

# AIR ENGINEER



The Journal of the Royal Air Force Air Engineer Branch



1989



## Editorial

### *Tales of the Unexpected*

I have a feeling it was test pilot Brian Trubshaw who said, 'Always expect the unexpected.' If it wasn't, I beg his pardon and that of the wise man who did utter those words, although I suspect that such advice has actually been voiced by many experienced aviators in the past. In recent months there have been several instances in both military and civil flying of unforeseen problems which have resulted, sometimes, in accidents. It is not my intention to give a lesson in semantics, but please note the difference between *unexpected* and *unforeseen*. There are not many crews, surely, who expect to have problems of a serious nature every time they get airborne. We are so used to the high standards of safety and reliability to which our aircraft are designed and operated, that on the rare occasions when the fire bells ring or the overheat warning caption illuminates, there is always a momentary doubletake because serious problems are unexpected. Thankfully, such problems, although unexpected, are not unforeseen. A well-rehearsed drill is run through, the problem is contained and we walk away at the end of the trip feeling that we have earned our flying pay. Serious problems are rare and, therefore, unexpected, but they have been foreseen so procedures exist to cope with them. That, I think you will agree, is a generally accurate view of modern aviation.

Editorial continued ►

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## Please Note

Letters and articles for inclusion in the 1990 Journal should reach the editor before April 1, 1990. Please ensure that all articles are typed, double-spaced and, ideally, illustrated with photographs when relevant. The total number of words in the article should be printed at the end. Any items which you wish to be returned should be clearly marked with your name and address. This is one publication where the editor *does* accept full responsibility for what is published, even though *Air Engineer* is not an official publication.

Please ensure that your station co-ordinator is aware of any article which you intend to submit also provide a 'whipping' service should the editor have an empty 'In' tray two weeks before the copy date!

**On the cover ...** A Shackleton in flight to mark the plane's 40th year. See centre pages for the full story.

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What happens, then, when a problem arises which has not been foreseen? No well-rehearsed drill can be actioned, because there isn't one. The outcome will largely depend on the professional knowledge, expertise and airmanship of the crew members. The flight safety file in this issue deals with a particularly nasty unforeseen incident on a Nimrod. When XV257 suffered a bomb bay fire there was no drill to deal with it in the flight reference cards. The crew had to cope with what they had: experience, knowledge, cool-headedness and good airmanship, and they survived. As a result of that incident there is now, of course, a regularly practised bomb bay fire drill but, because the cause of that fire has also been eliminated there is now virtually no chance of that problem ever occurring again. Herein is the irony – we have drills and procedures for problems that have been foreseen, but because they have been foreseen they are guarded against by preventative servicing, safety checks and the like. Therefore, the foreseen problem is not very likely to happen.

How can we prepare ourselves for the unforeseen? The simulator is a good place to start although simulation is not without its problems. Simulators are becoming incredibly lifelike as regards 'feel' and visual effects, but one falsity that is very difficult to overcome is that crews expect serious problems in the simulator, whereas they do not in the air. Equally, the emergency situations which they face have not

only been foreseen, but often previously briefed to the crew. There is undoubted value in such training, but the unbriefed, multiple emergency scenario has its place in training crews to deal with the unforeseen. There are those who criticise the idea of multiple, unrelated systems failures, claiming (rightly) that the chances of losing so many systems are millions to one, and (wrongly) that such exercises constitute 'trapping', not training. The value of such sorties lies in the need for crews to prioritize and fall back on

### How can we prepare ourselves for the unforeseen? The simulator is a good place to start.

experience, knowledge of the aircraft, and airmanship, exactly as they would have to do when faced with an unforeseen major emergency in the air.

In a brand-new 737 and a 20-year-old 747, unforeseen problems have recently struck. There are accounts in this journal of a Nimrod and a Shackleton, both very nearly lost through unforeseen emergencies. Whoever it was who exhorted us to expect the unexpected was right, but we could take it one stage further. Don't just expect the unexpected – expect the unforeseen.

Phil Coulson



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# Memories Of The Past, Kept For Tomorrow

Since 1973, the Air Electronics Engineer and Loadmaster School (AEE&LS) at RAF Finningley has been the home of Air Engineer basic training. Over this period, the training syllabus has been transformed out of all recognition; where once many months were spent in the classroom, followed by 60 hours of flying in the cold, draughty and noisy Varsity, we now use sophisticated computerised training aids and a modern purpose-built simulator to achieve the same aims.

As the home of the Air Engineer, it is, therefore, fitting that Finningley should play host to a more permanent reminder and tribute to the branch's past history. The Air Engineer heritage room, in the AEE&LS, began to take shape in late 1988. Many of the original exhibits came from the school itself and delving into cupboards and filing cabinets produced a fair selection of memorabilia in the form of photos, forms and old training notes. After much delving, scrounging and advertising, the 'mini museum' is now beginning to look a little more full. The widow of a former engineer in the last war, Mrs Wright, has kindly loaned her husband's medals, including a DFC and DFM, together with the associated flying log book and citations, to be displayed as a fitting tribute to his exploits. The centre also boasts an original war time ops room clock and features a copy of Norman Jackson's citation for his VC. The centrepiece of the display is, undoubtedly, the original set of St Athan boards, that list the honours gained in the last war by students of the, then, flight engineers school.

Ironically, the birth of the Air Eng branch was spawned from a shortage of pilots during the last war; but the room is not just about World War Two; it is about our branch, then, now and into the future. The continued existence and success of this project depends on all of us. If you have any items or photos, or you know of anybody that has, which you think may be suitable for inclusion in the centre, then please contact OC Air Eng Sqn at Finningley on Doncaster 770771 Ext 577. Let us keep this small token of our past, for all who come after, to see and share, so that they may realise that they are part of a larger family with a proud and distinguished heritage.



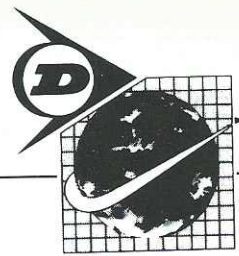
Change of command at the Air Engineer Training School, Finningley: Sqn Ldr Brian Waters (right) took over as OC Air Eng Sqn on February 22 after a tour in Ops at Brize Norton. Sqn Ldr Fran Hopkins has moved to MOD (PE) in London.

And finally, my thanks must go to Master Eng Ralph Green, who has carried out all the leg work over the past year, to obtain exhibits and organise the room into some sort of order. Without his diligence and enthusiasm, the project may never have got off the ground. He is credited with being the centre's first curator; the first, hopefully, of many.

The Air Engineer heritage room Finningley.







## Anti-Skid and Auto-Brake Systems

It was in 1934 that Dunlop produced the first aircraft hydraulic brake control system. Subsequent evolution in aircraft design has created a demand for sophistication that has led to present day advanced electronic anti-skid and auto-brake control systems.

Dunlop's expertise in the field of total braking systems is reflected in the retrofit of the British Aerospace Hawk with the latest adaptive electronic anti-skid system to complement the existing Dunlop equipment now standard on the aircraft. This indicates the validity of the total system concept that enables the integrated design of matched components for ultimate performance.

Historically, the first anti-skid requirement originated in the late 40s with the advent of aircraft fitted with tricycle undercarriages. Wing lift at the start of the landing run reduced the net wheel loads such that even with careful application of brake pressure, locked wheels were unavoidable. To counter the situation, Dunlop introduced in 1951 the first Maxaret anti-skid device.

This device was driven by the braked wheel and, on detecting a rapid wheel deceleration, operated a hydraulic dump valve which reduced brake pressure. This direct action, combined with the proximity to the hydraulic brake cylinders, ensured quick response and good performance. As a result the trade name Maxaret became synonymous with skid control systems and Dunlop skid control equipment has been fitted to more than 40 different aircraft types constructed in many countries throughout the world.

There has been continuous development of this device and its derivatives since its introduction so that its performance and cost effectiveness guarantees its consideration by constructors of today's aircraft. Recent selections include HS125-900, Jetstream 32 and ATP.

However, during this same period other advances in technology have seen a widespread use of electronics in aircraft systems, including anti-skid. The heart of an electronic anti-skid system is, in effect, a small computer located in the anti-skid control unit which derives wheel speed intelligence from the wheel speed transducer located in the axle. In response to inputs from the anti-skid control unit, the hydraulic proportional control valve modulates pressure to the brake to ensure optimum braking.

Today Dunlop has total capability in the field of aircraft retardation, a subject that is complex and

covers many disciplines and it would be prudent at this point to introduce a more technical explanation of the anti-skid process as applied to the electronic system.

### Electronic Anti-Skid Systems

Broadly there are two types of anti-skid control systems known as on/off and adaptive. The on/off system simply removes brake pressure at the onset of a skid and re-applies it when the wheel spins up. The adaptive system continually modifies the brake pressure in response to the varying runway conditions, thereby achieving the shortest possible stopping distance for the aircraft.

On/off control is effective in preventing burst tyres and maintaining reasonable aircraft ground handling control and provides a cost-effective system for many aircraft. However, high performance military and multi-wheeled transport aircraft in general require the extra efficiency of an adaptive system. The principle of Dunlop's adaptive system is now further explained.

As brake pressure increases so does drag and the wheel starts to exhibit slip or a slight slowing down from the free rotational speed. Maximum braking effect is obtained when the wheel is in a slight skid.

The aim of Dunlop's adaptive system is to modulate the brake pressure to search for the peak of the curve to produce maximum braking drag and hence high retardation. Control is maintained on the

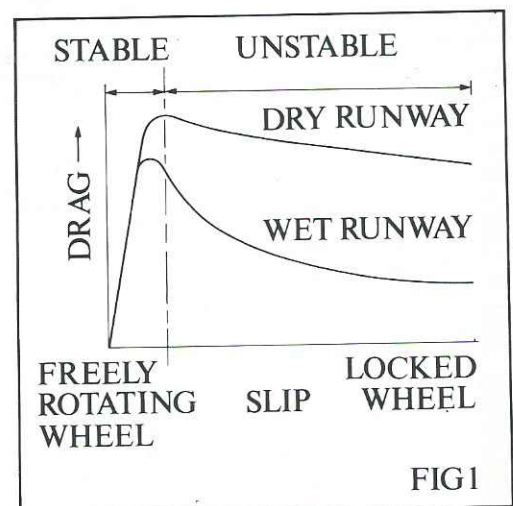


FIG1  
Relationship between drag and slip.



# technical talk...



positive or stable side of the curve in order to ensure good lateral stability and preservation of aircraft manoeuvrability.

This control is achieved by Dunlop's 'Quasi Slip System' where the computed slip velocity is derived from the difference between instantaneous wheel speed and previously 'remembered' wheel speed. In a fully adaptive system the electronic control elements, analogue or digital, attempt to maintain a brake pressure such that slip velocity is held at a value that coincides with maximum drag.

Additional control circuitry adjusts the brake pressure to suit average runway conditions by operating on the frequency and nature of previous variations in wheel speed. This pressure is continuously modified to provoke and correct small amounts of slip about the desired value thus maintaining high efficiencies throughout the braking run in spite of changing aircraft dynamics and variations in runway conditions.

Icy patches or sudden slick conditions are catered for by high response networks which immediately fully dump the brake pressure until the wheel spins up.

Touchdown protection is a feature which allows the pilot to demand maximum brake pressure prior to landing. Logic circuits detect that the aircraft still hasn't landed and dump brake pressure. On landing, wheel spin-up causes brake pressure to be applied in a controlled manner in order not to provoke an unnecessary skid or produce an uncomfortable initial deceleration.

A policy of careful circuit design and component screening has resulted in a highly reliable control unit. Built in test equipment (BITE), fail-safe circuits (FSC) and component redundancy provide a system giving an extremely high degree of confidence in its correct operation. However, design is such that brake pressure is automatically returned to pilot control should there be any malfunction.

In addition, before any system is fitted to an aircraft it undergoes a series of type tests. These tests demonstrate the system's ability to survive rigorous environmental conditions including high and low temperature, sand, dust, driving rain and vibration. Furthermore, the system is also subjected to tests to ensure that it is electro-magnetically compatible with other systems on the aircraft.

## Auto-Brake

We have seen how the anti-skid system will control pressure at the brakes to give optimum stopping performance. This, of course, leaves the pilot free to concentrate on other duties at the time of peak workload during take-off and landing. Nevertheless, he is still required to depress the pedals to initiate

braking and maintain this for the braked run. This function can be eliminated by fitting an auto-brake system.

The auto-brake system allows the pilot to select a value of aircraft deceleration and will automatically apply braking to achieve that deceleration without further pilot intervention. This is achieved by including a logic function in the anti-skid electronic control unit and adding an electro-hydraulic valve in the brake system which will bypass the pilot's brake pressure control valve when in auto-brake mode. Finally, in order to enable the pilot to cancel auto-brake and return braking to his control a comparator is fitted. This unit compares the auto-brake supplied brake pressure with any brake pedal selected pressure causing cancellation of the auto-brake function when the brake pedal selected pressure exceeds the auto-brake pressure.

The control unit is linked to a selector on the flight deck which incorporates an arming switch and a three position selector. This gives a choice of deceleration rates varying from maximum achievable for a short stop through medium (ten feet/second/second) to minimum (five feet/second/second). Auto-brake is activated in two phases; firstly, prior to landing when the system is armed, and secondly upon landing when it is triggered into action.

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# technical talk...

Before the pilot can arm the system the following conditions must be satisfied:

- ▼ Anti-skid system operational.
- ▼ No pressure on the brakes.
- ▼ Pilot's pedals not depressed.

Under these conditions arming will be indicated to the flight crew before the aircraft lands.

The auto-brake will be triggered into action when the throttles have been moved to ground idle and the wheels have spun up. The control unit will attempt to maintain the pre-selected deceleration rate by comparing actual wheel speeds with a 'memory' of wheel speed, which decays at a fixed rate. Deviations at individual wheels due to runway conditions are catered for by normal anti-skid control.

## ***The Merits of Digital over Analogue Electronics for Anti-Skid Control***

All the early electronic anti-skid devices used analogue system, whereas more recently digital

electronics have enabled significant improvements to be made.

The advantages of digital control are:

- A standard hardware package could be used for a number of different aircraft types. Changes to the software programme would be all that is required.
- Optimisation of a control unit from inception through to the establishment of a production standard may be limited to software changes only.
- The employment of more sophisticated algorithms for wheel control and monitoring gives improved performance and maintainability.
- Interrogation of the control unit by the aircraft central computer gives ready access to the state of the system by the flight crew and maintenance engineers. On board fault diagnosis to LRU level should reduce the number of removals and aircraft downtime.
- A reduced component count gives higher reliability.

The latest developments in micro computers facilitate the production of multi-function units (ie system integration) which Dunlop is actively pursuing at the present time.

