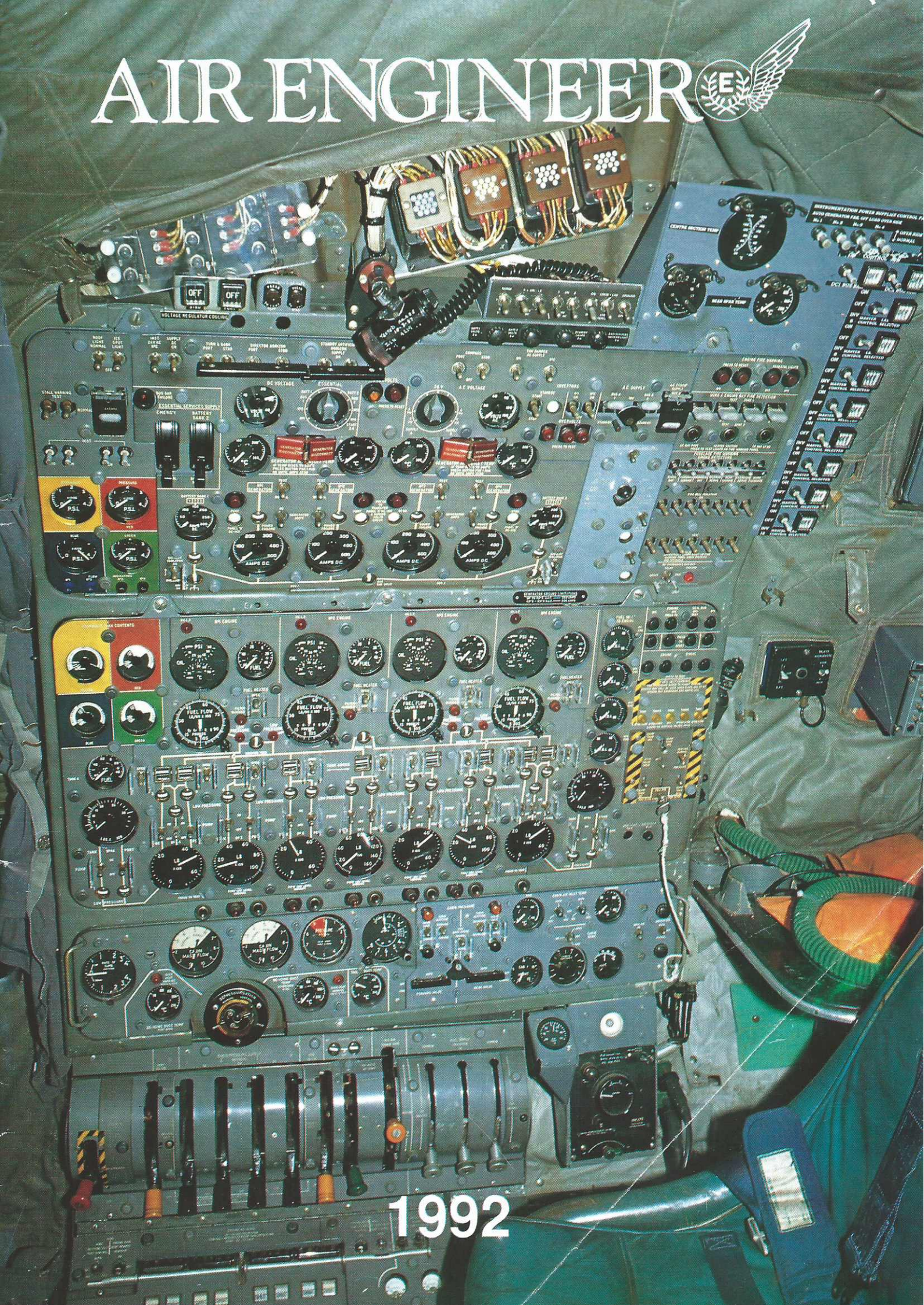


# AIR ENGINEER



1992





## Editorial

It was a particular disappointment that in 1991, the 50th anniversary year of the air engineer branch, it was not possible to produce an issue of the Air Engineer magazine. Notwithstanding the tremendous moral support for the Forces from a proud and relieved nation in the wake of the Gulf War, the fierce grip of economic recession had a stronger influence on Industry. Supportive advertising is the life-blood of this journal, and if kind comment and good wishes could have served as a substitute then we could have published a book last year.

Let me hasten to add, especially in the light of the quality advertising support in this issue, that no ill feelings exist towards Industry. The Air Engineer was but one victim amongst thousands in 1991 and the ability to publish this issue reflects the practical goodwill of aerospace companies. Although genuine economic recovery is still awaited, there is a growing feeling that better times are ahead. Most established organizations are leaner and fitter, better placed to compete in the world market. The civil aviation companies, significantly reluctant to lay off aircrew as the recession bit, are cautiously recruiting again. Emergence from the doldrums is not going to be spectacular but, hopefully, it will be sustained.

The same forecast can, arguably, be applied to the collective experience of the RAF today. As we aim for a total number of personnel that will not significantly exceed the number of Bomber Command casualties in WW2, we are constantly reminded by our leaders that the emphasis is on quality, not quantity. Within the confines of our individual experience it is too easy to scoff at such aims and, with rose-tinted specs firmly in

place, to look back and say "it was better on Shacks, Hastings, Brits etc". Perhaps the comprehensive articles in this issue on the history of air engineer training will help to restore perspective.

