remained in a conventional upright position. The final solution to the G forces problem was the pilot's G suit.

Wally next trials series was on a stealth aircraft, nick named the "Durex Delta" and manufactured primarily from a rubberised material. It incorporated an inflatable delta plan wing and a 55 h.p. engine of Czech origin. Its typical cruising speed was 40 mph and its max. altitude 300 ft. It was intended for use in getting agents across the Iron Curtain into Russia. The aircraft's controls were extremely sluggish and high control forces were required. The trials aircraft eventually crashed into the woods near to the runway. Fortunately, Wally survived the crash virtually unscathed.

Wally then returned to the ETPS to become a Test Flying Tutor and then Chief Flying Instructor. It was during this period that Dunsfold developed the technique of using role-yaw coupling on the Hunter aircraft to induce an inverted spin. This was carried out at 35,000 ft. With the aircraft at 180-200 knots, the stick was moved to the far left corner to induce a 200 deg/sec spin. The stick was then eased back still with full aileron applied. The result was a flat inverted spin. The technique for getting out of the spin was to apply full opposite rudder and then to move the stick fully forwards with ailerons neutral. It was important for all students to learn this spin recovery technique. It should also be noted that all more recent fighter aircraft have the potential for encountering roll/yaw coupling. This is because they all incorporate a heavy engine, long fuselage and their wings are both swept back and much thinner than their earlier subsonic counterparts. The overall result is a significant reduction in the roll-yaw inertia.

5 December 2006 The Airbus A380 – From Dream to Machine, the Story so Far, by Rob Bray, Airbus Bristol.

The Airbus company

Airbus Industrie was formed in 1970 as a group of four companies. In 2000/1 these companies were formed into a single company, Airbus, driven by the need to take on the risk of developing the A380. The first Airbus aircraft was produced in 1974, the 3,000th in 2002.

Airbus aircraft range from the A320 Series with 120-190 seats through the A330/A340 Series and upwards to the A380 with 550 or more seats. The A330/A340 Series will ultimately be replaced by the A350XWB being designed to compete with the Boeing 787.

Background to the A380

The A380 is required because of:

- The continued growth in air traffic*;
- Increased congestion at airports (caused by the increasing number of aircraft movements);
- Environmental pollution caused by the increased number of aircraft flights;
- The need for airlines to gain a competitive advantage over other airlines.

* 2005 saw 2.6 trillion passenger km. This is set to increase at 5% p.a.

There are two views on how to cater for the increases in traffic.

View 1 – Fragmentation:

- Hub By-passing;
- Market driven;
- Frequent flights on direct routes, e.g. direct flights from a provincial airport in one country to a similar airport in another.

View 2 – Consolidation:

- Global Networks;
- Flights between major hubs only;
- Alliances between the existing airlines.

In practise the future is likely to be a combination of both Views. The A380 falls into View 2. It is designed to be a replacement for the Boeing 747. Studies showed that 37 airports throughout the world handle 80% of 747 traffic.

The market over the next 20 years for passenger aircraft is predicted to be:

- 15,000 single aisle;
- 6,000 twin aisle;
- 1,665 multi-aisle.

It is important to note however that the last category represents 20% of the overall value of the aircraft market and the A380 is aimed at this market.

20+ airlines, 60+ airports, the ICAO and the ACI were all involved in the discussions which lead to the definition of the A380 specification. The result is an 11 billion dollar development programme.

A380 Specification and Development

The overarching requirements for the A380 were:

- Increased capacity and passenger comfort;
- Reduced operating costs (by at least 15-20 %);
- Reduced environmental impact;
- Longer range (than the current 747);
- All coupled with further development potential and versatility;

- Must fit into current airport infrastructure (this limits the aircraft size to 80 m x 80 m x 80 ft high – note mixed units).

Improvements to be achieved by increased use of composites, improved aerodynamics and engines, reductions in the weight of control systems.