### **Mandatory acknowledgement**

*This article has kindly been provided by Dunlop Aviation Division.*





# technical talk...

## Moving Towards The Non-Metallic Aero Engine

by Bob Teal

Some years ago Rolls Royce began a major programme which will lead to the use of new materials for future high-performance aero engines. Composite metal and ceramic-matrix materials are expected to take over from metals for a wide range of military engine parts in less than 20 years' time. Metal alloys will account for an increasingly small percentage by weight of advanced engines and the largely 'non-metallic' engine is on the horizon.

These changes are being driven by the demand for ever higher performance, particularly in the military field. Materials are needed which will be much stiffer and lighter than those of today and which can operate at much higher temperatures. Continuing development of metal alloys cannot provide the properties needed for the major performance advances required beyond the year 2000.

Military combat engines will then be providing a thrust 20 times greater than their weight; this compares with a thrust/weight ratio of 8:1 today. They will operate at TETs (turbine entry temperatures) approaching stoichiometric, compared with around 1,650°K today, and at compression ratios up to 30:1 compared with the 23:1 of advanced engines today.

These figures represent immense advances compared with the performance of the first jet engines, which had a thrust of around three times their weight, a TET of less than 1,100°K and a compression ratio of 4:1.

The latest engines now rely on basic metals technology proven some 20 years ago. Continuing development of these materials still offers performance increases, but changes in design, materials and manufacturing technology are required to achieve the next leap ahead in engine performance.

Rolls Royce is working to develop and prove the technology for advanced high-performance materials, particularly metal – and ceramic-matrix composites. These materials cannot be directly substituted for current metal alloys. They will demand radical changes in the way engine components are designed and manufactured.

Engineers in future will not choose a metal alloy best suited to the temperature and stress levels of a particular component. They will decide the

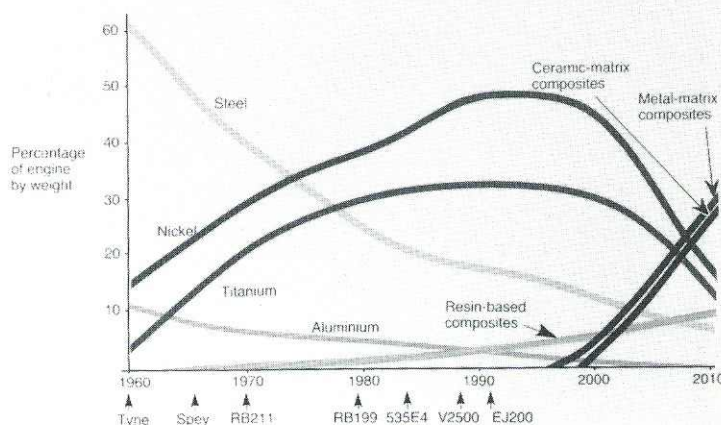
temperature and stress levels needed by a component for a new engine and will then design a material to meet the requirements. Fibre-reinforced materials components can be designed for minimum weight by providing increased strength in the direction in which it is required.

In this respect they will be comparable with the directionally solidified turbine blades of today. These are cast with long metal crystals aligned along the blades to cope most effectively with the centrifugal loads experienced. But composites have different properties from metal alloys and a totally new design and manufacturing approach will be needed. There will have to be a much closer integration between the design and manufacture of components than there is today.

### Performance Targets

Targets for the performance of an advanced military engine for beyond the year 2000 are that the engine will have a thrust 20 times as great as its weight and, compared with current engines, it will use 25 per cent less fuel for a typical mission. Its first cost and maintenance costs will also be reduced by one quarter. The engine will be designed for an operating life of up to 5,000 cycles.

PREDICTED TRENDS OF MATERIAL USAGE IN JET ENGINES





# technical talk...

To achieve this performance it will be mechanically simpler than current types, with fewer parts, and will operate at much higher TETs and components loadings. Reliability and component life will be better than for current engines. This advanced engine is expected to achieve half its performance advance through improvements in materials and half by improved design – for example, compressors and turbines operating at higher efficiency.

The new materials are likely to be introduced later for commercial engines. Weight and fuel consumption reductions are key aims for such engines. British Airways recently stated that a saving of one pound in the weight of a long-range Boeing 747 is worth £500 a year to the airline.

The Rolls Royce programme to develop and introduce new materials has been based on a study of expected engine developments over the next 15 years needed to provide competitive improvements in engine performance. This study has provided the targets for major advances in materials technology, mechanical design and manufacturing techniques.

Rolls Royce is now working to meet these targets. The programme is funded mainly by the company and covers work inside Rolls Royce, at universities and at the supplier companies. The results will benefit a wide range of Britain's engineering companies.

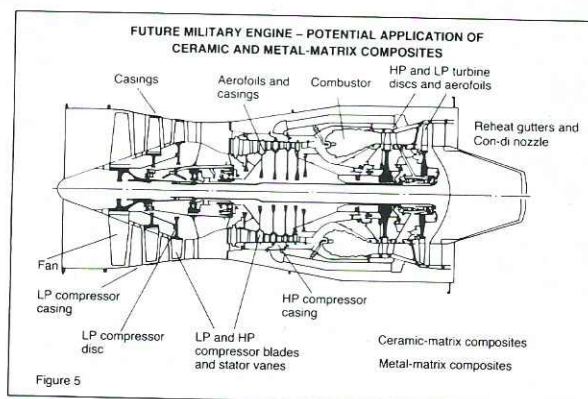
There are three predominant needs for the future materials. They must have predictable behaviour at high stress levels; they must be very much stiffer; and they must be able to operate effectively at much higher temperatures. These requirements will lead to the use of non-homogenous composites.

Use of metal-matrix and ceramic-matrix composites is expected to grow rapidly from the late 1990s. By the year 2010 it is predicted that nearly 60 per cent of the weight of high-performance jet engines will consist of these two types of composite material.

The move to metal-matrix and ceramic-matrix composites will be a radical change, but it continues the trend towards new materials to meet performance needs.

Until 1960 steel accounted for about 60 per cent by weight of engines and was used in most major components – discs, bearings, gears, blades and casings. The percentage of steel fell as high-temperature nickel-based alloys were extended from turbine blading to other applications in the mid 1950s and low-density titanium alloys were introduced in the early 1960s. Today steel accounts for less than 20 per cent by weight of modern civil and military engines and the trend is still downwards.

Aluminium alloys have found widespread applications in compressor blades, impellers and castings. Structural casings which can operate at up to 300°C have been produced in aluminium alloy. The development of aluminium-lithium alloys provides



materials of lower density and greater strength, with considerable potential for uses where light weight is needed.

Titanium alloys have a density just over half that of steel and a specific strength higher than for most other structural materials. This strength is maintained to relatively high temperatures. As a result titanium has been used widely and now accounts for more than 25 per cent of the weight of current civil engines. Alloys have been developed which can operate at temperatures approaching 650°C. Titanium components are used for most compressor applications – fan blades, rotors, discs and casings.

## Composites

By 1990 low-density titanium and high-temperature nickel superalloys will account for more than 65 per cent of an engine's weight. But these alloys cannot meet future needs for high-temperature, high-stiffness and high-strength materials. A wide range of composite materials – resin, metal and ceramic matrix – is required.

The Rolls Royce programme is ambitious because there are a number of drawbacks at present with composite materials. Reinforcing fibres which can operate at the high temperatures needed are not available, although suppliers are working on this.

Advances are needed in the technology of fibre coating and in control of the interface between the fibre and the matrix. Testing techniques must be developed and the current lack of scientifically based behaviour and design technology for composites must be overcome.

The weight of current compressor components is determined by the requirements for the stiffness of casings and aerofoils. Current low-density materials such as aluminium and titanium exhibit low stiffness, which can be increased only by the use of the strong, stiff fibres now available. Other materials offer similar advantages in conjunction with these fibres.

Epox y-based glass-fibre composites were first used for compressor blades and the compressor casing in the RB162 lift jet and booster engine more than 25 years ago. More recently, carbon-fibre composites have been applied to the cowling doors on the 535E4 and RB211-524 engines. On the 535E4 these provide a weight saving of 98lb per engine compared with the light-alloy doors which would otherwise be used.



# technical talk...

Another carbon-fibre application is the bypass duct for the Tay turbofan engine.

The replacement of aluminium components by resin-based composites gives a cost saving up to 25 per cent and a 20 to 30 per cent saving in weight. So far, reinforced thermo-plastics have not been used inside the engine core because they cannot be used above 180°C. Improvements in their operating temperature and tolerance to damage will lead to wider use in structures and they would be applicable for engine core components.

Composite materials based on aluminium have been produced using whiskers and continuous fibres. Fibres such as boron, silicon carbide and alumina are possible reinforcements, but there are problems with temperature, which must be less than 400°C, as well as cost, the brittleness of the fibres, the complicated requirements for design and stressing and the evolution of manufacturing methods.

Titanium offers possibilities for operation at higher temperatures. Development of titanium aluminides may well produce materials of low density which retain their high-temperature strength and good oxidation resistance to 900°C. In the long run the requirements for compressors for the year 2000 will lead to the use of fibre-reinforced titanium.

Glass offers an alternative matrix to titanium with better compatibility with the silicon carbide fibres needed for higher temperatures. Its inherent brittleness can be offset by designing a tough composite structure, making the material a strong contender for future aerofoils.

In future, turbine discs will need higher-strength materials than those of today and the ability to operate at 800°C. Likely materials are nickel aluminides, nickel-matrix composites and, in the longer term, reinforced ceramics.

## Ceramics

Materials for turbines have to meet demanding requirements for tensile strength, creep resistance, low and high-cycle fatigue and resistance to hot corrosion and impact damage. If possible they should also be of low density, in order to reduce stress levels in the blades and disc imposed by centrifugal loads, and should permit cost-effective manufacture.

Today the nickel-base alloys used for cooled nozzle guide vanes and turbine blades are operating in gases hotter than their melting point and at metal temperatures closer to it than almost any other structural material in engineering.

Further improvement in alloy properties is unlikely to be cost-effective, although manufacturing technology may permit some further advances in cooling techniques, and short-term improvements

## EFFECT OF PRESSURE RATIO AND TURBINE ENTRY TEMPERATURE ON THERMAL EFFICIENCY

Mach 0.8 cruise: component polytropic efficiency = 88 per cent

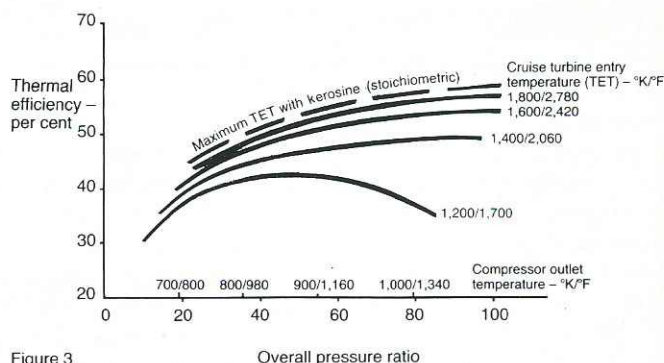


Figure 3

worth between 50°C and 100°C may come through thermal barrier coatings.

Ceramic thermal-barrier coatings have been used for more than ten years in the combustion system of the RB211 engine. They have doubled combustor life by reducing component temperature by 50°C or more. Such coatings have also been used on turbine stator-blade platforms of the 535E4 engine. This has avoided the need for film cooling of these platforms and thus has increased the engine's fuel efficiency.

Advanced blade cooling has been used to permit nickel superalloys to operate at higher gas temperatures. In a large civil engine today up to 20 per cent of the compressor delivery air is used for cooling purposes, reducing the overall efficiency of the cycle. The use of ceramic materials, with their higher temperature capability, is expected both to reduce the need for cooling air and to allow significant increases in the operating gas temperature.

Many types of monolithic ceramics are available, but silicon nitride ( $\text{Si}_3\text{N}_4$ ) and silicon carbide ( $\text{SiC}$ ) offer the greatest potential for gas turbine engines. They are stronger than the nickel superalloys at temperatures above 1,000°C and have better creep strength and resistance to oxidation, as well as being potentially cheaper. Another advantage is that the density of these materials is less than half that of the superalloys – typically 3.2gm/cm<sup>3</sup> compared with 7.9gm/cm<sup>3</sup>.

The drawback of these ceramic materials is their brittleness, sensitivity to flaws and thus lack of reliability. Mechanical brittleness of ceramics is caused by their crystalline structure which under an applied stress does not permit the existence or movement of dislocations. The plastic flow which occurs with ductile materials is not possible.

If ceramic components are to be used in gas turbines they must be at least as reliable as the metal components they replace. Substantial advances have been made in the last ten years with two approaches to this problem:

- 1 Learning to live with the brittleness, and developing an understanding of the failure



# technical talk...

micromechanics of ceramics-flaws and their relation to strength. With this approach, statistical methods and non-destructive or proof-test techniques could be used to specify design requirements such as strength or component life.

**2** Identifying the source of strength-limiting defects and developing processing methods to eliminate them. This is not as easy as it sounds because the critical defect size for ceramics is around 1/100th of that for metallic materials at typical operating stresses.

Several companies have carried out proof-of-concept and component demonstration with these

## **Rolls Royce has bench tested ceramic blades, turbine shroud rings and air bearings in an experimental helicopter engine.**

approaches. Rolls Royce has bench tested ceramic blades, turbine shroud rings and air bearings in an experimental helicopter engine. Garrett/Ford and Allison have run ceramic radial-turbine rotors, stators, combustors, regenerators and seals in programmes aimed at motor-car applications. Work has also been under way for several years in Germany and Japan on components for automotive gas turbines.

## **Resistance To Fracture**

The two approaches described rely on the design stress in components being kept well below the failure stress. Catastrophic failure results if the failure stress is exceeded for any reason. A more 'forgiving' type of failure is essential for components which operate in aero engines. This can be achieved by a third approach – designing ceramic microstructures which have improved resistance to fracture and thus some tolerance to defects.

For this reason much attention is now being given to fibre-reinforced ceramic-matrix composites. It is assumed that strong ceramic fibres can prevent catastrophic failure by providing energy-dissipation during the advance of a crack.

The feasibility of this was demonstrated as far back as 1969 using carbon fibres, but the composites degraded at temperatures between 330°C and 400°C. Most effort to date has been given to continuous-fibre reinforced glasses and glass ceramic composites because they can be produced relatively easily by hot pressing.

Other reinforcing materials have been used,

particularly whiskers of refractory oxides, carbides and nitrides. One composite system SiC/SiC, has received considerable attention and has demonstrated high 'toughness' levels and non-catastrophic fracture. Ceramic fibres which have been available for some time experience problems above 1000°C. Newer products are now available, although even high temperature capability will be needed for operation up to stoichiometric.

Studies suggest that the annual free-world market for reinforced ceramics could reach £300 million by the year 2000 and rise to £2,000 million by 2010.