To such a youth as I, whose (happy) flying experience has been Nimrod, Nimrod and more Nimrod, there is a certain romance attached to the old 4-engined "heavies" such as the Lanc, Stirling, Halifax and Liberator. I remember listening to an old ex-Coastal type who was recounting, without any attempt to impress, the tale of his rescue after his second (or was it third?) occasion of writing-off a Sunderland. (Filthy night, wrong altimeter setting, idiot of a flare-path officer, you know!). Of course I didn't know because, in one generation, things have changed enormously for the better. These older colleagues whose war-stories are so entertaining were, in the main, poorly equipped, poorly paid and, by today's standards, very poorly trained. Experience was their best teacher but they had to live long enough to know that. Controversy and incompetence at staff level were the formidable enemies of those who sought to improve training standards in the past, and money has always been tight.

In any economy, whether it be home, national or military, there are always decisions to be made as to spending priorities. The temptation to save money by paring training to the bone is as strong today as it has ever been. The evolution of air engineer training has been in spite of financial constraints and largely the product of unstinting effort and professionalism on the part of members of the branch. MEng Tony Bateson devoted enormous amounts of time and effort to the production of the Argosy Trainer

pictured later in this issue. In financial terms alone the RAF derived great benefit, but who can judge the potential savings, in lives and aircraft preserved from accident, because of the improvement made to the training of aircrew?

Such projects are beyond the branch today, not because the vision and expertise are lacking, but because legislation (much of which is beneficial) prohibits them. In fairness, much of the need for projects of the Argosy Trainer kind has gone. Almost every aircraft type in RAF service now has a flight simulator, and computer-assisted training packages are increasingly common. Where training resources still seem to be scarce is at squadron level where fag-packet calculations, knee-pad drawings and scrawled-on uckers boards are very much the norm. Ab-initio training has, over the years, improved beyond recognition but post-OCU continuation training still fights for resources.

Although the training and the duties of the air engineer have changed greatly during the 51-year history of the branch, there is nevertheless a tremendous bond between past and present members. The reunion dinner arranged last year by members of 6FTS was a great success, and the ex-"heavy" eng's were as keen to hear of modern-day flying as the present day eng's were to hear the write-off stories. Professionally the branch is in good shape and much of the credit for that must go to those who made it their task to improve training standards throughout the past 50 years. To those air engineers, from the current wearers of the "E" brevet, thank you.

Phil Coulson

**On the cover: The Engineer's panel of (almost) the last flying comet, XS 235.**

**AIR ENGINEER**

**Editor:** Squadron Leader Phil Coulson

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### Please Note

Letters and articles for inclusion in the 1993 Journal should reach the editor before 1st April 1993. 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.



# The Airmen(Aircrew) Desks

by Wg Cdr D. T. Calvert, PA4

No doubt those of you who need to know are all quite familiar with the airmen(aircrew) postings set up and have got to know the desk officers well. Clearly, it is time for a change. Two things happened a couple of years ago which led to the present set up. First, the Robson report recommended more desk officers at the RAF PMC and so the AEOs, and commissioned ALM and Air Engs, who had been looked after by the airmen(aircrew) desk officers, got their very own minder (PA4g). Secondly, the new Terms of Service (TOS) for airmen (aircrew) required an extra officer to oversee the implementation; a new post was created for that purpose (PA4h) and Flt Lt Keith Pick was the first incumbent. He also picked up the new task of preparation for the airmen(aircrew) merit promotion board. Keith was replaced by Flt Lt Dave Bellis who organised the promotion and assimilation boards but found that implementation of the new TOS was virtually complete. In order to stop him taking even more leave, I needed to find him additional work.

As a consequence, we have combined the tasks of Dave Bellis and Wg Cdr Bob Cumming, who was the AEO, Air Eng and ALM minder (PA4g), and who had also found time to take leave. These posts were combined in March and were taken over by Sqn Ldr John Cooke.

Once we had started the re-structuring it became difficult to stop. All other desks within DDPA3's organisation are manned by officers of the appropriate specialization but this has rarely been the case with the airmen(aircrew) desks; those desk officers have usually been navigators from one of the multi-engine forces. This is because it has often not been possible to find sqn ldrs of the right branch at the right time. Without wishing to cast any aspersions on previous desk

officers' abilities or accomplishments, I believe that it would be better for the customers if their desk officers were of the same specialization as themselves.

The only sure way to achieve this was to change the rank of the desk officers to flt lt; that way we could be certain that an AEO and an Air Eng or ALM would be available to fill the posts. An additional advantage was that we would have a wider choice of candidates and could almost certainly find someone with recent and relevant front-line experience. Indeed, because we do not have DE commissions to these specializations, this would mean that a desk officer would be ex-airmen(aircrew) himself. Against that there is the perception that the posts might in some way be diminished by the reduction in rank of the incumbent. I don't believe this to be the case; I have no doubt that the flt lts will do an excellent job and if such a perception does exist they will quickly dispel it.

These changes have been implemented and all 3 desk officers share an office. As a consequence, all Air Engs, AEOs, AEOps and ALMs below the rank of sqn ldr, but including specialist aircrew sqn ldrs and including airmen(aircrew), will be looked after from the same office. All this might seem straightforward and so I intend to throw in some changes to post designators for good measure, which will result in the following new structure.