The A380 will be in two variants; the A380-800 passenger aircraft (560 tonnes, 555 or more passengers, 8,000 nm range) and the A380-800F (590 tonnes, 150 tonnes of freight and a shorter range). Comparison with 747 is:

	747-400	A380-800
Range	7,100 nm	8,000 nm
Wing Span	65 m	80 m
Wing Area	560 m^2	845 m^2
Length of Runway for Take-off	11,500 ft	9,800 ft

Wheelbase	- Wheelbase shorter on A380-800 thereby minimising airport impact
Pavement loading	- Lower for A380-800
Floor space	- A380-800 50% more than 747-400
Noise Footprint	- A380-800 impact area 35% smaller than that of 747-400 as 5 dB quieter.
Emissions	- A380-400 lowest.
Flexibility	- A380-800 - extra 20 inches of width and full two deck passenger design allows airlines to have flexibility of first, business and economy on both decks. Bottom deck for crew rest area, cargo and other innovations.
Engines	- A380 will use Rolls-Royce Trent 900 or GP 7200.

Infrastructure and Transport for A380 Build

Factory locations include Toulouse, Hamburg, Filton and Broughton. 3.75 billion investment in new manufacturing facilities. In UK 13,000 employees. Filton – design, procurement and detail parts manufacture. Broughton – wing manufacture.

Inter-factory transport by combination of barge, ro-ro ferry and road.

Build, Test and into Service

First wing from Broughton joined to fuselage at Toulouse in May 2004. First flight with MSN001 in April 2005. Extensive testing of components since 1996 followed by multi-system tests, fatigue tests, electronics tests (with Iron Bird). Engine tests on A340 test aircraft. Now 5 aircraft in flight test programme. Tests have included min.unstick velocity, water trough, cold weather, high altitude and emergency evacuation. First "virtual flight" with passengers was on 9th May 2006 – mainly to test use of cabin and in-flight entertainment.

Long flight testing and technical route proving began in November 2006 - satisfactory. Confirmed 35% faster boarding than 747. Uses 90-100% of existing airport equipment.

EIS type certificate expected December 2006. First A380-800 aircraft into service will be with Singapore Airlines in fourth quarter 2007. A380-800F first flight first quarter 2009 and into service 2010.

Lecture fully sponsored by Midlands Aerospace Alliance

23 January 2007 - Micro Air Vehicles, tools or toys by Gordon Dickman, Principal Systems Engineer, Blue Bear Systems Research Ltd.

Blue Bear Systems Research Limited (BBRL) was founded in 2000 and started working with UAVs in 2002. The aim was to develop Micro Air Vehicles (MAVs) having a maximum dimension of 150 mm in any direction, incorporating a day/night imaging capability and having a high degree of autonomy. The options were for fixed, rotating and flapping wing technologies. BBRL elected for fixed wing technology since most of their expertise was in that area. The 150 mm constraint on maximum dimension was soon found to be too tight a constraint; it was too small to carry a useful payload.

1. General

Military applications include: Surveillance (over the hill); Infra-Red images of battlefields and Urban Areas (round the corner); Search and Rescue; Aircrew Retrieval; Mine Detection in War Zones; Biological, Chemical and Nuclear Agent Detection; Battle Damage Assessment.

Civil applications include: Chemical and Biological Detection; Agricultural Monitoring; Environmental Monitoring; Communications Nodes; Surveying; Traffic Monitoring; Boarder Patrol; Police Surveillance; Crowd Control; Planetary Exploration.

Challenges are: Endurance (2 hours is desirable); Payload; Robustness; Flight Controls; Autonomy; Communications; Reliability; All Weather Operations; Day/Night Operations; Training/Useability; Oortability; Logistics Train; System Maintenance; Environmental Considerations; Airspace Deconfliction/CAA Regulations.

Hurdles are: Low Reynolds Number (i.e. Ratio of Inertial to Viscous Forces leading to Scale Effects as MAVs are very small); Mass and Volume Limits; Power; System Integration. Scale Effects result in high susceptibility to wind gusts.

2. Enabling Technologies

Energy Sources are: Lithium Polymer Batteries (Li-Po); Zinc-Air Batteries; Fuel Cells; Hybrid Systems; External Energy Sources e.g. Solar Panels and the Wind. The aim is to combine these technologies into a hybrid system. Li-Po batteries currently located in the wings.