Other composites with potential applications are the carbon/carbon materials. They are used today in rocket engine nozzles and aircraft brakes, but

## **It is assumed that strong ceramic fibres can prevent catastrophic failure by providing energy-dissipation during the advance of a crack**

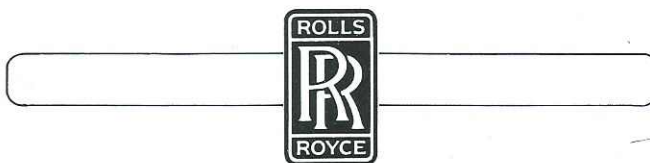
application in aero engines is limited by their poor resistance to oxidation above 400°C. This shortcoming may be overcome by use of coatings based on silicon carbide.

Contrary to some expectations, the performance of aero engines has not gradually reached a 'plateau'. Large increases in performance lie ahead, though much is dependent on the introduction of advanced materials.

The jet engine of the future is likely to have a composite compressor and a ceramic turbine – a non-metallic engine – provided the design, materials and manufacturing technology can be developed to a production stage. They will mark the start of a new era in materials for many industries, initially driven by the needs of high-technology manufacturers such as Rolls Royce.

*Bob Jeal joined Rolls Royce in 1968, following six years with the Central Electricity Generating Board. After five years working on fatigue and fracture of materials and components he was responsible for setting up a materials engineering group at Derby, becoming head of civil engine materials research and engineering and now as chief of materials and mechanical technology.*

*This article first appeared in the Rolls Royce Magazine, March 1988, and has been reproduced by kind permission of both the author and the Rolls Royce Magazine editor.*





# technical talk...

## The Sunderland flying Boat

*MEng Cliff Hall (Ret'd)*

*During my last few years as an instructor, many students have been interested in my early days on Sunderland flying boats, so hopefully the following reminiscences will illustrate a little of what a fascinating life it was.*

On May 19, 1951 I had my first taste of flying in a Sunderland, an experience which remains the most rewarding of my career.

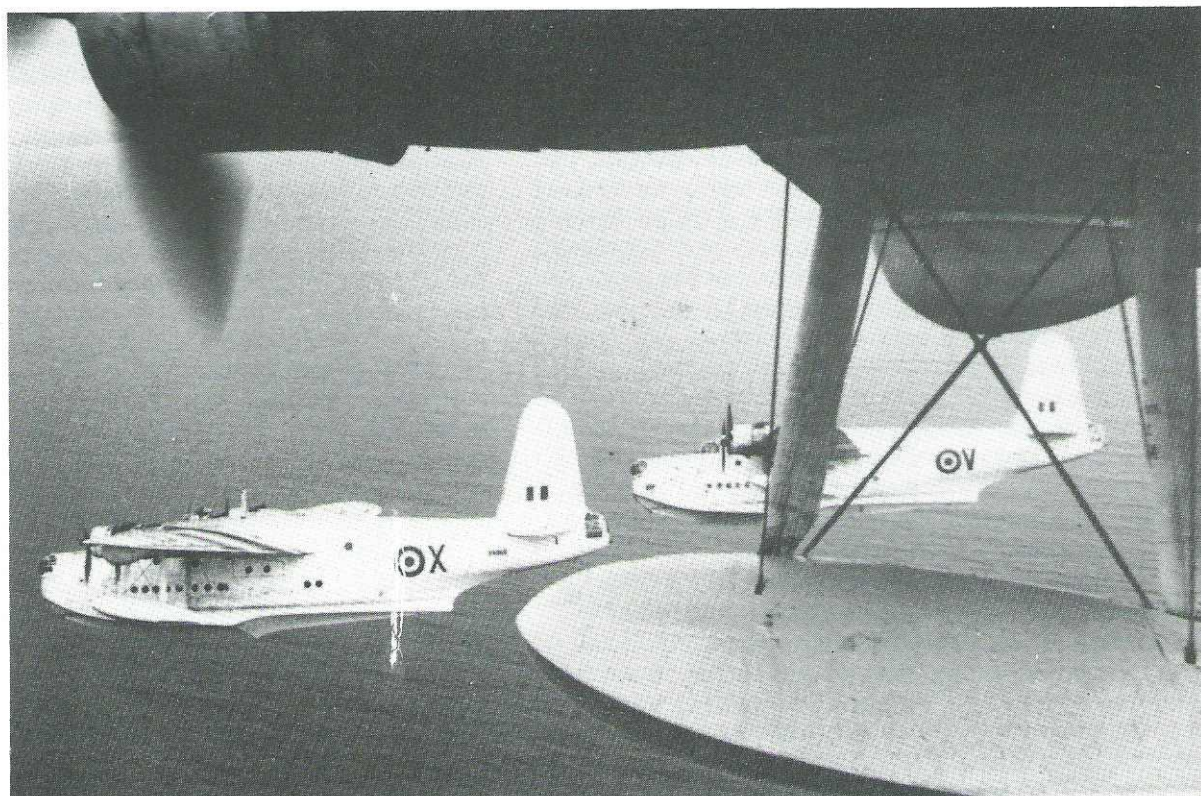
The differences between this flying boat and the wartime version were two-fold – the newer version was painted a glistening white and it had lost the mid-upper turret. But it was still a formidable flying fortress, its armament consisting of front and rear .303 gun turrets, fixed nose guns (pilot operated) and 2.5 waist guns. It was also equipped to drop depth charges, bombs and Lindholme gear, although it proved to be more efficient and practical to throw out

the 25lb fragmentation bombs by hand.

Being a member of a Sunderland crew was quite challenging; not only were you expected to operate in your aircrew category but also to relieve the gunners, assist in mooring the aircraft and, most importantly, cook in the galley. Being able to cook was a prerequisite of joining any crew!

My first tour, after I'd qualified, was on 209 Squadron (HK) stationed at RAF Seletar. The duties of the Squadron were many but one of its foremost tasks was operating in Korea. The detachments were six weeks duration and during this period we were

**In 1960 the Sutherland flying boat was deemed to have outlived its usefulness and the entire fleet was sold to Chinese businessmen for scrap.**



Formation  
practice  
– Singapore.



# technical talk...

stationed at Iwakuni (Japan) sharing accommodation with American and Australian forces. Our main task was carrying out anti-submarine patrols in the Tsu-Shima Straits, each patrol lasting between six and ten hours. The temperature often fell to  $-40^{\circ}\text{C}$ , contrasting sharply with the sticky humidity of Singapore. The powers that be, worried at the epidemic of head colds, issued all aircrew with copious supplies of Haliborange tablets!

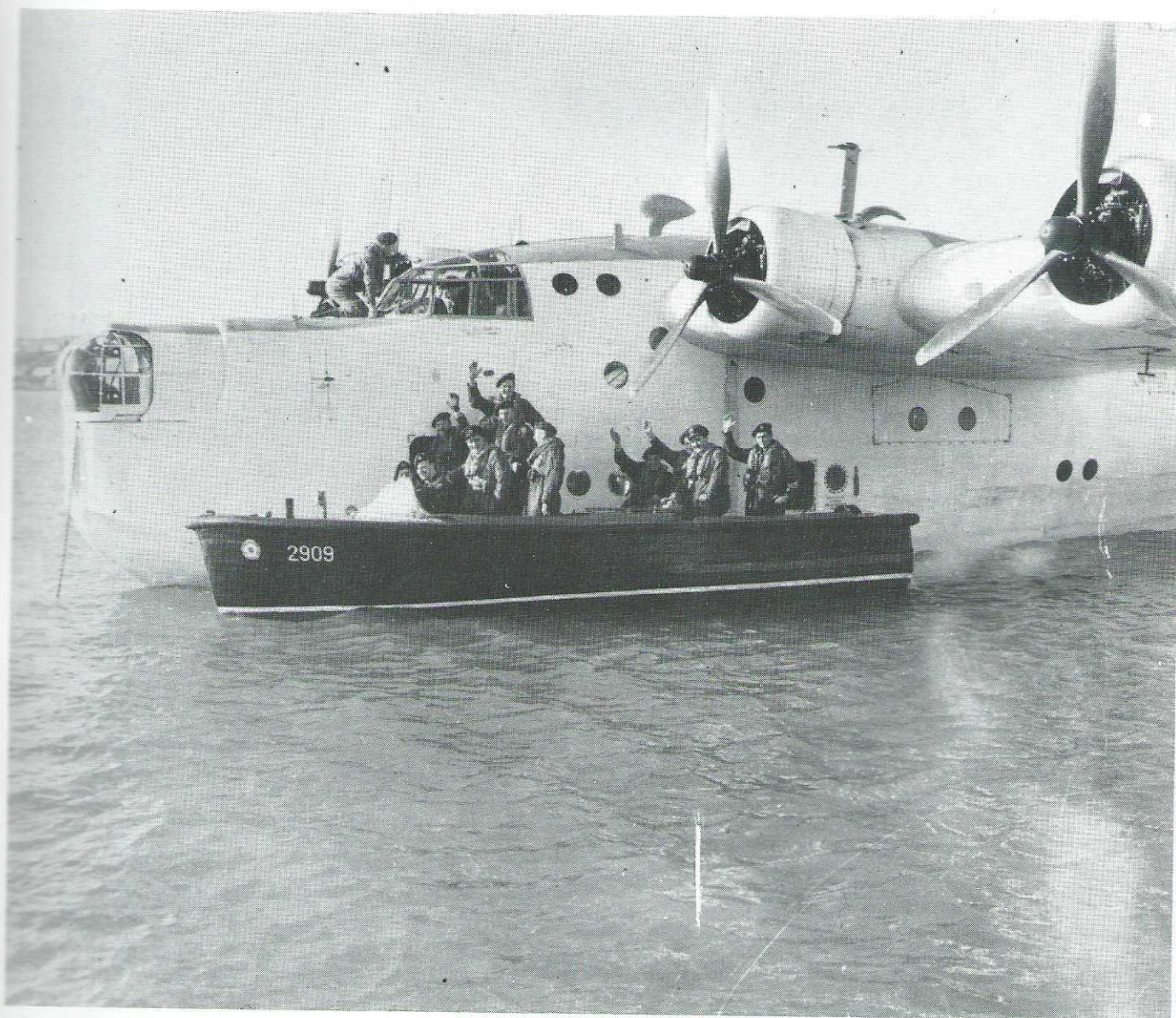
Back in Singapore the Squadron periodically bombed and strafed kampongs which were known terrorist hideouts, carried out search and rescue duties in Hong Kong and were often invited to Borneo on courtesy visits.

One of the highlights of this tour was a flypast over Singapore involving 12 Sunderlands in close formation. The flypast was in honour of the coronation of Queen Elizabeth II and was an awe-inspiring sight.

In October 1954 I joined 201 Squadron at Pembroke Dock and spent the next two and a half years on Air Sea Rescue duties and Naval exercises.

In 1957 I returned to Singapore and joined 205/209 Squadron. The Squadron's commitments were virtually the same as the previous tour except that the Korean war was ending and so no more Iwakuni detachments. However, it had been decided to open up Gan as a staging post and an extra duty was to supply the runway construction teams with food and supplies. As we could not fly this distance direct we staged at Trincomalee.

In 1960 the Sunderland flying boat was deemed to have outlived its usefulness and the entire fleet was sold to Chinese businessmen for scrap. A very sad end for a wonderful flying machine.



Pembroke Dock – crew arriving at the a/c. Me at the rear of the boat.





# Joint Air Transport Establishment

*MEng Gordon Hampson*

*Medium stressed platform drop.*

JATE is a joint service establishment located at RAF Brize Norton and is commanded by an army colonel. The present commandant is Col G R Owens. JATE is manned by officers, warrant officers and men drawn from all three services, and a substantial number of civilian personnel.

It is controlled by and directly accountable to the central staffs of the Ministry of Defence.

JATE is responsible for the study, development and service testing of equipment and techniques for air transported operations and airborne assault. It also has an important function as an advisory service with regard to design criteria for projected new equipment which may have the requirement of being air transportable or of being air droppable.

Other responsibilities include the day to day management and printing of Air Transport Operations Manuals and drafting of Army Electrical and Mechanical Engineering Regulations (EMER's) for the Aerial Delivery Range of equipment. Duties also extend to investigation of malfunctions (MALDROPS) and associated defects of parachute and airdrop equipment, together with investigation of all reported aerial delivery equipment defects in accordance with Army EMER. The establishment is also tasked to train instructors and key personnel of the three services with regard to techniques and equipment involved in air transported operations and airborne assault, and

all related aspects connected with ground handling of helicopters.

The above tasks are carried out by one or more of the JATE trials and development sections namely Aerial Delivery, Airportability, Airborne Trials,

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**JATE is responsible for the study, development and service testing of equipment and techniques for air transported operations and airborne assault.**

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Helicopter, Training, Engineering and Flying sections. These sections are in turn supported by JATE Administration, Design and Drawing, MT, Photographic and Printing sections.

Flying Section conducts JATE fixed-wing flight trials using the Hercules (C Mk 1, C Mk 3, C Mk 1K) aircraft allocated from RAF Lyneham on a requirement basis. It is established for one Hercules crew and a Role equipment fitter. An aircraft is allocated to meet necessary flying trials, ground trials



## *Joint Air Transport Establishment*

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and crew continuation/route training. In providing the airlift capability for JATE the section is currently involved in projects such as continuing work with high altitude high opening (HAHO), high altitude low opening (HALO) parachuting with the new military ram air parachute and in conjunction with Aerial Delivery section involved with airdrop development of the medium stressed platform (MSP) loads and the rigid inflatable boat (RIB).

The Flying section is also responsible for producing amendments to standard operating procedures (SOP), for transport calculated air release points (CARP) and advising generally on all aircrew aspects of Transport Support operations. When not required for trials and development the crew are available to fly 1GP tasks in support of the Hercules worldwide commitment.





by Flt Lt Ian Morton (34!)