PA4c Sqn Ldr John Cooke  
Extension 6170

*Career management of JOs and sqn ldr SA of the Air Eng, AEO and ALM specializations.*

*Preparation for, and Secretary of, the Airmen(Aircrew) Promotion and re-engagement Boards. Formal career interviews for airmen(aircrew).*



Sqn Ldr John Cooke, PA4c



Flt Lt Dave Bellis, PA4c(2)

PA4c(1) Flt Lt Brian Dryborough  
Extension 6163

*Career management of AEOps and Air Sigs(RC).*

PA4c(2) Flt Lt Dave Bellis  
Extension 6165

*Career management of Air Eng and ALM.*

## THANK YOU

**A special thank you is extended by the editor to the following companies who have supported Air Engineer with advertising and made this publication possible**

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# ROUND & ABOUT

## NEW LEASE OF LIFE FOR 'CANOPUS'

By the end of 1992 the only Comet aircraft still operating will be Comet 4C XS235 which first flew on 26 September 1963 from Chester to Hatfield. It was then fitted with racks and interior fittings as a flying laboratory, before delivery to Boscombe Down on 2 December. It is now in its 29th year of operation and has a total flying time of only 8000hrs. (Compare this total with that of the RAE Farnborough 'Comrod' which had already flown just over 22000hrs when it was delivered to Farnborough on 7 October 1968!)

In June 92 XS235 emerged from the Nimrod Major Servicing Unit at RAF

Kinloss after a major overhaul that will prolong its active service for another 5 years or more.

Low flying hours on the aircraft does not signify a low level of activity overall. Many of the experiments take time to install, calibrate and ground test, before the ultimate airborne testing. For every hour of flight, between 10 and 20hr of data analysis is generated in the laboratory. The aircraft also has to be subjected to more than its fair share of non-destructive testing (NDT) of the structure, as it is in effect being treated as a fleet of one aircraft with no others able to share in the load.

This Comet, named *Canopus*, is operated by the Flying Division on behalf of the Radio and Navigation Division of Boscombe Down and is generally used for new avionics, mainly for navigation, plus radio altimeters and also for photographic work. The original underfuselage bathtub radome once used for Doppler trials has been replaced by an aerial boat to carry communications aerials without penetrating the pressure hull.

The purpose of a flying laboratory is to give maximum space for the installation of equipment and carriage of flight observers. The aircraft needs to be

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equipped with a comprehensive range of radio and navigation aids of sufficiently high accuracy and reliability to act as a standard for the equipment under test. Sufficient electrical power in whatever form required must be available to operate the systems and a high-capacity flexible data recording system is provided to record information from both the master reference systems and equipment under test, to carry out the post-flight analysis.

The Comet provides an ideal platform for the testing of systems under evaluation for transport and maritime aircraft. In the rear cabin are five dedicated trial stations, and adequate space for fitting additional equipment under test. The reference navigation system is centred round high quality inertial systems which continuously produce aircraft position, velocity, heading and altitude. This datum equipment includes an old but accurate Decca Mk 19 and a pair of Litton inertial navigation systems uniquely assembled for Boscombe Down with top-grade specially selected Z-gyros on all three axes.

All data is recorded on magnetic tape once per second using a Plessey GPS receiver and an STC five-channel GPS receiver. The reference area in the forward cabin contains three seats for the

datum manager, an assistant and a controller of the recording systems. A print out is made every minute to ensure that the equipment is still functioning. The onboard recording system has sufficient capacity to log the required parameters from the datum equipment, and monitor the large amounts of data from the equipment under test for up to the maximum 6hr endurance of the Comet. A number of interface units have also been developed to enable a variety of data streams to be recorded.

Over a two-year period the Comet flew 150hr to evaluate seven different inertial navigation systems for the Nimrod MR2 update programme. It is not usually the accuracy of the systems which is in any doubt, but more checking the operational performance.

In the spring of 1989, all the ground-based radio antennae of the Radio Trials Facility at the A&AEE were recalibrated using the Comet with its fit of highly accurate antennae. The facility is constantly in use for all Controller of Aircraft (CA) Release trials of communications and radio navigation equipment with the associated aerial installations.

During the summer of 1989, 56hr were flown in support of an international test programme, evaluating GPS Navstar

user equipment. For this purpose, the Comet was based at Thule AFB in Northern Greenland, allowing flights over the North Pole and back in 4½hr. This was a NATO programme sponsored by the joint programme office at HQ Space Command in Los Angeles. Those flights were made over the geographic North Pole, which is where inertial systems can have the greatest problem due to attenuation on the ice cap. The Rockwell Collins GPS receivers were the main units under evaluation, but a bonus was also the chance to test British-built systems at the same time.

This Comet came to the British Aerospace Open Day at Hatfield on 1 July 1989, to celebrate the 40th anniversary of the first flight of the prototype Comet by John Cunningham. At the rate it is flying, and bearing in mind the excellent condition of the aircraft, there is probably no reason why it should not be around to celebrate the 50th anniversary as well. Its graceful lines and spritely performance are still good, even by today's high standards of technology.

#### **Acknowledgement**

Much of this article has been reproduced, by kind permission, from the book 'De Havilland Comet' by Philip J. Birtles and published by Ian Allen.

## **FIRST FEMALE AIR ENGINEERS GRADUATE FROM NO 6 FTS**

On 5 June 1992, the first female Air Engineers graduated from No 6 FTS. Sgt Sue Lansdell (on the right), an ex SACW A Mech P, and Sgt Anne Marie Shouls, an ex JT MT Tech, have completed training with No 163 Air Engineer Course and have been posted to RAF Lyneham to commence training on the Hercules. Sgt Shouls was awarded the Reynolds plate for most improved student and the Air Engineer Ground Studies Trophy for achieving an average of 97.8% in all exams. Sgt Shouls and Sgt Lansdell were presented with a special certificate to commemorate this unique occasion. The first direct entrant female air engineer has just commenced training with 169 Air Engineer Course.