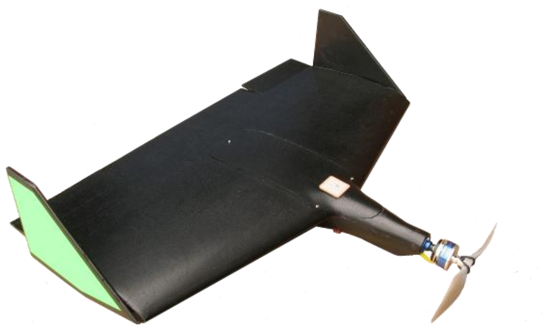
Power Plants are: Electric Motors; Internal Combustion; Piezo Electric; Micro Turbines; Micro Jets.

Actuators: Servo Electric (Less than 4 gm now less than 2 gm – mainly from aeromodelling industry) and Piezo.

Payloads are: Electro-Optical Sensors (CMOS/CCD); Infra-Red Cameras (50 gm weight cameras now avialable); Nuclear, Biological and Chemical Sensors; Meteorological Sensors.

3. Progress to Date

BBRL have been involved in rapid prototyping – faster better cheaper. Aim is to take sensors and wrap airframe around them. No wind tunnels but instead actual flight testing. Civil market innovations are being used to feed through to military and defence applications. Much of the work is for UK MoD.



Airframes are made from expanded polypropylene. Initially a standard radio control system is fitted. Eventually this will be replaced by a full autopilot. The wing mounted Li-Po batteries last approx. 30 min..

Flight testing has confirmed good performance in wind, i.e. strong lateral and directional stability. Catapult launched.

BBRL have developed their own GPS based autopilot Originally this weighed 600 gm including batteries and just about provide pitch and yaw control. Now 64 gm including batteries, 3 gyros, 3 accelerometers, barometric and differential pressure sensor, GPS interface and a thermometer. The next stage is to incorporate more complex control algorithms. Control is by a nonlinear dynamic inversion technique which allows the system to be tuned via the radio link whilst the MAV is in flight. Still much work to be done for wind compensation. Urban environment presents difficult environmental conditions including the need for obstacle avoidance. End aim is for a more stable MAV with gimbal mounted cameras.

BBRL attended their first US/European MAV Competition at Garmish-Partenkirken in September 2006.

4. Conclusions

MAVs are far from Toys and much more than just an airframe. They have a wide range of applications and enabling technologies are coming along fast.

13 February 2007 - The Design of the Trent 1000 for the Boeing 787 Dreamliner by Jonathan Wandless,Chief Design Engineer Trent 1000, Rolls-Royce plc

RR today is a global company built around gas turbines and other related products. RR is divided into consists of 4 divisions, one of which is civil aerospace. It has £26.1 billion in orders, £7.3 billion half year sales and , 35,000 employees worldwide. There are 54,000 RR gas turbines in service. One half of RR civil engine sales is after sales service related. This is an expanding area, especially where RR hires out engines and takes on all the through life risks.

Trent engines range from the Trent 700 to the 1000 and all are used on large civil passenger jets. Currently Trent engines are on 50% of all large civil aircraft. GE is the main competitor. Current engine orders for the Boeing 787 are GE 57%, RR 43%. The Trent 1000 engine for the Boeing 787 is another derivation from the Trent family.

The variants of the 787 are 787-3 (shorter range, shorter fuselage), 787-8 (normal range) and the 787-9 (longer range, longer fuselage). They will replace the 767 and the 757 but with greater range. Aimed at capturing markets where a 747 aircraft is too large but range is required. The 787 will also provide an increased cargo capacity (greater than 747).

Inside 787 the cabin altitude will be 6,000 ft instead of the more usual 8,000 ft. This increases comfort and has been made possible by making a fuselage from composites. Also higher humidity, larger windows (with photochromic control instead of blinds), large overhead bins and a light and airy cockpit providing greater vision at airports.

Work on the 787 started in 2002. 787-8 first flight is expected later this year and it is due to enter service in 2010.

Work on the Trent 1000 started in 2004. It will have a lower noise level and a lower fuel consumption than any of its predecessors. In term of fuel economy GE engines are marginally better but overall the performance of the two engines for the 787 is approximately the same.