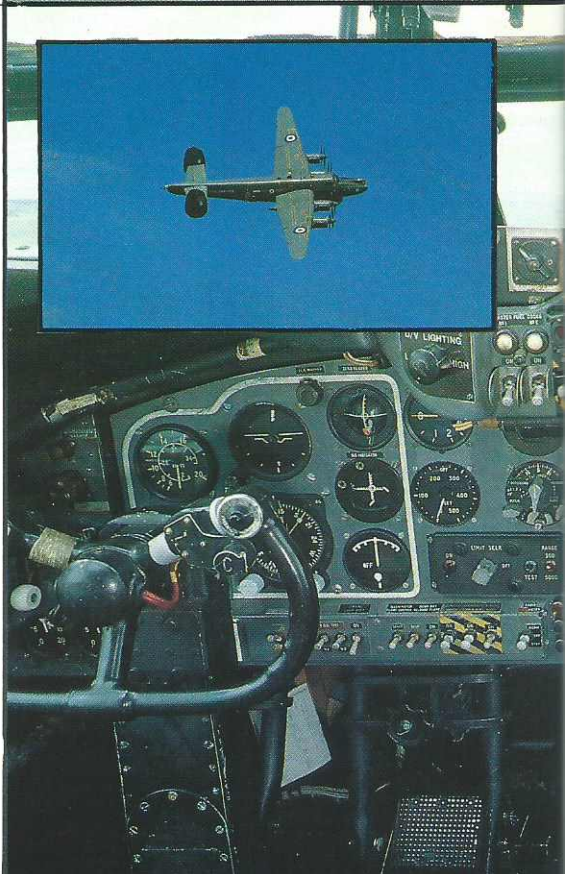
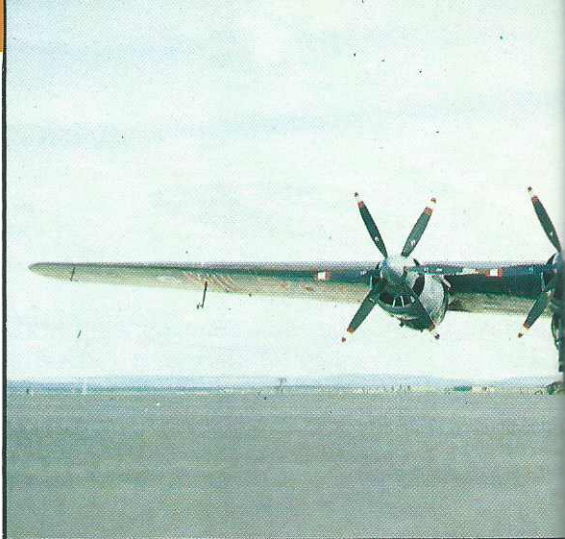
For those who don't know (and there should not be many!), the Shackleton is 40 years old this year. Yes, she's showing her age: grey hairs, wrinkles, the odd crack here and there but, being well looked after, she continues to give sterling service as the last multi-engined piston aircraft on operational duties anywhere in the world. This article is written to give a brief insight into this find old lady's past, present and future.

The Avro 696 Shackleton GR (general reconnaissance) Mark 1 first flew on March 9 1949. The aircraft, named after the explorer Sir Ernest Shackleton, was the last in a line of 'heavies' from the drawing board of Roy Chadwick, chief designer of A V Roe and Company Ltd. Its predecessors were the under-powered Manchester of the mid-30s, the highly successful and world-famous Lancaster of 1941 and the Lincoln of 1944. Sir Henry Royce mustn't go without a mention as it was his brilliant Merlin engine that formed the basis of the more powerful Griffon which, married to a contra-rotating prop using Sir Jimmy Martin's ingenious translation unit, has powered the 'Shack' throughout its life and given the world the characteristic 'Griffon Growl'.

The first Shackleton, VW 126, displayed her bomber ancestry with a mid-upper turret, twin cannon in the nose barbettes and an in-flight refuelling point in the tail! The second prototype dropped the nose cannons and refuelling points (thank goodness!). The first Mk 1A Shackleton was delivered to 120 Squadron at Kinloss, Moray, in April 1951 for maritime patrol duties. Problems with the chin-mounted radome, single tailwheel and rather inefficient braking system gave rise to the Mk 2 Shackleton with a retractable radome (nicknamed the dustbin) aft of the wing. The nose was lengthened and given a bomb aimer's position plus a nose gunner's position with two Hispano Cannons, and the tail section was also lengthened and given a lookout position. The definitive Shackleton shape had arrived. Still not satisfied with the Mk 2 tail-dragger with its problematic pneumatic brakes, the slightly bigger Mk3 was produced with a tricycle undercarriage, hydraulic braking system, modified wing with tiptanks, and updated cream and brown interior with a proper galley, rest area and *full sound insulation!* These improvements resulted in the Mk 3 having a maximum AWW of 108,000 lb compared to the 82,000 lb of the Mk 1A. In order to haul that lot off the ground two Viper jets were later fitted into the outboard engine nacelles.

Research was carried out on a Mk 4 version with a single fin, four Napier Nomad engines and projected maximum AWW of 132,000 lb, but the aircraft never left the drawing board.

In her various guises the Shackleton fulfilled her task of the UK's Maritime Patrol Aircraft (MPA) admirably, regularly flying patrols in excess of 12 hours. One of an MPA's duties is Search and Rescue (SAR) and with her slow speed, long endurance,







many excellent lookout positions and ability to carry large amounts of SAR equipment, she is still reckoned to be one of the best land-based fixed-wing SAR platforms ever built. Perhaps the most famous SAR incident was her assistance in the rescue of the few survivors of the burning liner *Lakonia* off Portugal in 1963.

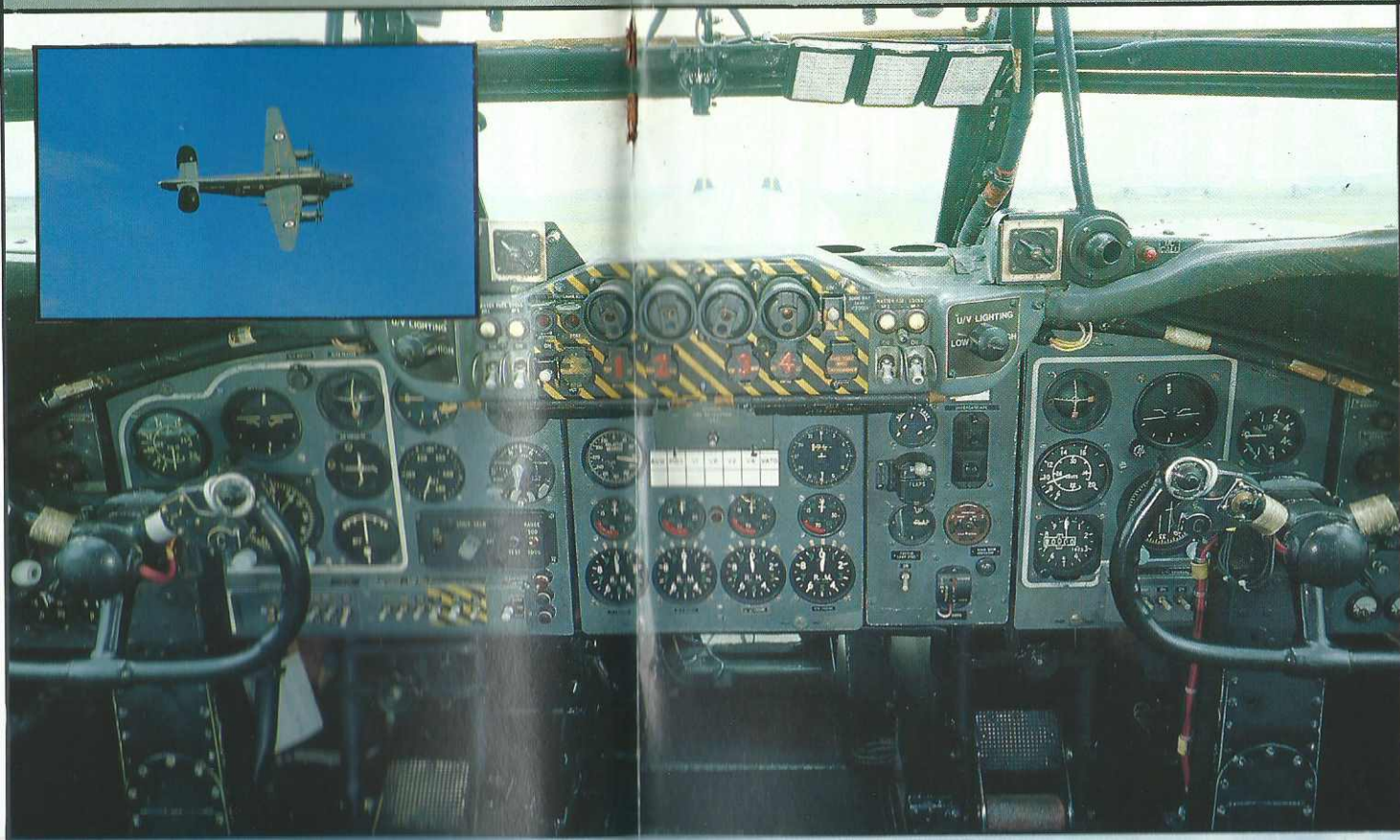
In addition to her primary role she undertook nearly all those tasks that can be attributed to aircraft: from colonial policing in Brunei, Borneo and the Middle East to disaster relief in Belize and Morocco; from meteorological reconnaissance to troop carrying from UK to Cyprus during the Suez crisis. In her various MR Mk3 and phases she operated all around the globe. In addition to her UK bases of Kinloss, Ballykelly (Northern Ireland), St Eval, St Mawgan and Honington, she had overseas operating bases at Aden, Sharjah, Changi, Gibraltar and Luqa. From all these bases she sallied forth on numerous detachments to such places as Andoya, Ysterplaat, Majunga and Hawaii, and there is many an oil-stained apron bearing witness to a passing 'Shack' detachment. Of course no detachment was without its 'war stories' (the repairing of injector diaphragms with inner tube rubber, the troublesome starter motors being bludgeoned into action with a 'swift belt') and no doubt some tales were apocryphal, but one which wasn't was the one about the crew that took an unscheduled 72 days to return from Changi via Majunga – a mean speed of 1.75 knots!

After two decades of operations the Shackleton was finally replaced by the Hawker Siddeley Nimrod MR 1. However, all was not lost. With the demise of the RN aircraft carriers and their Gannet AEW aircraft, and a need to improve the early warning radar coverage for the United Kingdom's Air Defence System, the Shackleton was given a new lease of life as a temporary 'stop gap' AEW aircraft until a new aircraft was procured!

Although the Mk 3 Shackletons looked quite youthful, they had run short of fatigue life so it was the older Mk 2s (still with their leaking brake sacs) which were selected for conversion. The ASW equipment was replaced by the high-powered APS 20 search radar (robbed from the retired RN Gannets), the radio fit was improved and the SAR capability retained. Twelve 'new' AEW aircraft entered service on January 1 1972 with No 8 (AEW) Squadron, one of the oldest and most distinguished squadrons in the Royal Air Force. Some ten years later the strength was reduced to six aircraft under John Nott's defence review of 1981. Eight years later the same six aircraft are still flying, 17 years after their introduction as a 'stop gap' measure!

So what does the old lady get up to nowadays? One aircraft is continually allocated to the UK Air Defence QRA (quick reaction alert) task for the detection, tracking and reporting of 'intruding' air tracks within the UK Air Defence Region. Some readers may raise a wry smile at the words 'quick' and 'Shackleton' appearing together, but the Shack fills any gaps in the UK's radar coverage and has been known to 'take trade' from NATO AWACS lording it at 35,000 feet. Continuation training for the radar teams occurs on a daily basis, working with the fighters of 11 Group and often controlling the aircraft during practise intercepts. Work is also carried out with the RN for fleet AEW.











Life isn't just 12-hour flogs over the North Sea, however. Frequent detachments are made to Cyprus, working with fighters on their armament practise camps. Liaison visits 'flying the AEW flag' are made, to France in particular, but obtaining large amounts of Avgas at overseas bases can be a problem.

Appearances at air shows feature throughout the summer where the youngsters of today stand in awe at the sight of such an antiquated lady, and as SAR equipment is still carried the crews are kept current in its use and occasionally are involved in live incidents.

Of course, a 40th birthday cannot pass without celebration. To mark the event five Shackletons left Lossiemouth (four-ship plus trail) to visit Woodford where the BAe workforce downed tools to witness the home-coming. The sixth aircraft missed the party as it is undergoing major surgery to its rear spar. A giant birthday cake was presented to OC 8 Sqn, Wg Cdr Dave Hencken at the Manchester Museum of Science and Industry which houses the magnificently-kept WR 960 AEW II aircraft. After a buffet luncheon and presentation the five crews retired to Bredbury Hall which must be nearly as well-known in Air Force circles as the Shack itself. The following day the five aircraft, all serviceable I hasten to add, returned to Lossiemouth sporting red noses as part of Comic Relief. After take-off they routed directly over Chedderton (Greater Manchester) where the aircraft had been built all those years earlier.

So, to the future. The Squadron is planned to begin operating the Boeing Sentry aircraft in June 1991 at Waddington, but until then they will continue with their QRA and training duties. What happens after that? Does she become a training aircraft for the Battle of Britain Memorial Flight, or a display aircraft for a private concern (BAe, Rolls Royce)? Whatever happens, the Shacks must not just go to the scrap man. Would it not be a fitting finale for a 'last detachment' to be made around the world visiting all those oil-stained aprons left from years before?

## Miscellany

Aircraft in service with No 8 (AEW) Squadron (as at March 9 1989):

### WL 747 – 'Florence'

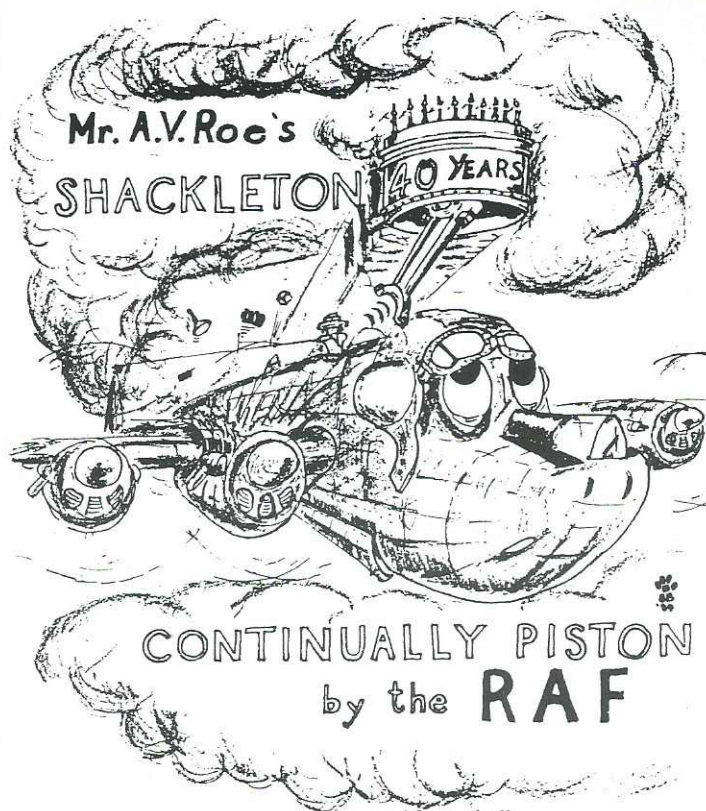
First flew Woodford – February 5 1953, 269 Squadron Ballykelly – April 3 1953, 204 Squadron Ballykelly – August 11 1954, 42 Squadron St Eval – June 11 1958, Avro (Woodford) – September 18 1958 – 2/1 refit, 210 Squadron Ballykelly – October 19 1959, Avro (Woodford) – April 13 1961 – 2/2 refit, 37 Squadron Aden – November 4 1961, HSA (Bitterwell) – May 8 1964 – 2/3 refit, 210 Squadron Ballykelly – September 12 1966, 204 Squadron Ballykelly – March 30 1969, 5 MU – December 17 1970, HSA (Bitterwell) – February 2 1971 – AEW conversion and 8 Squadron – March 16 1982.