## **THE AIR ENGINEER BRANCH 50th ANNIVERSARY by Sgt M. D. Boulton, 6 FTS.**

1991 saw the 50th Anniversary of the Air Engineer in the Royal Air Force. The first Flight Engineers (as they were then known) were employed in 1941 with the arrival of the new large multi-engine bombers, the first of which to enter service was the Stirling. Since then the Air Engineer has seen continuous service on a variety of aircraft within the RAF. It was decided within the branch that a number of events would be organized to mark this milestone in aviation history and the task fell to the staff of the Air Engineer School at 6 FTS, RAF Finningley.

The Finningley Air Day in September was chosen as the venue for activities. A static display was constructed to show the history of the branch from its conception in 1941 to the present day and a special marquee was erected so that Engineers past and present could meet and socialize.

The display was organised and set up by Sgt Ray Triccas and Sgt Dave Lomax. Anyone who saw it would agree that they made an excellent job of setting up such an informative and interesting display.

The hospitality marquee was also a great success and was attended by a large number of Engineers who

consumed an even greater number of pints.

Although the events of the Air Day were a great success, it was felt by the staff of the AEPT at Finningley that this was not enough. Master Engineers Rob Bailey and Mick Alderton came up with the idea of holding an Anniversary dinner. Plans were soon drawn up and a lot of hard work was put in by all the AEPT Staff, particularly Sgt Simon Cox.

The dinner was held at the Moat House Hotel, Doncaster, on 4 October. Just over 100 Engineers past and present attended. An excellent meal was followed by a speech from Sqn Ldr Roy Waters to mark the occasion. The festivities continued well into the night with the last people leaving the bar just before dawn! Flt Lt Ian McKay and other members of 24 Sqn provided the transport from Lyneham and Brize Norton – my heart and stomach went out to all those travelling back by Hercules the following morning!

So here we are in 1992 and all I can say is that I'm looking forward to the 100th Anniversary of the air engineer branch, when I'll be a tender 76 years of age!





Nearly 100 past and present members of the Branch – 4 October 1991



The Flight Deck of XS235



'Canopus' at RAF Kinloss – June 1992



Sgt Sue Lansdell (right) and Sgt Anne Marie Shouls, the first female Air Engineers to graduate from 6FTS



## TECHNICAL TALK

# Petroleum Refining Processes

In the early days of crude-oil production the only part of the crude used was the kerosine which replaced vegetable and animal-oil fuel for lamps. The low-boiling highly inflammable part (gasoline) and the high-boiling residue both had to be discarded as useless. It was soon found that the kerosine straight from crude oil was sometimes not very satisfactory; it had an obnoxious smell and burnt with a smoky flame, which necessitated some method of treatment to make it acceptable. Similarly, the first internal combustion engines ran on the previously discarded gasoline but soon developed a superior taste and the plain gasoline had to be improved by treatment or the addition of other higher quality material. As the popularity of the internal combustion engine increased, the quantity of gasoline in the crude oil was insufficient to satisfy the demand and methods of producing gasoline from other parts of crude oil had to be invented.

Similar problems are encountered throughout the whole range of petroleum products and means must be found to change both the properties of the naturally occurring material and the quantity available from crude oil, by the use of various refining processes. As crude-oil components range between propane and butane used for camping stoves and bitumen used for road-making, it is not possible to process the whole crude at once to provide all the various products in the quantity and quality required and so the first stage is to split the crude oil into more manageable portions.

## DISTILLATION

This is the start of the refining process where the crude oil is split into a number of parts or cuts. The separation is made on the basis of boiling-point and groups of hydrocarbons boiling within a certain range are produced. The boiling-range cuts may vary depending on the type of crude oil and processing scheme to be employed and there is, therefore, no fixed way of cutting up the crude. A typical split may be as follows:

Boiling range degrees C	Product
Less than 0	propane/ butane
0-70	light gasoline
70-140	benzine
140-180	naphtha
180-250	kerosine
250-350	gas oil

The distillation is carried out continuously in towers which have special trays at intervals of about 2 feet all the way up. The purpose of these trays is to improve the separation between the lower and higher boiling materials. Oil is heated and pumped into the tower. The vapour formed by heating rises up the tower and is cooled, condensed and part of the condensed liquid pumped back to the top of the tower (reflux). Each tray has a number of holes through which the vapour can pass up and a weir so that a level of liquid is maintained on the tray and the vapour forced to bubble through it. On each tray the hot vapour from the tray below preferentially evaporates some of the lower boiling material in the liquid on the tray and some of the higher boiling material in the vapour gets left behind in the liquid which then falls to the tray below. This process, "fractionation", occurs on each tray, concentrating the lower boiling material at the top of the column and the higher boiling material at the bottom. Alternative contacting devices for the vapour and liquid have been developed, such as valve or sieve trays which operate by the same principle but are cheaper to manufacture than bubble caps.

The separation between low and high-boiling materials (fractionation) is improved by increasing the number of trays in the column and also by increasing the amount of reflux. It is possible to take off liquid from an intermediate tray which will have a boiling range intermediate between the top and bottom products. This tray liquid, called a "side-stream", will, however, contain traces of low boiling material which can be removed in a small subsidiary column (stripper) and passed back to the main column. By having several sidestreams it is possible to cut the crude into a number of fractions with one main distillation column.

When cuts with boiling-points over 350 degrees C are required it is necessary to do the distillation under vacuum to reduce the temperature at which the material boils, as some high-boiling compounds start to decompose when heated to their boiling-point at atmospheric pressure.

Frequently the crude oil will contain salt, either because of contamination with salt in the producing formation or subsequent contamination with sea-water during shipping. Salt causes many problems as it may be deposited in heater tubes during distillation or react at high temperatures with small quantities of water inevitably present in the crude to give hydrochloric acid which causes

corrosion. Even small quantities of salt cause trouble and it is advisable to reduce the quantity to below 0.001 per cent weight in the crude by washing the oil with fresh water at about 120 degrees C under pressure before distillation. The oil and water easily form emulsions and special chemicals or electrostatic precipitation are used to help the separation of the oil and salt solution.