The same Trent 1000 engine will be fitted to all three aircraft variants but the thrust will vary between 54,000 and 74,000 lbs. This has considered logistics advantages for aircraft operators.

RR have tried to use common parts over several Trent variants, hence the Trent 1000 is evolutionary rather than a new design. The engines will be all metal except for the spinner. The blades will be of swept hollow titanium construction with a wide chord fan. They will be the lightest and strongest yet. The engines will incorporate Full Authority Digital Engines Controllers (FADEC).

RR have resisted the use of lean burn combustors (although they might appear on later Trent variants). The engines do include a new novel feature – contra rotating lp and hp turbines. This increases turbine efficiency by approx. 1.5% and fuel efficiency by approx. 0.75%. The engines also include active de-icing.

The Trent 1000 is RR's highest bypass engine ever. It has 20 fan blades as against 24 in the Trent 900. This together with a reduction in blade speed reduces fuel burn during climb.

Boeing required much more electrical power than for previous aircraft types (1 Mva instead of 120 KVa). This power is still required during descent (flight idle). This lead to a decision to take the power from the lp rather than the hp turbine. The benefits are a lower idle thrust, hence less brake wear on the ground and a reduction in noise levels during idling on the ground.

The engine will be "intelligent" and incorporate full health monitoring. This will enable the engine to "flag up" when unscheduled maintenance is required. In addition the engine construction will be modular to facilitate ease of maintenance.

The main selling points for the engine are: low emissions, low noise, low cost of ownership, low fuel burn, low weight, high thrust. Specific fuel burn is 16.5% lower than for the engines on a 767. The engine is a “rigid stiff “ design and will retain its performance throughout its life (25 years). The target is for an engine with zero in-flight shutdowns and zero delays/cancellations due to the engine.

Engine programme is 14/02/06 first engine test, July ’07 engine certification. RR have purchased a 747 to act as a flying test bed. Flight trials with Boeing will commence in 2008.

Joint meeting with I. Mech. E.

13 March 2007 - Development and Certification of the Eclipse 500 by Dr. Oliver Masefield, Senior vp, Eclipse Aviation Corporation

The hub and spoke operational structure of the commercial airline business means that many flights between centres of population are slow and tedious. A journey between Santa Fe and San Antonio can take 7 hours although the straight line distance is only 700 miles. The solution is the air taxi which provides a door-to-door service at double the effective ground speed. The Eclipse 500 is intended precisely for this purpose. Typically it will be used over ranges of 300-700 nm and be purchased both by private individuals (say 200 hrs/year) and air taxi operators (say 3,000 hrs/year).

Pre-US deregulation in 1979 approx. 10% of US passenger miles was using air taxies. Since then the business has contracted and the design of air taxi type aircraft has stagnated. The Eclipse 500 is intended to re-open that market by providing a 75% reduction in new aircraft purchase price compared with existing entry level jets and to operate at only half the existing operating costs. In other words the idea is to change the way people travel by offering a cost effective alternative to the scheduled airlines.

The main parameters of the Eclipse 500 are:

1. Max. Cruise Speed 375 knots
2. Stall Speed 67 knots
3. Seating Capacity 6 (including pilot(s))
4. Range (with 4 occupants) 1,280 nm (allowing most of Europe to be reached from London)
5. Useful Load 2,250 lb
6. Take-Off Runway Req. 2,155 ft
7. Max. Take-Off Weight 5,640 lb

Particular care was taken in designing the interior and this has a considerable bearing on the overall aircraft design. It was considered important to be able to seat 5-6 people in comfort and this includes their ability to move round the cabin and the level of comfort and temperature control in the cabin. The size of the cabin has driven the design of the rest of the aircraft.

The design incorporates a highly integrated digital avionics fit which is far in advance of many other small jet aircraft currently in service where design the avionics fit is at least 30 years old. Such an avionics fit both reduces weight and increases reliability.