Hrs flown: 13,974

### WL 756 – 'Mr Rusty'

First flew Woodford – April 1 1953, 37 Squadron Luqa – July 28 1953, 38 Squadron Luqa – December 16 1955, 37 Squadron Aden – July 18 1957, Avro (Woodford) – January 23 1961 – 2/2 refit, 205 Squadron Changi – January 11 1962, HSA (Langár) –

22 Air Engineer



October 3 1966 – 2/3 refit, 204/210 Squadron Ballykelly – October 26 1967, 204 Squadron Ballykelly – December 10 1969, HSA (Bitterwell) – April 2 1971 – AEW conversion and 8 Squadron – May 4 1972.

Hrs flown: 13,676

### WL 757 – 'Brian'

First flew Woodford – April 10 1953, 37 Squadron Luqa – August 5 1953, 38 Squadron Luqa – October 15 1957, Avro (Woodford) – September 29 1958 – 2/1 refit, 210 Squadron Ballykelly – October 30 1959, De Havilland Hawarden – March 27 1961 – 2/2 refit, 224 Squadron Gibraltar – December 15 1961, HSA (Langar) – March 30 1966, 2/3 refit, 205 Squadron Changi – May 25 1967, HSA (Bitterwell) – August 26 1971 – AEW conversion and 8 Squadron – August 29 1972.

Hrs flown: 13,932

### WL 790 – 'Mr MacHenry'

First flew Woodford – January 23 1953, 240 Squadron Ballykelly – October 6 1953, 204 Squadron Ballykelly – August 9 1954, 269 Squadron Ballykelly – November 11 1958, 210 Squadron Ballykelly – December 1 1958, 49 MU – January 7 1959 – 2/1 refit, 210 Squadron Ballykelly – May 12 1959, Avro (Woodford) – January 10 1961 – 2/2 refit, 205 Squadron Changi – June 21 1962, HSA (Langar) – August 29 1966 – 2/3 refit, 205 Squadron Changi – August 31 1967, HSA (Bitterwell) – September 30 1971 – AEW conversion and 8 Squadron – September 20 1972.

Hrs flown: 13,891

### WR 963 – 'Ermintrude'

First flew Woodford – March 11 1954, 224 Squadron Gibraltar – October 6 1954, Avro (Woodford) – March



During the Caribbean tour the Squadron carried the band of the Royal Hampshire Regiment to Caracas, Venezuela, to take part in the 150th anniversary of that country's independence.



**Look mate! This aircraft is noisy enough without your band practice.**

9 1959 – 2/1 refit, 210 Squadron Ballykelly – February 23 1960, De Havilland Hawarden – March 15 1961 – 2/2 refit, 38 Squadron Luqa – November 23 1961, 205 Squadron Changi – January 14 1966, HSA (Langar) – July 21 1966 – 2/3 refit, 205 Squadron Changi – July 1 1967, HSA (Bitterwell) – June 30 1971 – AEW conversion and 8 Squadron – July 19 1972.

**Hrs flown: 14,957**

## WR 965 – 'Rosalie'

First flew Woodford – April 7 1954, 37 Squadron Luqa – November 5 1954, 38 Squadron Luqa – July 8 1957, Avro (Woodford) – March 23 1959 – 2/1 refit, 224 Squadron Gibraltar – April 6 1960, De Havilland Hawarden – August 28 1961 – 2/2 refit, 203 Squadron Ballykelly – April 10 1962, HSA (Langar) – March 17 1966 – 2/3 refit, 205 Squadron Changi – May 24 1967, 204 Squadron Ballykelly – December 2 1968, HSA (Bitterwell) – April 28 1972 – AEW conversion and 8 Squadron – January 16 1971.

**Hrs flown: 14,586**

## Technical Details

### Airframe

The Shackleton is a mid-wing monoplane of wingspan 120 feet and length 87 feet four inches, with a large bomb-bay. With twin tail fins and tailwheel undercarriage, its appearance is reminiscent of that of its predecessor, the Lancaster, but its overall size is significantly greater. The colour scheme employed by No 8 Squadron is dark sea grey with a matt black anti-dazzle panel forward of the cockpit, and the

Squadron emblem, an Arabian gambia (dagger), in a white circle either side of the nose. The Squadron colours, yellow, royal blue and red, appear in horizontal stripes, 'fighter style', either side of the fuselage roundels. Also, as a recent addition, the Squadron number is worn on the fuselage sides.

### Crew

Complement of the Shackleton comprises a flight crew of two pilots, one navigator and one flight engineer, and a mission crew or radar team of five, led by a TACO (tactical co-ordinator). The aircraft captain may be a pilot or navigator.

### Engines

The Shackleton AEW Mk 2 is powered by four 36.7 litre Rolls Royce Griffon Mk 58, V12 liquid-cooled piston engines which have fuel-injection and are supercharged. Each develops a maximum of 2435 bhp which is delivered to two three-bladed, contra rotating De Havilland propellers. The aircraft carries nearly 3,300 gallons of high octane petrol.

### Radar

The basis of the Shackleton Airborne Early Warning system is the AN/APS 20F(1) search radar equipment with three operator positions. The aerial is mounted in a radome under the fuselage forward of the bomb-bay.

### Author's Footnote

*I wish to extend my sincere thanks to the other members of 8 Squadron who helped me produce this article, not least Flt Lt Andy Thomas (Taco/Historian) and MAEOp Brian Burns (radar controller/ artist 'Band 6').*



# Flight Safety File

## The Flight Of Nimrod XV257

Early one morning in June 1984 the sirens sounded at RAF St Mawgan as a period of Tactical Evaluation (Taceval) commenced, and aircraft and crews were quickly brought to readiness. 42 Squadron crew four, the previous day's Search and Rescue (SAR) crew, was briefed to hold exercise SAR standby. The captain of the crew was one of the most experienced pilots on the fleet, as was his co-pilot who was 'guesting' on the crew for the exercise period. The flight engineer was 18 months into his first operational tour since the completion of his training. As the crew began the waiting game which is so much a part of the SAR job, their aircraft, Nimrod MR2 XV257, was being refuelled and having its bomb bay loaded with air-sea rescue equipment. Mounted on carriers at the rear of the massive bomb bay were several five inch recce flares which are made of magnesium and burn at a temperature in excess of 2000°C. The flares are used to illuminate large areas of sea at night, a job they do well as they emit 13 million candlepower for over three minutes.

Crew four were not kept waiting for long. The Tannoy burst into life, 'Dinghy, dinghy, dinghy, search and rescue crew scramble!' At 1100hrs XV257 lifted off from runway 31 and, as the aircraft turned left in the climb, the crew carried out the after take-off and circuit leaving checks. What the crew did not yet know was that either during the take-off roll, or shortly after take-off, one of the five inch flares had become detached from its carrier and fallen onto the closed bomb bay doors. As soon as the captain ordered 'SAR checks outbound' (1), the Nav selected nose and tail fusing and, despite the many safety devices fitted to it, the flare ignited.

The following voice transcript has been compiled from the original aircraft and air traffic control tapes. It should be noted that there was a lot of off-intercom conversation going on which does not appear in the transcript. Hence the apparent lack of continuity with some of the conversation. Note also the compound nature of the emergency and the timescale. The captain was occupying the right-hand seat and the co-pilot the left, a common procedure on the Nimrod. The numbers in brackets relate to the diagram of the flightpath of XV257.

**1102:40** Bomb bay fire warning bell sounds. (2)  
**Captain:** We have an ... underfloor warning test of the bomb bay. Can we have a look at the bomb bay please?

**Air**

**Electronics**

**Officer (AEO):** Certainly.

**Captain:** Bomb bay fire warning – turn back please.

**1102:50**

**Flt Eng:**

**Nav 2:**

Bomb bay heating is off ...

You've got it (St Mawgan) on the TACAN.

OK.

**Captain:**

**1103:00**

**Captain**

**(to ATC):**

**AEO:**

SAREX 51 ...

We have a fire in the bomb bay, we have a fire in the bomb bay. (3)

SAREX 51, mayday, mayday, mayday; fire in the bomb bay – coming back for an immediate landing on runway 13, immediate landing runway 13, mayday, mayday, mayday. (4)

**Captain**

**(to ATC):**

**1103:20**

**ATC:**

SAREX 51 your mayday acknowledged.

**Captain:**

Push it back fast boys – airbrakes out – let's get this thing on the ground.

**Co-pilot:**

Yes, coming back, don't worry.

**ATC:**

SAREX 51 steer 080.

Wing centre section overheat warning illuminates (5)

**AEO:**

It seems to be confined to the back end ...

**1103:30**

**Captain:**

OK, vacation of the aircraft will be from the front door at the moment so be prepared for a front door exit.

Aileron bay underfloor warning bell and light (6)

Front door copied.

**AEO:**

**1103:40**

**Flt Eng:**

**Co-pilot:**

Eng copied ...

**Flt Eng:**

Aileron servodyne ...

**Captain:**

Contact, break, break ...

**Flt Eng:**

Aileron servodyne bay ...

Break, break, centre section drill is complete, aileron underfloor ...

Aileron underfloor copied.

**AEO:**

**1103:50**

**Captain:**

All crew 100 per cent oxygen.

**1104:00**

**Flt Eng:**

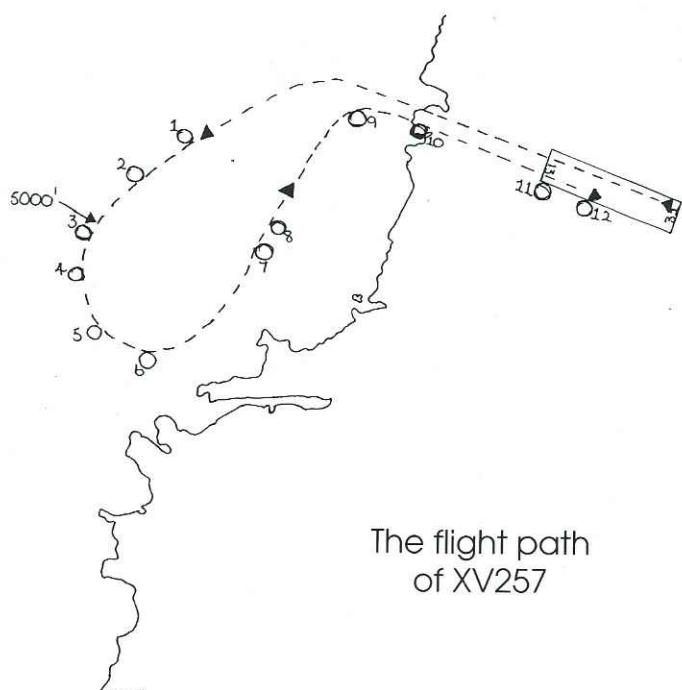
Underfloor warning immediate actions, aileron bay; all crew to both intercomms; smoke detector ... did not reset, bell isolation switches ... are off; crew member to check affected compartment ...

**ATC:**

SAREX 51, approach cable will be up, the circuit is clear. QFE for runway 13 is 986.



# Flight Safety File



The flight path  
of XV257

**Flt Eng:** Subsequent actions; all crew 100 per cent oxygen, smoke goggles are available, avionic cooling fans are ... off, galley master ... off. AEO (from) Eng, report.

**1104:20  
Dry 3:** AEO's on ...

**AEO:** AEO on intercomm, unable to get (CO<sub>2</sub> fire extinguisher) plugged into aileron bay.

**1104:30  
Captain  
(to ATC):** Mayday rescue 51 now has an under-floor warning in the aileron servodyne bay as well. There's no practise about this, sport.  
**ATC:** 51, that's understood.

**1104:50  
AEO:** (Fire extinguisher is) in the aileron bay, split-pin removed.

**AEO:** *Smoke starts to come into fuselage. (7) Smoke in the fuselage, standing by to fire the fire extinguisher. Total Green (main utility) hydraulic system failure. (8)*

**Captain  
(to ATC):** We now have smoke in the fuselage, intention's land, shutdown all engines, vacate starboard front door, and for Christ's sake get everything ready.

**1105:00  
Co-pilot:** Undercarriage is travelling down – what's the (touchdown) speed for me, Eng? Quick, please.

**1105:10  
Captain:  
ATC:** One ... thirty.  
SAREX 51, you have been cleared to land on runway 13, surface wind 270/10.

**1105:20  
AEO:** Eng (from) AEO, standing by to fire the extinguisher.  
**Flt Eng:** Go ahead.  
**AEO:** First burst going now.



A wreckage.