When the crude oil has been distilled the different cuts can be treated separately. Each cut may be either given a simple treatment to improve its quality or can undergo more complex treatment to change the chemical composition to produce more desirable materials.

## AVIATION PRODUCTS

The feasibility of powered flight had to wait until the invention of the reciprocating internal-combustion engine. Before that time the only practical mechanical power-source, the steam engine, was much too heavy and cumbersome for sustained powered flight.

Early aero-engines were adaptations of the contemporary water-cooled car engines, but the need to minimise weight soon led to the development of engines cooled only by air. While the air-cooled radial engine found wide application, particularly in transport aircraft, the liquid-cooled piston engine, with its low frontal area, remained the dominant motive force for high performance military fighter aircraft.

The very high power output required by modern high-speed aircraft is beyond the range of reciprocating (that is, piston) engines, which become too large and heavy above about 3,700 horse-power. In consequence, piston engines have largely given way to gas turbines, except in the power range below about 500 horse-power, in which they are still probably the best choice for light and simple aircraft.

It is only natural that, second only to absolute reliability, the dominant factor in the design of aero-engines is lightness. Following very closely after this in the order of priority are a desire for fuel economy and a need to maintain sustained power at altitudes where the density and temperature of the air are lower than those at ground level.

The exacting conditions imposed by flight, not least the safety factor, demand fuels, lubricants and aero products that can be relied on implicitly. In fact, the truly rapid growth of air travel and transport during the last fifty years is due in no small



measure to the consistent quality-standards and rigid adherence to specifications maintained by suppliers of aviation products during the whole of that period over the whole face of the globe.

## FUELS FOR AVIATION GAS TURBINES

Fuel quality for aviation gas turbines is governed by quite a different set of requirements from those applying to aviation gasolines. The fuel is burnt in the combustion chamber at constant pressure, and is a continuous process; there are no peak or fluctuating pressures. Anti-knock value is therefore of no importance; what is of great importance is that the fuel should be clean-burning, with good combustion characteristics and a high energy content. The two types of jet fuel are kerosine, which is widely used, and a wide-cut gasoline, which has a wider boiling range than kerosine, since it includes some of the higher fractions of gasoline. Aviation turbine fuels are invariably produced by blending straight-run distillate fractions obtained from crude oil.

(i) *Specific Gravity and Calorific Value.* Aircraft design and operation are dependent on the availability of a certain pre-determined minimum amount of energy in the form of heat. Specific gravity and calorific value are therefore important properties, since they control the total energy content of a given "up-lift" of fuel on, respectively, a weight basis and a volume basis.

(ii) *Volatility.* Ease of vaporisation is important with gas turbines, as with piston engines. The volatility of turbine fuel is determined by distillation, final boiling points being limited to exclude heavy fractions that would be difficult to vaporise and that could adversely affect long-term engine combustion performance. The Reid vapour pressure of wide-cut fuels is controlled to allow ease of engine-starting at very low temperatures, and at the same time prevent losses of the more volatile fractions through tank-vents at high altitude.

Flash point is specified for aviation kerosines since this gives an indication of the maximum permissible temperature for fuel handling and storage without serious fire hazard.

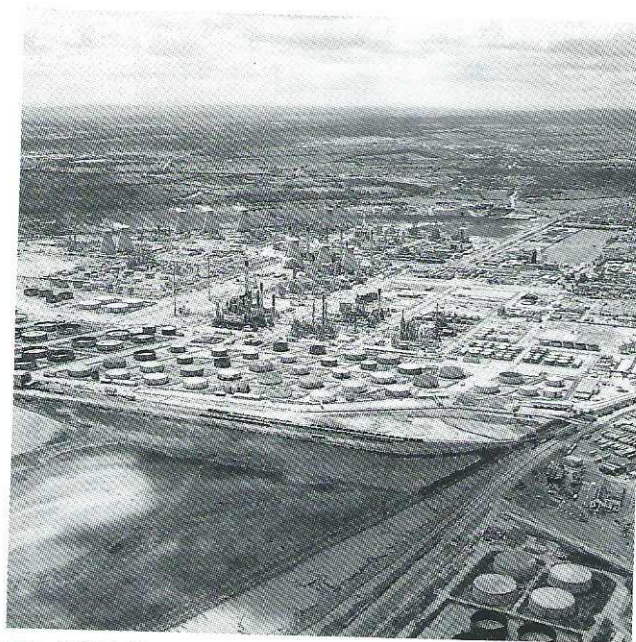
(iii) *Combustion Characteristics.* This aspect of quality is related to the hydrocarbon type of the fuel. Aromatics generally have the least desirable combustion characteristics for jet fuels, since they tend to burn with a smoky flame and to release a greater proportion of their chemical energy as undesirable thermal radiation than other hydrocarbon types. Combustion quality is therefore controlled by specifying the characteristics of the flame that would be produced if the fuel was burnt under

prescribed conditions, and also by simply limiting the total aromatic content.

(iv) *Fluidity at Low Temperatures.* The freezing point of aviation turbine fuels is particularly important; it must be sufficiently low to preclude the possibility of an interference in the flow of fuel to the engine during long cruises at high altitude. Fuel-viscosity is limited to ensure that an adequate flow and an adequate pressure are maintained within the fuel system over the entire operational-temperature range of the aircraft.