Innovative technology and practices have been used throughout the aircraft’s manufacture, including the use of friction stir welding to replace rivets on most of the fuselage. Machined parts have been used instead of the traditional “build-up” structures. As a consequence all parts fit together like a building block and the aircraft build cycle is just 9 days compared with an industry average of 3-9 months.

The philosophy throughout has been to have a development and production programme which meets the circle of requirements of lean production, low price and hence sales volume.

All major sub-assemblies are bought in from companies already experienced in their manufacture. There has only been one significant problem with this approach. This was the need to switch engine manufacturer after the aircraft’s first flight in 2003 showed a very disappointing engine performance. The engine is now a Pratt and Witney PW610F which is similar to the 615F in the Cessna Mustang.

The first flight of the Pratt and Witney engined aircraft was at the end of 2004. This aircraft has now flown over 4,000 hours. Certification date was September 2006. There are now 9 production aircraft flying, 50 aircraft on the production line and 2,500 aircraft on order with a total value in excess of $3 billion.

1 May 2007 - The Story of UK Jet VSTOL by John Farley, ex-Chief Test Pilot, Dunsfold

The concept of Vertical/Short Take-Off and Landing (VSTOL) originated from work carried out by scientists at the Royal Aircraft Establishment (RAE) in 1952. The requirement was to design an aircraft with an engine thrust greater than the weight of the aircraft. The problem was how to control the aircraft as it was taking off. Initial experiments were carried out with a flat surface having downward pointing air jets at each end. These tests were so successful that RAE were able to specify to Rolls Royce a full sized flying test rig, the Flying Bedstead. This incorporated reaction controlled jets to stabilise to provide attitude stabilisation. The first free hover of the Flying Bedstead was achieved on 3rd August 1954 and lead on to the RAE Aerodynamics Research Fighter manufactured by Shorts as the SC1.

The SC1 incorporated 4 vertically mounted lift engines and one horizontal engine. To get out of ground effects take-off was over a pit fitted with a grating (the Bedford Grating). In April 1960 the SC1 took off vertically, accelerated and then returned to the hover position.

In October 1960 work started on the Hawker P1127 later to become the Harrier. Sydney Camm of Hawker Aircraft did not like the idea multiple lift engines and, as a result, the P1127 had one important difference from the SC1; it incorporated one jet engine instead of 5. Lift was obtained by vectoring the thrust from the one engine. The idea of vectored thrust originated from the gyrocopter concept originally defined by Marcel Dassault. In the gyrocopter concept a series of fans were driven from a separate engine to produce the downward thrust.

P1127 engine was the Pegasus 1 from Rolls-Royce. In essence this is a standard jet engine with extra ducts to bleed air out from behind the forward fan and from behind the final compressor stage. This air could be vectored by means of four rotatable nozzles. A further bleed pipe was positioned over the HP compressor to provide air for the reaction control jets located at the nose, tail and at the ends of the wings.

Much of the concept design of the aircraft was carried out by Ralph Hooper at Hawker Aircraft. This included the design of a “self shortening leg” located in the centre fuselage position to both cushion the landing forces and to permit the aircraft to rest, not only on the leg but on the nose wheel and the two wheels mounted at the ends of the wings.

The Harrier entered service with the RAF in 1969. The US Marine Corps expressed interest in the Harrier aircraft in 1971 and this lead to substantial US sales and significant collaboration with the US on later Harrier designs.

It became apparent that lift provided by the engine was insufficient to lift the aircraft when it was fully laden with fuel and stores. In 1974, the result was the Ski Jump which allowed the Harrier to take off from a ramp angled at 20 degrees, hence the Short Take-Off in VSTOL.

The Harrier GR7, GR9, T10 and T12 are still in service, all fitted with a new US wing design offering significantly increased fuel capacity and hence aircraft range. One more recent development is the VAAC Harrier in which the nozzle lever adjacent to the engine throttle has been removed and replaced with a fly-by-wire system. This will allow a completely automatic approach and landing on a ship.

The Joint Strike Fighter (JSF) (Joint Combat Aircraft in the UK) is due to replace the Harrier in 2014. This incorporates a separate vertically located fan driven off the main engine as well as vectored thrust nozzles at the rear of the aircraft. The latter aspect is a return to the original ideas of Dassault.