# Flight Safety File

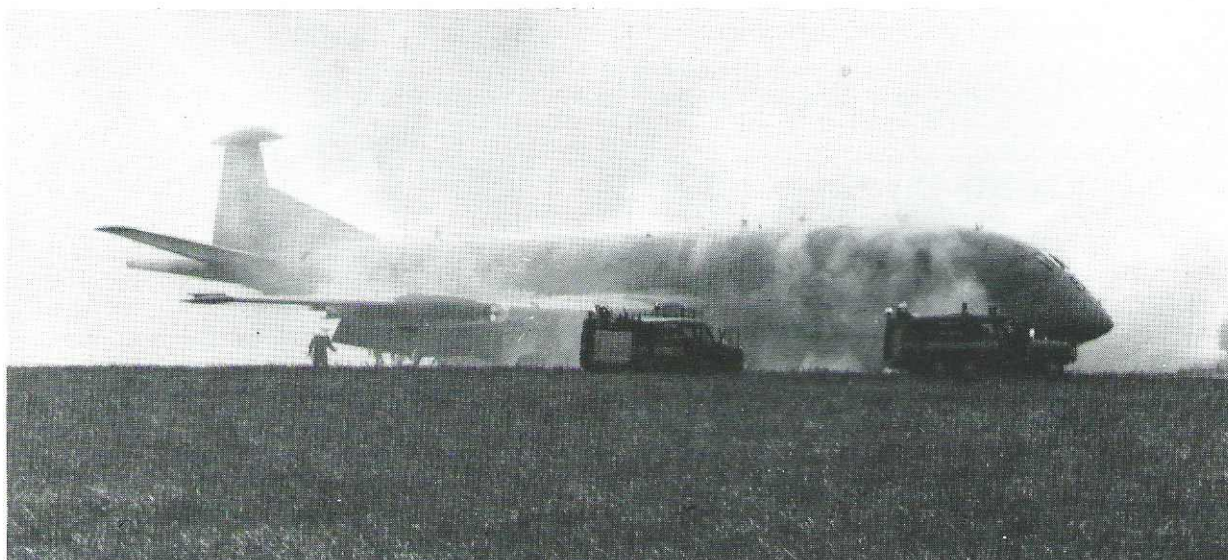


**1105:30**  
**Co-pilot** OK, check your brakes on the red,  
**(to Captain):** please.  
**Captain**  
**(to ATC):** Mayday 51 ...  
**Captain:** Brakes are on red ... checking ...  
**Co-pilot:** Checking ...  
**AEO:** First burst complete, Eng.  
**Flt Eng:** Eng copied.  
*Undercarriage has failed to lower*  
*(400ft finals!). (9)*  
**Co-pilot:** We haven't got any undercarriage  
 coming down. We've got an under-  
 carriage stuck up.  
**Captain:** Oh, Christ! Undercarriage to red,  
 please ... Undercarriage to red  
 selection.  
**Flt Eng:** Red ...  
**Captain:** Red pump on.  
**Co-pilot:** There we are ...  
**Captain:** Red selected ... Two greens ...  
**1105:50** *Fire warning sounds for zone 2 of No*  
*2 engine. (10)*  
**Captain:** Fire in No 2 engine, zone 2 ... shutting  
 down No 2 engine ... HP cock off ...  
 LP cock shut ...  
**Flt Eng:** One and 2 HP air supply levers are off.  
**1106:00**  
**Captain:** Firing first shot ...  
**Co-pilot:** OK, I'm landing ...  
**Captain** OK, landing off this, we've now got a  
**(to ATC):** fire indication in No 2 engine ...  
 There's a real fire in the bomb bay as  
 far as we can see.  
**ATC:** SAREX 51.  
**AEO:** Second shot going, the aileron bay is  
 full of smoke.  
**1106:10**  
**Flt Eng:** Eng copied.  
**AEO:** Strap in, strap in.  
**Captain:** Brace, brace, brace.  
**1106:20** *Aircraft lands. (11)*  
**Co-pilot:** OK, reversers in now, please.  
**Captain:** In, running up.

**1106:30**  
**AEO:** Front exit when aircraft stops ...  
**Co-pilot:** Check brakes, Gordon.  
**Captain:** You have no pressure at the moment  
 ... brakes onto red.  
**Co-pilot:** Red, please.  
**Captain:** You have red ... Checking brakes, no  
 maxarets, 600 (psi) both sides ...  
**1106:40**  
**Flt Eng:** Total green system failure, total green  
 system failure.  
**Captain:** No, brakes are working ...  
**Co-pilot:** We're on the red ... reverse idle.  
**1106:50**  
**Captain:** Reverse idle.  
**Co-pilot:** Turning off next exit on right.  
**Captain:** OK, Oh ... Kay.  
**Flt Eng:** Fire second shot into No 2 engine.  
**Captain:** It's out.  
**Flt Eng:** Sorry.  
**1107:00** *Underfloor warning in elevator servo-*  
*dyne bay. (12)*  
**Captain:** The underfloor has moved to the  
 elevator bay as expected - flow.  
**AEO:** AEO copied.  
**Co-pilot:** We'll stop here.  
**Captain:** OK. Everybody out, everybody out.

*Only four minutes and 20 seconds had elapsed since the original bomb bay fire warning sounded!*

One shudders to think what the consequences would have been if the aircraft had been any further out from base or if the turnback had been delayed. The ferocity of the fire was such that the rear section of the bomb bay was destroyed, the pressure hull of the cabin which forms the roof of the bomb bay burnt through, hydraulic pipes melted and fed their contents to the fire which moved out into the port wing root area, and the rear fuselage fuel tank, fortunately housed in a pressure box, had started to melt. Some five years after the incident, XV257 is still not airworthy.





# 'those were the days'

## 'Many A Mickle Mak's A Muckle ...'

*by MEng Roy Craig*

*Once upon a time there was a Shackleton Mk 3 Phase 3 on detachment from Ballykelly to Akrotiri. The time had come to return home, the long flight planned to take three days with night stops at Luqa and Gibraltar ...*

Sunday, and the aircraft was loaded up with the belongings of the ten crew members and nine ground-crew/passengers. The Squadron pack-up and some of the luggage was loaded into two (unjettisonable) panniers in the bomb bay. As it was only two weeks to Christmas, we had lots of sacks of fruit which, with the rest of the luggage, was loaded in the nose of the aircraft. (The Mk 3 Shack was very tail heavy and all extra weight had to be loaded forward of the C of G.)

### **Monday**

Akrotiri to Luqa – four hours 40 minutes at 1000ft – uneventful.

### **Tuesday**

Luqa to Gibraltar – six hours – flew through a severe sandstorm for one hour.

### **Wednesday December 13 1967**

Early morning, looking forward to getting home after six weeks away, arrived at the aircraft to be met by the chief who says that they have accidentally over-fuelled us – would it be OK? Quick check of the ODM for take-off distance etc and decision made to accept it, 3500lbs above planned TOW.

Eventually got airborne from Gib for our planned nine hours 30 minutes flight to Ballykelly.

Some two-and-a-half hours into the flight, vibration was felt through the aircraft and the airspeed fell by about 20kts. A check of all powerplants showed that No 1 engine's propeller translation unit had failed and ball-bearings and sparks were flying off it as it broke up. This failure meant that we had lost control of the rear prop which, under CTM, had gone fully fine, and the front prop had coarsened off to compensate. The engine was shut down and the front prop feathered, but it continued to windmill slowly. We were now 90 miles NW of Lisbon so, after a Pan call had been made, we informed Lisbon that we were diverting there. Wing-tip fuel was jettisoned, (3600lbs), and the aircraft was turned towards Lisbon. The Vipers were

prepared for immediate start-up and fuel jettison was started from the main tanks.

A few minutes later, 17 minutes after the TU failure, the signaller in the starboard beam look-out position called the flight engineer to report oil leaking from around the jet-pipe of the starboard Viper. The eng went back and confirmed that it was oil leaking from the No 4 Griffon. The leak rate rapidly increased and the captain was informed that No 4 would have to be

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As it was only two weeks to Christmas we had lots of sacks and fruit which were loaded in the nose of the aircraft.

---

shut down. It was obvious that the engine was 'gulping' but, instead of the oil coming out of the normal vent pipe, it was pouring out of the cowlings and going straight down the intake of the starboard Viper. The imminent loss of a second Griffon meant that the Vipers would have to be lit up, so fuel jettison was stopped. (The Vipers ran on AVGAS and it was banned to jettison fuel and run the Vipers at the same time because of the fire risk.) The starboard Viper would not light up – no big surprise seeing 30 gallons of Griffon engine oil had gone through it – but the port Viper was started before No 4 was shut down and its props feathered.

A mayday call was transmitted and, with take-off power on both inboards and the port Viper at 100 per cent, the aircraft stabilised at 500ft and 150 kts IAS. We decided not to attempt a further start on the starboard Viper because it was soaked in oil and the fuel from the first attempted light up and the fire risk was too great. A further consideration was that we couldn't afford the extra drag from the open intake door for the 40 seconds or so it would take to try and start it.

Nursing the aircraft along, and running the Viper for periods of between five and ten minutes with one



# 'those were the days'

minute rests, we could just manage very shallow turns but, even in these, the airspeed fell off to a perilous 140 kts. Trying to rest the Griffons by throttling them back from 2750 rpm caused an instant loss of speed so that they were kept at take-off power throughout.

By the time permission was given by ATC for a direct approach to runway 03, we were hugging the coastline at the entrance to Lisbon harbour and having to map-read our way to the airfield because the ADF was u/s and there was no radar available. Visibility had dropped to one-and-a-half miles in the smoke-haze from the city and 'it was with some surprise' that we saw the Salazar Bridge directly ahead and above us! (Because of its recent construction the bridge wasn't on our charts!)

As we could not fly beneath the bridge and we hadn't got the power to climb over it, we turned away and flew down the estuary in a desperate but unsuccessful attempt to gain height. At this stage, the captain of a Portuguese Boeing 727 belonging to TAP heard on R/T of our predicament and offered his assistance. He then closed in, reduced his speed to

match our 140 kts, and led the way across the outskirts of the city to the airfield. Fortunately, thermal uplift as we coasted in gave us a valuable 400 ft increase in altitude so we were now 900 ft amsl but still only 500 ft agl.

At two miles the runway became visible and we informed the 727 captain that we were visual. The 727 was dead ahead and at the same height as us as the Portuguese captain selected power for his overshoot. The consequent turbulence made the poor old Shack perform aerobatics and the airspeed fluctuated down to 90kts!

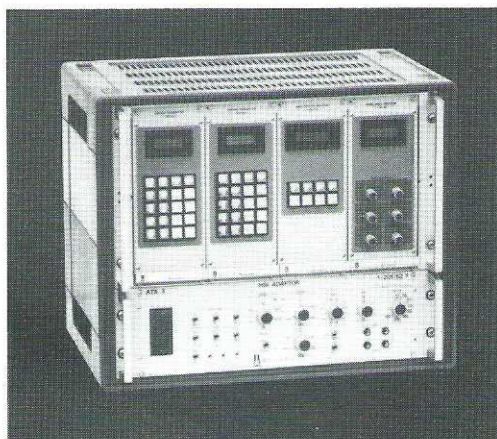
The eventual touchdown was made at 120kts and 26 minutes after the failure of the second Griffon. The aircraft captain, the late Flt Lt M Bondesio, was awarded a well-earned AFC.

#### Footnote:

As a direct result of this incident, trials were carried out and the aircraft was cleared to jettison fuel with the Vipers running. The Viper controls were modified so that variable power settings were available instead of only full power or idle. The handling SOPs were also changed so that if a Griffon engine failed, both Vipers would then be started and run at idle power, available if required. This meant, somewhat humorously, that when the four-engined Shack lost an engine, it subsequently ran on five!

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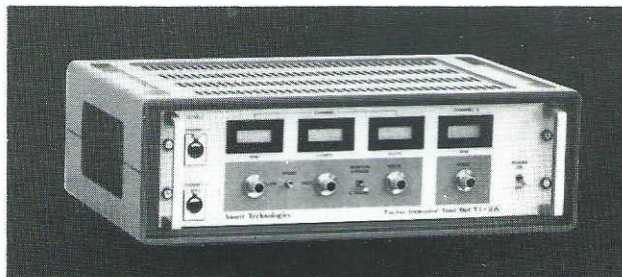


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# 'T' Plus 20 And Counting

Seven am, a mighty diesel barks into life. Its tyres, as tall as the driver, take the strain and 204 ft of finely sculpted aluminium begins another journey.

Seven-ten am. The tug grows down through the gears at the road crossing – gates stop half-way, just like yesterday and the day before! 'Bloody gates!'

A traffic queue appears. And, just like yesterday, there's the one with the camera. He leaps out, squares the lens, holds his breath and snaps ... Concorde!

It's a Saturday morning, seasonably cold with a smirr of rain drifting on a light south-westerly. Cast a net forty miles around Heathrow today and among the haul one would capture 95 like-minded travellers, six stewards and stewardesses, a captain, a co-pilot and a flight engineer, all converging on a point defined for the INS as 51 27.6N 26.6W and each making a personal transition as mile by mile anticipation of the day ahead expunges the mundane.

Seven-twenty am. Golf-Bravo Oscar Alpha Alpha's 84 ft wing span slips comfortably between the NLM Cityhopper and a Boeing 757. She teeters to a halt at Stand V15 at Heathrow's Terminal 4, rocking gently as the tow-bar damps the last trace of kinetic energy. Two hours to go. The flight crew have met: no introductions needed as the crew bus shuttles them over to the crew briefing centre. With just 20 crews to man the seven aircraft (utilisation rarely exceeds three hours per day) everyone knows everyone else, and their wives or girl-friends, and kids, hobbies, sports and attitudes. For ten years we maintained a stable workforce – invaluable in placing such a radically different aeroplane into airline service. Technical/operational briefings and de-briefings, unusual in civil operations, drew a steep learning curve in the formative years. The philosophy remains, with each carrying a responsibility for communication and all reaping the benefits.

An hour and a half to go. At the flight crew check-in desk all three names are recorded. The BA 273 London-Shannon-Barbados has a crew and the standbys breathe a little easier. There is always a standby crew but rarely the luxury of a standby aircraft; in addition to Barbados, the Saturday operations have one aircraft overnighting in New York, the 10.30 London-New York, 13.00 London-Washington-Miami, 19.00 London-New York, and this weekend a Cairo charter. The seventh is on major maintenance.

From check-in to flight planning.

While the co-pilot checks through the fuel flight plan calculations and the captain the Met, the flight engineer grabs the AIS briefing looking for significant changes to en-route, destination and alternate facilities.

We run a fully integrated flight deck. Each has a thorough understanding of the others' tasks, and gets his chance to practise them when the simulator programme cycles round to the 'incapacitation detail'.

One hour to go. Alpha Alpha greets her crew with a

cacophany of noise as ground power is applied; not for us the luxury of an APU – can't afford the space, can't afford the weight. I could refuel and start my Comet 4s on batteries: I could refuel and start my VC10s on batteries but not Concorde. She needs ground power. I guess the design intention was for Concorde to operate between major centres where facilities abound. Ironically, we have visited more stations than all our other types put together. One hundred and sixty-five destinations in 61 countries; from Rovaniemi to Oshkosh, from Monrovia to Finningley.

Forward galley operator has produced her first pot of tea. Ground crew chief appears; he gets into a huddle with the flight engineer. The talk is of

---

**He leaps out, squares the lens  
holds his breath and snaps ...  
Concorde!**

---

electronic power plant control and an interchange to be evaluated (duplicated channels), reheat instability at 1.6 (heady stuff) and a cold water tap that tends to stick on but seems OK now.

Each departure and arrival is attended by a small team of technical specialists drawn from the group who perform scheduled maintenance and defect rectification. They came out of the hangar and onto the ramp to ensure prompt attention to departure problems and, most importantly, to set up a direct dialogue between flight and ground crew; invaluable. So many of our snags manifest themselves during supercruise – 120°C skin temperature, eight inches structural expansion – only to disappear as the aircraft transitions to subsonic.

External check completed, the flight engineer negotiates the eight foot 'tunnel' leading to the flight deck. To the left and right are the main electronic equipment racks humming vigorously under the combined effect of five fans, three pulling and two pushing, up to 100 pounds of air per minute, extracted from the cabin and forced through the electronics en-route to the forward discharge valves. Equipment cooling is a subject in itself; suffice it to say that the electronics requirements are far in excess of those for the 109 souls we will carry today. Capacity of the four air-conditioning systems is based upon rack cooling – if they're alright, we're alright!