(v) *Corrosion Control.* Jet fuels must be free from acidic material and corrosive sulphur compounds in order to prevent the corrosion of metals in fuel systems. It is essential to control the total sulphur content of the fuel since sulphur oxides that would otherwise form during combustion would prove corrosive to metal parts of the turbine.

(vi) *Thermal Stability.* Unduly large quantities of gum and other non-volatile material can contribute to fuel-system deposits that could become sufficiently excessive to cause malfunctioning of the engine. The advent of supersonic aircraft has imposed an additional requirement in regard to thermal stability. In sustained high-speed flight, the fuel is subjected to a considerable amount of heat derived from kinetic heating of the airframe; in addition, bulk fuel is often used as a coolant for the engine lubricant, the hydraulic fluid and the air-conditioning equipment. In view of this additional duty, the fuel must have assured thermal stability in order to prevent the formation of lacquer and deposits on surfaces, which could adversely affect the efficiency of heat exchangers, metering devices, fuel filters and injection nozzles.



The BP Refinery at Grangemouth. (Photo by John Rae Studios, Larbert)

## LUBRICANTS FOR AVIATION GAS-TURBINE ENGINES

No moving parts are involved in the combustion process of a gas-turbine engine; lubrication is required solely for the bearings of the turbine and of the compressor, and also for various auxiliary equipment-drives. In the turbo-prop engine, lubrication is needed also for the reduction gearing serving the propeller.

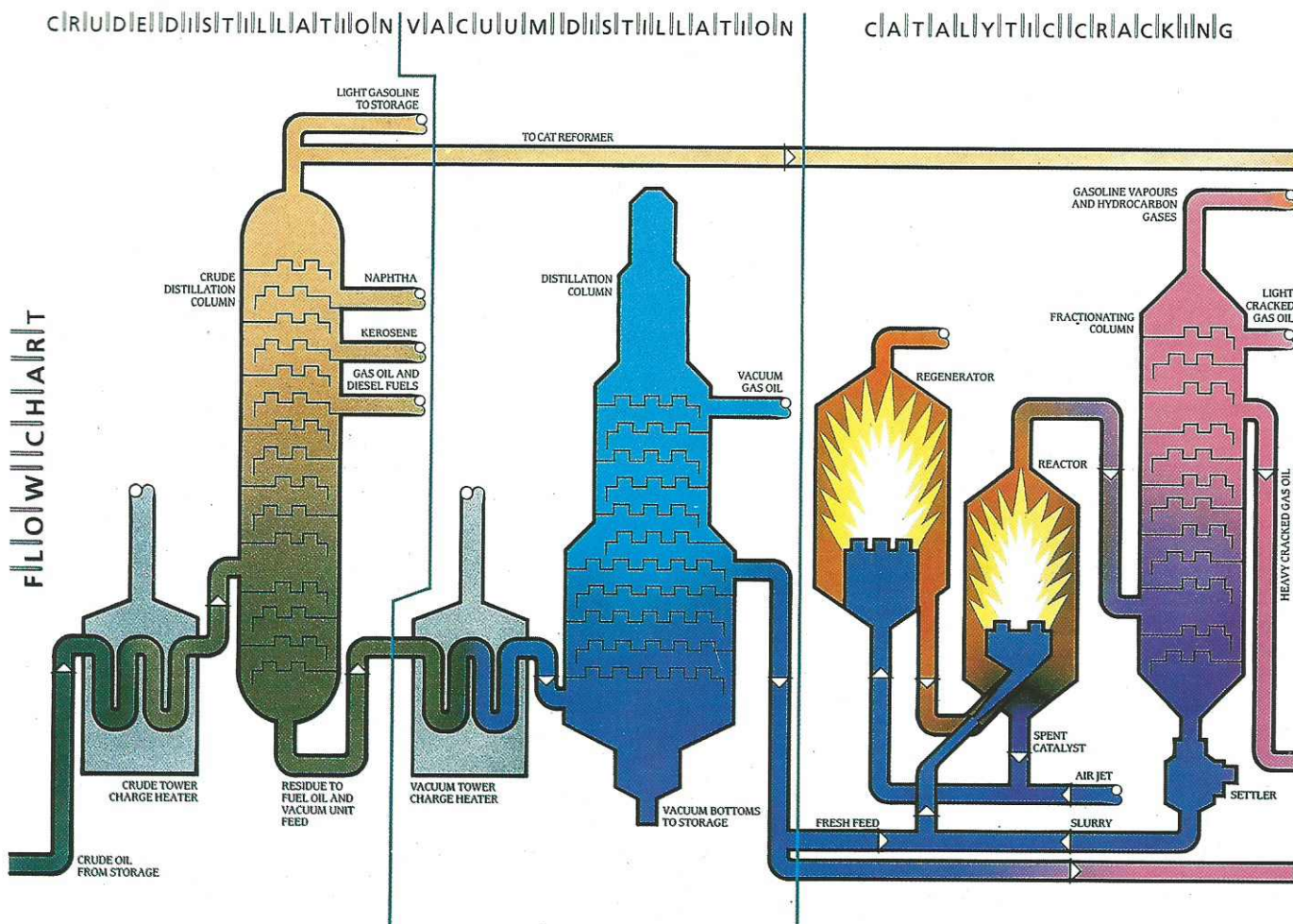
The fundamental requirements of the lubricant are that it should remain stable and fluid over a very wide temperature-range, retain its initial physical and chemical properties with no significant changes in viscosity and acidity, have adequate load-carrying ability at high temperatures, be non-corrosive and be compatible with the wide variety of metals and elastomers used in the engine.

Mineral oils do not readily conform to these requirements. Certain organic liquids, however, remain fluid at very low temperatures but do not evaporate at the high temperatures involved in aviation gas turbines, and they can therefore provide effective lubrication in these conditions. Most aviation gas-turbine lubricants are based on carboxylic esters, which are products of a chemical reaction between a carboxylic acid and an alcohol. Because they are manufactured products and not naturally occurring, they are referred to as "synthetic" lubricants.

Most synthetic lubricants are a blend of specially developed ester oils and include additives to limit oxidation degradation and corrosivity and to increase load-carrying ability.

(This article was derived largely from the excellent BP publication "Our Industry - Petroleum" and has been reproduced by kind permission. Special thanks is due to Jim Docherty of the BP Refinery, Grangemouth).





Crude oil is a mixture of many hydrocarbons, substances with different boiling points and different molecular structures. Refining involves the breaking up of the crude into its constituent fractions to obtain the various products.

Once the crude has been stabilised to remove water and excess gases it is heated by a combination of steam from the power house and heat from the process system, to a temperature of over 300 degrees Centigrade. From the heater the hot liquid oil and vapour enter a fractionating column. The vapour cooling as it rises within the column, passing through a number of trays fitted with self-activating valves, while the hot oil descends.

The vapours cool as they rise, the heavier fractions with the highest boiling points condensing first on the lower trays. The lighter fractions with the lowest boiling points condense last towards the top of the column. The separated fractions are then taken off from their collector trays and are passed on to other units for treatment.

With temperatures and pressures carefully controlled, the fractioning column gives the basic breakdown of crude oil into propane, butane, motor spirit, benzene, naphtha, kerosene, light gas oil and heavy gas oil.

Up to 60 per cent is processed in the first phase, with the heavy residual liquid passing to the bottom of the tower. At this stage it is suitable for power station fuel, and a quantity is drawn off for the use of the refinery's own power station, but most of the residual passes next to the vacuum distillation unit.

Essentially, the vacuum distillation unit repeats the previous process, but under conditions where the pressure in the column has been reduced below atmospheric pressure. This is designed to lower the boiling point of residues in the 350-550 degree Centigrade boiling range.

Vacuum distillation produces a wax distillate, which can be used for lubricating oil manufacture: this however is produced by BP's Llandarcy plant in Wales, so at Grangemouth the wax distillate is used as feedstock for the fluid catalytic cracking unit and for the hydrocracking unit.

In the early days of the oil industry, separation of the main fraction by distillation was all that was required. But to meet today's demands for high-grade products – constituents of premium grade petrols, for examples – it became necessary to subject the oil to a process which would change its molecular structure by means of a chemical reaction. Cracking is the name given to

this type of process which breaks down larger heavy oil molecules into smaller, lighter and more valuable oil and gas molecules.

With the use of a catalyst – a substance which can accelerate the reaction without itself undergoing any chemical change – a much finer control is achieved in the cracking process. The catalyst used in the cat cracker is an alumina-silica powder heated and fluidised to pass between the reactor and the regenerator sections of the unit.

The cat cracker takes the heavy, waxy oil from the vacuum distillation unit; the oil is heated and when it meets the stream of hot catalyst it vaporises. The mixture enters the reactor vessel where the cracking takes place, the gaseous product passing on to the fractionating column for separation of the high-grade lighter fractions.

During the reaction, carbon (coke) is deposited on the catalyst granules, so in a continuous action the catalyst returns to the regenerator where the carbon is burned off. The process then begins again. There are over 150 tons of catalyst in continuous circulation in the Grangemouth cat cracker.



# Mission Simulation – Harrier GR Mk5 and Mk7

by Ian Finlayson, Marketing Services Manager, Link-Miles Limited

## THE HARRIER AIRCRAFT

The Harrier GR Mk5 and Mk7 aircraft have a primary operational role in low level offensive support. This is very exacting for the pilots as it involves operating at speeds in excess of 500 knots at low altitude over undulating terrain in all weather conditions by day and by night. Tasks are performed under manual control using visual reference only, without the benefit of terrain following radar. The pilot's work load is very high as he operates in a complex modern ground/air warfare theatre with the hazard of sophisticated electronic defence measures, and particularly difficult in low light conditions using Forward Looking Infra-Red (FLIR) and Night Vision Goggles (NVG).

## TRAINING REQUIREMENTS

As the procurement of the Harrier GR Mk5 and Mk7 aircraft was going ahead, the Royal Air Force, knowing the exacting role specified for the aircraft, gave detailed consideration to the needs of the pilots for both conversion and ab initio training. Account was taken of the decision by HM Government not to procure dual-seat training aircraft, and also of the strident voices from the environmental lobby demanding curtailment of low level day and night flying. These factors gave extra drive to the recruitment for comprehensive, high fidelity, synthetic training.

The result of the deliberations was the Air Staff requirement for a suite of training equipment including Computer Based Training, Procedures Trainers, Harrier Avionics Systems Trainer and, at the highest level, mission simulators for the Mk5 and Mk7. The requirement for the mission simulators stipulated that they must provide the full spectrum of VSTOL operational flying training in flexible wartime scenarios including Nuclear, Biological and Chemical (NBC) and Electronic Warfare (EW) conditions. It was apparent that visual cues alone would not provide the required realism of simulation. Indeed research findings indicated that the visual system had to be fully integrated with a simulator which provided complementary, accurately correlated cues through motion system, control loading, G-seat and G-suit. So the requirement spelt out the need for a high resolution, wide field of view visual system integrated with a wide range of psycho-physical cues and accurate flight

and systems simulation to match the Harrier's roles, speed and agility.