In the flight deck proper, headroom is down to four feet six inches even though there is still 25 feet of nose stretching ahead. It's a classic flight deck, designed for three fully participating airmen, a good balance between technology and manual functions, a wealth of information to announce aircraft and system performance – full-time not just when the software writer dictates, the complete antithesis to the quiet dark cellars now foisted upon the industry.



Forty-five minutes to go; pre-flight checks in full swing. Initially each man scans his panels, from memory, setting-up or testing, in a defined pattern: then the ritual litany of the 'before start check'. Co-pilot reads the checklist up until the aircraft moves under its own power; flight engineer takes over at the taxi check.

The check runs down to a natural 'hold', awaiting arrival of final payload data and the loadsheet. At this point take-off calculations are complete having used predicted load:- assessment of actual T/O weight compared to regulated T/O weight – if it's better than

Fifteen minutes to go. 'Concorde 273, this is load control, your load-sheet figures.' Over Company VHF comes prompt advice of the critical data; T/O weight update to verify T/O data, zero fuel weight and zero fuel centre of gravity for flight engineer to insert into the triple C of G computer system – each computer now knows the amount and disposition of payload, it knows the moment arm of each of the 13 fuel tanks from its program and taking the instantaneous reading from each fuel contents gauge, can calculate the aircraft's centre of gravity – pre-take-off transfer completes the radio message, this a calculated fuel quantity that must be transferred from the forward transfer tank (9) to tank 11 (aft of the cabin) to set the aircraft CG to take-off value.

Finally, at five minutes to go, all are ready for start-up; a standard low-pressure start truck is connected to port and starboard nacelles there being no cross-bleed link across the aircraft centre line.

Start valve open. Flight engineer checks start pressure, electric start pump running, N<sub>2</sub> rising. At ten per cent, solenoid-controlled HP valve open, 600 kgs per hour worth of highly atomised kerosene discharges through the start sprayers, ignitors on, and ... light up. Instantly EGT and rate of rise signals feedback to the engine amplifiers, merge with an ambient pressure term to modify the electric throttle

valve opening, itself modulating engine acceleration, leading it gently up through rotating stall clearance to a stable idle 65 per cent 1100 kgs/hour.

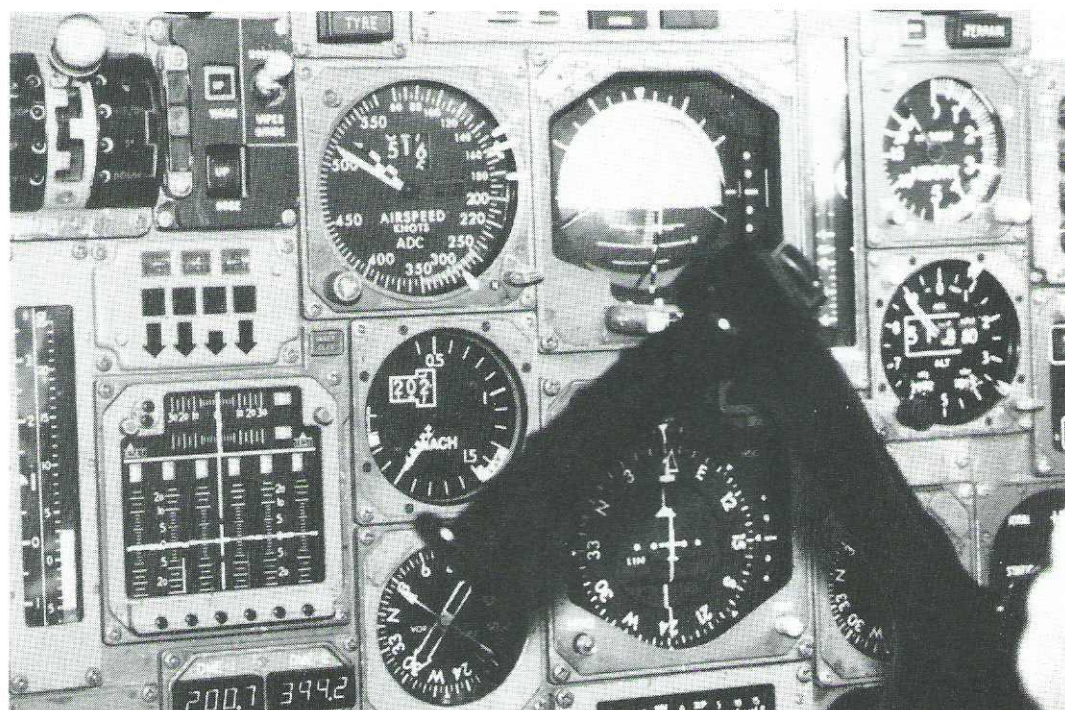
The engine driven fuel pump is built to push out 16000 kgs/hr and the combustion chamber vapourisers to pass 24,000 kgs/hr: both would be inadequate for atomising the low flows needed for engine start, hence the start pump and the start sprayers.

Two engines running, hydraulics on, elevons and rudders snap into line, then sweep full scale, three times – once to test the mechanical linkage between the control columns and the PCUs, a further twice to test each fly-by-wire channel – then a fourth under the influence of the trimmers.

Outside, a flurry of activity as crew chief signals for removal of start trucks and disconnection of ground power. Inside, flight engineer switches brake fans 'on' adding a shrieking octet to the deep purr of the exhausts and a compressor howl focussed and amplified in 11 feet of intake.

Another design compromise, in fact, two. So little space to stow the main gear dictates short axles; carbon fibre brakes buried inside the hubs necessitating forced flow cooling via brake fans. The same lack of space requires the gears to be 'shortened' as they retract upwards and inwards, accomplished by a mechanical linkage hauling the oleo ram completely into the barrel.

Outboard engines cross-bleed started on the tow, seven per cent below RTOW a reheat failing to light up during take-off can be accepted – V<sub>1</sub>, V<sub>R</sub>, V<sub>2</sub> and  $\phi_2$  (the initial pitch attitude on rotation, bugged on the ADI scale, and which will ensure achievement of V<sub>2</sub> following an engine failure after V<sub>1</sub>). Minimum fuel flow and minimum P7 for take-off are bugged on the associated instruments – tabulated data using OAT and pressure altitude – all take-offs are full power, no graduated power.



Concorde at 51,880ft in  
supercruise 516 Ks 1AS  
M2-02 heading 060°



systems established, visor hydraulically actuated forwards and downwards into a recess in the nose, then the whole nose forward of the windscreens hinged down to 5° for take-off.

At a ramp weight of 130,000 kg (max 186,000) idle thrust is more than enough to propel Alpha Alpha up the taxiway – brake temperatures must be watched – all too easy to reach 220°C, the take-off limit.

Final checks on instruments, flight controls, trims, T/O figures; 'fuel going aft' as CG is shifted from a ramp figure of 52.3 per cent to the take-off value of

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**'Concorde 273 clear to take-off, wind two two zero at seven.' Co-pilot acknowledges, captain shoots a glance across deck, 'OK?'**

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53.0 per cent standard mean chord. The standard take-off CG is 53.5 per cent but for light fuel loads it is set 0.5 per cent forward to prevent a rear boundary exceedance as part-filled tanks slop rearwards on rotation.

All three crew members check CG position. It has to be right. It is as fundamental to our operation as flaps and slats are to subsonics. Think speed, think CG. And no, it isn't automatic: the flight engineer has direct control of the pumps and valves concerned, with a 'pre-set' system available utilising a 'master forward or aft' selector.

Checks complete, at the take-off point 2.27 miles of LHR 27L an exercise in perspective. Reheats pre-selected, noise abatement count-down timers set to 42 seconds, conversation has stopped.

'Concorde 273 clear to take-off, wind two two zero at seven.' Co-pilot acknowledges, captain shoots a glance across deck, 'OK?'. Two affirmatives.

'Here we go: three ... two ... one ... now!' Three thumbs hit three stop-clocks: four throttles hit the stops.

Engine electronic control systems accelerate the HP spool, and drive the LP spool through the variable primary nozzle to achieve perfect compressor matching throughout the seven second slam. With positive control of  $N_1$  it can be run closer to surge boundaries to optimise mass flow.

Co-pilot is focussed on speeds, flight engineer on power. Check all four  $N_2$ s increasing together, see them clear through 90 per cent; drop down to  $N_1$ s all through 81 per cent, the reheat initiation point; drop again to fuel flows catching the reheat flow annunciator flags and a massive rise above 12,000 kgs/hour dry take-off value; skip the EGTs at this scan, they are moving too fast; drop to AJ (primary nozzle area) and ... wallop!

Kerosine racing to the jet pipes at 40,000 kilograms per hour lights up. Instantly 28,000 thousand pounds of additional thrust assures that we're going flying today.

The AJ instruments pause briefly at 50 per cent, the dry value, flight engineer willing them to make that big lurch from top dead centre to about four o'clock to show that reheat flow has lit (area driven wide open to

relieve P7 building-up that would slow down LP spool).

Back to the top.  $N_2$ s stabilising at 104 per cent,  $N_1$ s at 101 per cent, fuel flows above bugged value EGTs stabilising and not above 790. Areas in the reheated band.

Co-pilot calls, '100 knots!' Engineer responds, 'Power checked!' One hell of a 12 seconds!

A reheat failing to light can be re-selected to provide a further light-up sequence, but it has to be picked up on the first scan. A re-selection much after 60 kts, even if successful, may not achieve full thrust indications by the 100 kts power statement point.

$V_1$  comes and goes: 'Rotate!' A gentle pull over five seconds to 02, today 16 degrees. Airborne!! Two fifty knots, rising. A further gentle pull to 20° attitude to hold the speed.

'Positive climb, gear up'. And hard on its heels the pilots' clocks flash – five seconds to noise abatement. Flight engineer hunches, grips the centre console between his knees, right hand stretched far forward onto throttles, four fingers of the left hand poised one above each of the reheat selectors at the base of the

---

**Flight engineer hunches, grips the centre console between his knees, right hand stretched far forward onto throttles.**

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throttle quadrant.

'Three!' Check speed, it's a big power reduction; 'two ... one ... noise!'

At the 'n' of noise, throttles are snapped back to a bugged throttle lever angle and simultaneously reheats switched off while the captain de-rotates the aircraft to 11 degrees to maintain speed. Concorde tiptoes quietly over close-in housing; power is increased over an altitude schedule, achieving climb power at 8,000 feet thus protecting the more distant towns – a truly community friendly operation!

As soon as cleared, we pick up the 400 kt climb speed also the subsonic VMO. Mach 0.7 comes up at FL100, this being the cue to shift the CG back to 55 per cent: best position for stability during subsonic flight.

At around FL250 M0.93 is captured and held as subsonic climb to FL350 is completed. Subcruise is flown at M0.95, being the best speed for subsonic efficiency while still leaving a small margin before the steep drag rise at M0.97.

Thirty minutes later Alpha Alpha is on the ground at Shannon. Sixty minutes for the passengers to stretch their legs in the duty free shops, for the cabin crew to grab a bite to eat, but no rest for the flight engineer. As the last engine whines down to a slow clatter, Exxon home in on the refuel connections; four large diameter hoses already in position as Eng hits the tarmac at a trot.

Concorde expertise is pretty thin on the ground around the world. Unless BA or Air France have



trained staff on hand the crews will do it themselves. For the 25 scheduled Barbados flights between December and March we transit Shannon ourselves. Thirteen tank valves open. The hoses stiffen and roar; 75 tonnes of fuel will be loaded within 30 minutes. Density and sample checked: time enough to make the mandatory tyre pressure check before first tank fills.

Aer Lingus mechanics turn out, resplendent in green oilskins; they volunteer to do the tyres and the engine oils! So on with the walkround, most of which can be performed without leaving the shelter of the delta. A pause by the main gear brake fans to warm the hands. It all seems to be going well.

On the flight deck co-pilot keys a Sharp 1248 pocket computer loaded with a loadsheet programme, devised by one of Concorde's flight engineers. It's CAA approved and produces an accuracy as good as the company mainframe – with two or three useful refinements! Forty minutes after chocking it's all wrapped up. One final walkround, a hand-shake with Exxon, a hand-shake with Aer Lingus, tea and a digestive between checklist responses and we're down to the wire.

An unmistakable western Irishman gives start clearance from the nose-leg intercomm and everyone shouts 'debow'. A positive non-sequitor, but no-one is going to forget that warm Olympus 593s have to be run at half-idle speed for one minute to straighten the HP shaft.

The HP shaft is more like a rotating drum. While stationary, it cools unevenly and bows, hence the term 'debow'. Failure to debow would result in labyrinth seal rub and ultimately HOC.

This time 184 tonnes of Concorde takes a little throttle to unstick, the Dunlops still warm from brake heat: the pressures bore witness to that, recorded at

between 260 and 265 psi compared to nominal 232 psi.

This sector is what Concorde is all about, 3791 miles in three hours and 32 minutes. V1 = 169 knots, rotate = 192 knots. All four reheats quite definitely needed. Take-off CG is 54 per cent, the extra half per cent aft permits the rearmost tank to be filled to its 10500kgs maximum and ... think about this ... with a further aft CG, the trimmed condition during initial climb-out needs a bit more down elevon, from which we can claim a 'flap' effect and buy another tonne of regulated take-off weight. Beyond 54 per cent is strictly out of bounds due to nosewheel adhesion problems.

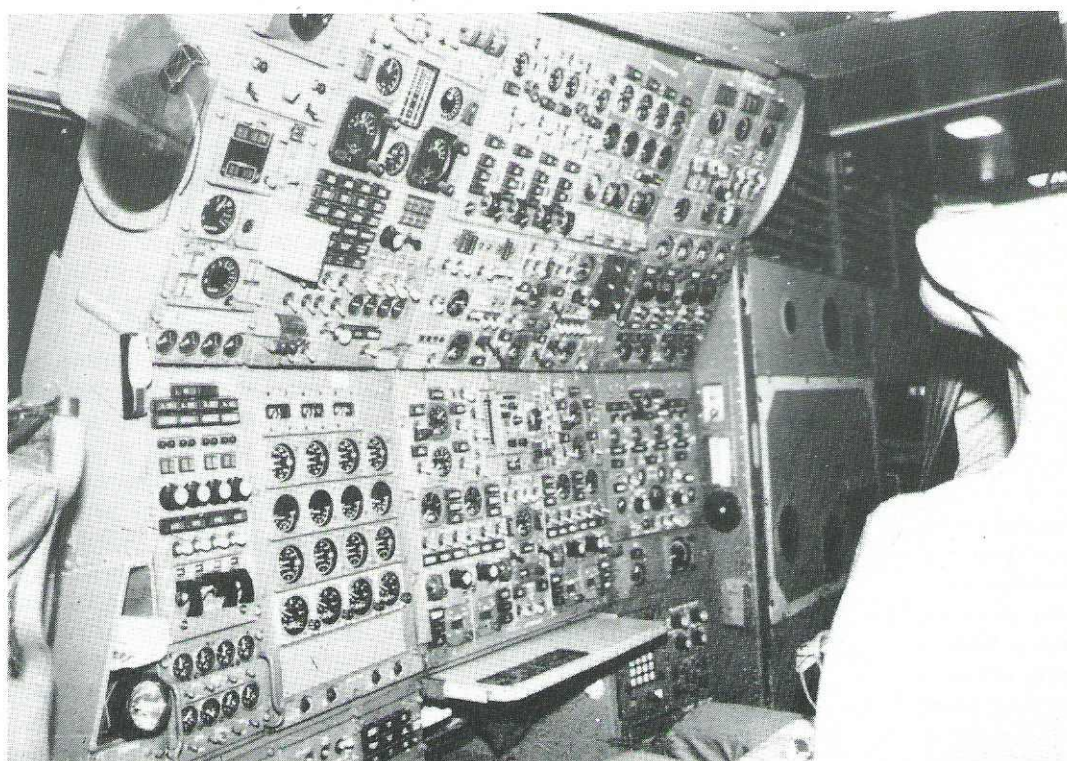
Backtracking 24 shows it to be heavily wet and puddled and indeed on landing there had been much anti-skid activity shown on the annunciators.

Water ingestion had been a problem on test aircraft, thus production aircraft sprouted a stirrup-like deflector over the nosewheels to flatten the bow wave, while a bar projecting across the front of the mainwheels breaks-up the rooster plume.

Eleven thirty am. Alpha Alpha wheels round onto runway heading, the Shannon estuary six miles ahead beyond a fine grey curtain. Shanwick delivers oceanic clearance, co-ordinating passage across east-west supersonic tracks – although the worldwide Concorde population is only 14, we occasionally get in each others way.

Take-off follows the same pattern, but at 183 tonnes it's not quite so hectic. Initial rotation is to a lower value, 13.5 degrees and with no noise abatement and the coast just ahead we go for a full performance climb-out. Gear up, reheats off at 500 feet, nose and visor up, shooting for VMO initially 300 knots, climb power at 1000 feet.

Climb power is selected by throwing a set of





ganged switches on the overhead panel, programming the electronic controls to re-datum turbine entry temperature to the climb schedule. Throttles remain on the stops.

Chasing the VMO profile, to 400 knots by 5000 feet. Once again at M0.7 adjusting the CG to 55 per cent. Climbing at 400 knots on dry climb power until just before the drag rise. Now at M0.95, flight engineer selects reheat on, in pairs this time to minimise the thrust effect on newly poured cocktails: centre of pressure sets off on an 11 foot traverse of the wing, centre of gravity has to keep up by further rearward fuel transfer.

Autopilot and flight director have a particular mode designed to follow the VMO/MMO profile, thus one mode will cope with subsonic climb, transonic region, acceleration and the M 2.0 cruise climb.

Mach 1, FL 290, just eight minutes from start of take-off roll.

Back in the cabins flight progress can be monitored on data displays showing Mach No, altitude, statute miles per hour and outside temperature: the last parameter replaced every 20 minutes with a four minute run of distance-to-go. There is bound to be comment on the lack of sensation as Concorde breaks the sound barrier – there always is. All we see as M1.0 is passed is a violent oscillation of the static fed instruments as a traversing shock wave roars up the static ports. Mach/CG relationship is closely monitored throughout the acceleration. Both CG

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### **There is bound to be comment on the lack of sensation as Concorde breaks the sound barrier.**

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instruments carry Fwd and Aft limit bugs driven by an air data computer mach signal: thus for instantaneous Mach No the permissible CG range is displayed. Conversely, on the machmeters, limit bugs show the Mach range available at the instantaneous CG position. With controllability at stake, both visual and aural warnings of transgressions are provided.

Approaching M1.3, FL 360, VMO at 450 knots increasing, we're approaching British Aerospace Guided Weapons territory – the intakes! Two automatic control channels with a manual inching reversion referenced to an intake pressure ratio instrument, basically a means of matching the intake to engine demand.

Intake start-up begins with a small angular deployment of the moveable roof panels (ramps) to stimulate a fan shaped growth of shock waves at the intake mouth, growing out of the lower lip: a terminal shock is positioned in the intake throat. Pressures inside the intake detect the developing shocks and drive the ramps vigorously down to catch the fan set and pin them securely at the lip throughout all atmospheric and engine condition variations. Mach two air hurtling through these shocks will undergo a fourfold deceleration and an eight-and-a-half fold pressure rise – magic!

Problems? Very few for such a radical system – typically ramps running to an off-schedule position; manual recovery using inching controls and intake pressure ratio indication is possible. A gross excursion would push the LP compressor into surge – non-damaging, but very, very noisy. Recovery begins with throttle closure to take the energy out of the surge.

The acceleration progresses, at M1.7, FL420 and maximum IAS of 530 knots, reheats are switched off. Their effectiveness from here on would reduce rapidly; they have done their job in pushing us expeditiously through the high drag zone.

Five thirty knots is held until it becomes M2.0 at a little above FL500. At this point that same autopilot mode locks on to a nominal M2.0, engines are set to cruise rating by throwing another set of ganged switches – the throttles are still on the stops: N2s are only half a per cent different to take-off value, but EGTs are about 670 compared to 770, reflecting the

---

### **Loathe as we are to relinquish supercruise efficiency, dropping a boom on the coast is a hanging effect.**

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lower turbine entry temperature programme. At constant speed and a fixed throttle setting Concorde settles into a classic cruise climb, averaging about 60 feet per minute on the crossing. CG has come to rest at around 59 per cent – proximity to the aft limit of 59.3 per cent is necessary in order to trim the elevons to half a degree down, to minimise drag during supercruise.

The fuel system is substantially asymmetric, with every conceivable corner used for tankage. As the aircraft goes out of balance first in one direction (laterally), then the other, the flight engineer will pick up the trend from a finely calibrated control position indicator and shift up to 500 kgs of fuel from heavy wing to light wing, keeping all elevons in line and half a degree drooped.

Total temperature has risen to 120°C, but outside it is -55°C; as we head towards the tropics SAT will drop to -75°C.

The high total temp brings its special set of problems. The four air conditioning systems each need a cold air unit running full time: hydraulic fluid runs at 120°C in the tank, higher out on the wing PCUs, seal material has a hard time: engine oil runs at 150°C: fuel temp at the engine is 90°C, in the tank 50°C: fuel tank sealant is stretched by structural expansions. Nevertheless the aircraft and her systems are designed for this environment and they do very well indeed.

M2.0 was reached 23 minutes after start of take-roll – not bad for a 100-seater! Next waypoint up is 20W, then pretty much direct Barbados, slipping past the Azores to the north at 30W, into the tropics at 50W.



Fuel checks to assess fuel on board overhead destination, are made at every ten degrees of longitude, while a running monitor of the tactical chart is maintained. The latter document, adjusted for conditions of the day provides an immediate statement of where to go on three engines or two engines – onwards, return, or en-route diversion. En route (and destination) alternates weathers are routinely garnered by the flight engineer from VHF or HF sources as appropriate: in general Eng handles all non-ATC comms as a routine. Once stabilised in cruise climb, out comes another Sharp 1248 – in goes Mach no, total temperature and altitude, then for each engine, N2, N1 and EGT. First five parameters are micro-processed into the EGT that a perfect engine would indicate at the spot conditions. A final keystroke subtracts 'ideal' from 'actual' and annunciates a 'delta EGT' to be plotted and compared with previous. We're basically monitoring the hot end, a 20C rise from previous, triggers repeat checks and a log entry. A continuing rise would require 'Eng' to make a shutdown judgement. Either way a borescope check of combustion chamber, NGVs and HP turbine would be made after landing. The object is to catch deterioration before it becomes a major damage; most recent finding being an easily repairable six inch crack in a combustion chamber.

18 N and 52 W. Alpha Alpha hits her operational ceiling at FL 600. As a type, Concorde has been tested up to 68,000 feet (and M2.23), but sixty was settled upon for the top of the flight envelope, a compromise, taking into account airconditioning and intakes systems performance.

Three hundred miles out, time to think about the decel(eration). Loathe as we are to relinquish supercruise efficiency, dropping a boom on the coast is a hanging offence! Flight level at decel point, wind component and temperature deviation are applied to a chart in exchange for a decel distance. Today a decel initiated at 200 miles from the Barbados airfield will enable us to become subsonic by the Mach1.0 point, 50 miles off the north-east point.

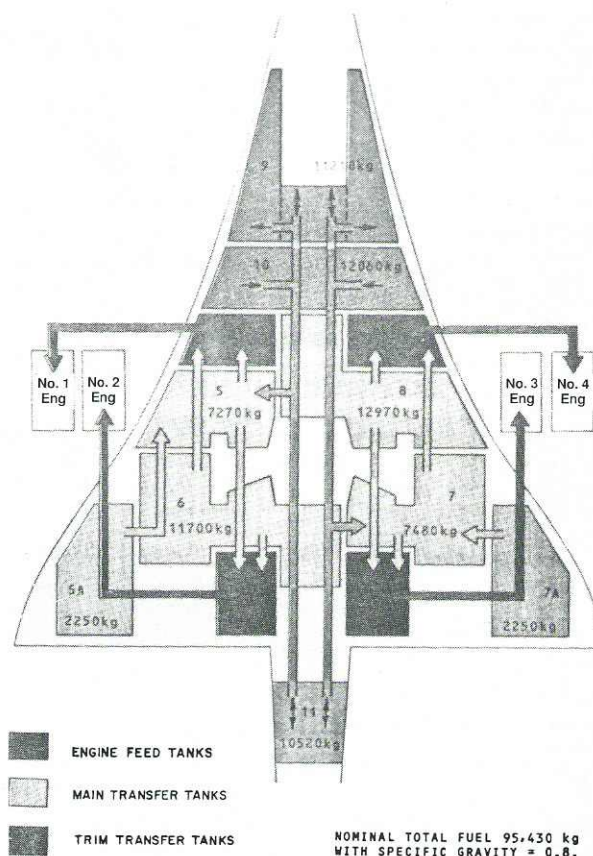
If not already in altitude hold then that mode would be selected at ten miles to go. Initial deceleration is flown level from M2.0, 430 knots to 350 knots, then a decel/descent at 350 knots begun.

Exactly at decel point throttles are moved for the first time since the slam acceleration at Shannon. Now though, it is a slow and gentle ease back to 18° as bugged on the throttle quadrant. As soon as the N2s respond flight eng transfers his attention to the intakes: it's a critical period – ramps lower to the limit of their authority as engine demand reduces. With yet more thrust to come off, the spill door in the floor of each intake opens for the first time to dump excess air. Even with such delicate handling, the deceleration effect is noticed by all.

Think speed, think CG. Next item on the decel check initiates a forward CG shift to match forward movement of centre-of-pressure. Fuel from the rear tank is pumped into the wings then into the four feed tanks.

The initial throttle position of 18° is governed by

### Tank Location



intake capability: idle power could be taken, emergency descent for example, but pop-surfing would occur.

At 360 knots, about M1.7, auto pilot is popped into vertical speed mode, the aircraft gently pitched over and IAS hold engaged at 350 knots.

A further power reduction is made at M1.5; still not idle, so as to preserve airconditioning and therefore equipment cooling flow (idle can be used from hereon without surge, but equipment cooling fans may have to be switched on).

At M1.3 intake surfaces are reset to subsonic mode, ramps fully up, spill doors checked closed. Distance out looks fine and Concorde 273 transitions to subsonic at FL 350. Grantley Adams, the Barbados airport co-ordinates the descent, a standard North Point arrival to fly down the west coast where Bridgetown and all the tourist hotels are located.

Flight level 150 and Alpha Alpha bursts through a layer of fairweather cumulus. Just three and a quarter hours after a bleak rainswept Shannon, 21 miles of surf-fringed Barbados basks before us, more magic!

Speed reduction to 250 knots begins and the approach check is run. Passage through 270 knots is



the prompt to lower the visor and nose to the intermediate five degree position. Wherever possible, and dependent upon glide slope guidance, a V REF + 7 knots decelerating approach is flown; it saves time and fuel and reduces noise. V REF is 157 knots, thus final approach will be flown at 164 knots. Angle of attack has been gently increasing.

As it passed seven degrees a mild buffet became evident, not unlike a subsonic with landing flap out: it's the big rolling vortex generated by each wing, the one that creates our low speed lift.

Tracking down the west coast, speed is reduced to 210 knots, more angle of attack, stronger vortex.

**As it passed seven degrees a mild buffet became evident, not unlike a subsonic with landing flap out.**

Running past Bridgetown, airfield in sight. Speed is reduced to 190 knots – all speeds dialled into the autothrottle system.

A left turn onto finals. At eight miles out the landing check. Gear is lowered – four greens (including the tail bumper gear) – nose is set to fully down at 12.5

degrees. Flight engineers seat is set to fully up; with his head bumping the overhead panel he is just able to keep the runway in sight, his interior scan taking in engines, airspeed and radio height. He calls, '1,000 feet radio' co-pilot checks and responds, 'five greens (four gear, one nose) go-around height set (in the altitude select window).'

All the radio height calls emanate from the flight engineer.

'800 feet' – autothrottles are set to final approach, 164 knots. There's a substantial thrust reduction, angle of attack increases as speed reduces.

'500 feet' – speed has stabilised at 164 knots, angle of attack at 14 degrees with throttles moving up to hold speed – a higher power setting than needed for 190 knots – it's that sort of wing. Co-pilot confirms, 'stabilised.'

'400 feet.' '300.' 'Decision height.' 'Continuing.' '200.' '100.' '50.' '40' (autothrottles out but power left as set). '30' '20' '15'.

**'Blood gates.' Concorde has landed but look at our eyes – we're still high.**

At 15 feet radio the aircraft is sitting in ground effect and on the vertical component of thrust, throttles are eased back to idle and she settles gently into the ground effect. Air trapped between wing and runway tending to tip the aircraft nose down – increasing up elevator holds the pitch attitude constant. Too much attitude and there would be a tailwheel touch followed by a bucket scrape (the rearmost part of the nozzle). Co-pilot will shout at 12.5 degrees.

The mainwheels land. Tyre smoke is whipped round by the decaying vortices. Engines are set to reverse idle and the nosewheel landed. With the stick pushed firmly forward to hold the nosewheel on, reverse power is applied. Eight carbon fibre brakes and four reversers create a substantial and reassuring stopping power.

Two engines are shut down for taxi-in and four tonnes of fuel transferred to the forward tank – now, no matter how unloading may be cocked-up, Alpha Alpha will never tip.

Ground power on – engines off and ... it's still only 11.20am. Even more magic! An hour later, outside the security perimeter fence of the Paradise Beach Hotel we wait patiently for the gates to be operated manually. 'Bloody gates'. Concorde has landed, but look at our eyes – we're still high.

**David Macdonald  
Flight Engineer Concorde  
1975 – to date.**

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