## INNOVATIVE TECHNICAL SOLUTIONS

The visual system needed for the simulator was, by the standards of the day (1986), of exceptional capability to meet the demands of the low level flight scenarios.

In low level flight, air to air refuelling, air combat and VSTOL flight transition it is particularly important to have a wide field of view providing rate cues in peripheral vision. The Harrier simulator visual display system was therefore required to give a field of view that was as near as practicable to that of the aircraft. The specification set a requirement of 80 degrees in elevation, 50 degrees in depression and plus or minus 120 degrees in azimuth.

Combined with the large field of view was a need for high scene detail in the area-of-interest (AOI). It was anticipated that the cost of a visual system that painted a high resolution image over the whole 130 degrees x 240 degrees field of view would be very expensive indeed, but the line-of-sight AOI is quite small and the eye only perceives a low resolution scene in peripheral vision. A number of slaved AOI visual displays were being developed in the USA at the time and as this appeared to be a less expensive solution, it was to this emergent capability that the MoD looked.

After their detailed evaluation processes Link-Miles (then Singer Link-Miles) was selected as prime contractor for the programme and CAE-Link (then Singer-Link) was selected for their MODDIG image generator and ESPRIT display system.

## THE VISUAL SYSTEM

As stated above, the requirements for the visual system on the Harrier GR Mk5 and Mk7 simulators were very stringent in terms of field of view and scene content. The CAE-Link Eye Slaved Projected Raster Inset (ESPRIT) blends a high resolution AOI image subtending 18 degrees at the pilot's eye into a low resolution background image. The AOI display is slaved to the pilot's head and eye movements through a closed loop servo system activated by head and eye tracking devices mounted on and within the pilots helmet.

Clearly the whole system has to be very fast. As the eye moves the optical signals to the brain are temporarily blocked (this is known as saccadic suppression) and in this interval the AOI visual has to be moved so that it is in position in the new line-of-sight before the eye can perceive the absence of high resolution scene. To achieve this the AOI is projected through a small servo controlled mirror in a system that is designed to achieve step responses in excess of 700 degrees per second and accelerations up to 50,000 degrees per second per second. The low resolution image is projected through a wide angle lens designed to cover the required FOV.

The AOI and peripheral visual images are generated in two channels of CAE-Link's Modular Digital Image Generator (MODDIG) system. A third channel provides the means to simulate the Harrier's Angle Rate Bombing System (ARBS) and Forward Looking Infra Red (FLIR).

MODDIG furnishes the comprehensive range of visual effects specified for the Harrier training task including effects of air to ground, air to air, SAM and AAA weapons and correctly correlated ground, air and maritime targets.

## AVIONICS AND WEAPONS

The very advanced visual system would be of little use without a high fidelity of core simulation in the aircraft avionics and weapon systems.

The avionics system in the simulator comprises a mix of real aircraft and simulated systems interfaced through a simulated 1553 Muxbus and controlled by a Mission Computer. Unmodified aircraft Operational Flight Programmes (OFP) can be loaded and the simulator system is additionally designed to respond to instructor initiated, or programmed, freezes and resets.

The pilots Head-Up-Display (HUD) is a modified item though this is difficult to detect. The focal length of the displayed symbology is adjusted and re-mapped to reduce the focal length from infinity to coincide with the inner face of the visual display dome to make the HUD appear as in the real aircraft.

## FLIGHT, HANDLING AND PERFORMANCE

Here again the quality of simulation must be high. The simulator provides a range of stimuli which reinforce the pilots



perception of a real environment. These include the sense of motion from the motion system, G-seat and G-suit, aural cues from the digital sound system, feel of primary controls generated by the digital control loading system, and the reactions of displays and instruments. All these stimuli must be precisely programmed to respond in any situation in the same way as the real aircraft and in correlation with the visual system and each other. This is achieved with careful integration and high fidelity software modelling of the underlying aerodynamics, engines and aircraft systems.

Historically the latency of response after a control input has been a significant issue in flight simulation of agile aircraft like the Harrier. Fortunately, advancing computer technology has provided the means to reduce the time it takes to perform critical flight loop calculations and, by ensuring that the three major elements of the simulator (core simulator, MODDIG and ESPRIT) are closely integrated and operating at a 60Hz iteration rate, the simulator has achieved a response time from control input to visual system update in the order of 130 ms. This is much closer to the aircraft's inherent latency than has been achieved previously and well within the 220 ms specified by the MoD.

### NIGHT OPERATIONS

To operate effectively in the Electro-Optic environment the pilots have to develop new skills of dexterity, perception and judgement, and if these skills are to be trained on the simulator the

simulation of night vision aids must be comprehensive.

This presents its own challenges to the training systems designers.

NVGs are helmet mounted and have a field of view of 40 degrees, so in the simulator the AOI is enlarged to this size when the NVG helmet is in use. There is no need for eye slaving as the line of sight is constrained by the goggles, so head slaving is used. The cockpit and instrument lighting must be compatible with the NVGs in the simulator in the same way as in the aircraft itself.

For the GR7 FLIR simulation will also be implemented. The simulator uses as-aircraft head-up and head-down displays, but the IR sensor has, of course, to be simulated. This is done by the third MODDIG channel modified electronically to introduce characteristics of the FLIR system fitted in the aircraft.

### INSTRUCTOR FACILITIES

The pilot workload in the Harrier GR Mk5 and Mk7 is high and, as this means that the instructors are also highly loaded, it is important to minimise the effort the instructors expend in controlling the simulation and give them the best tools for the training tasks. To this end the instructors have a comprehensive suite of mimics of cockpit instruments, displays and controls in a layout that reflects their disposition in the cockpit, and colour monitors displaying all simulator and sortie data.

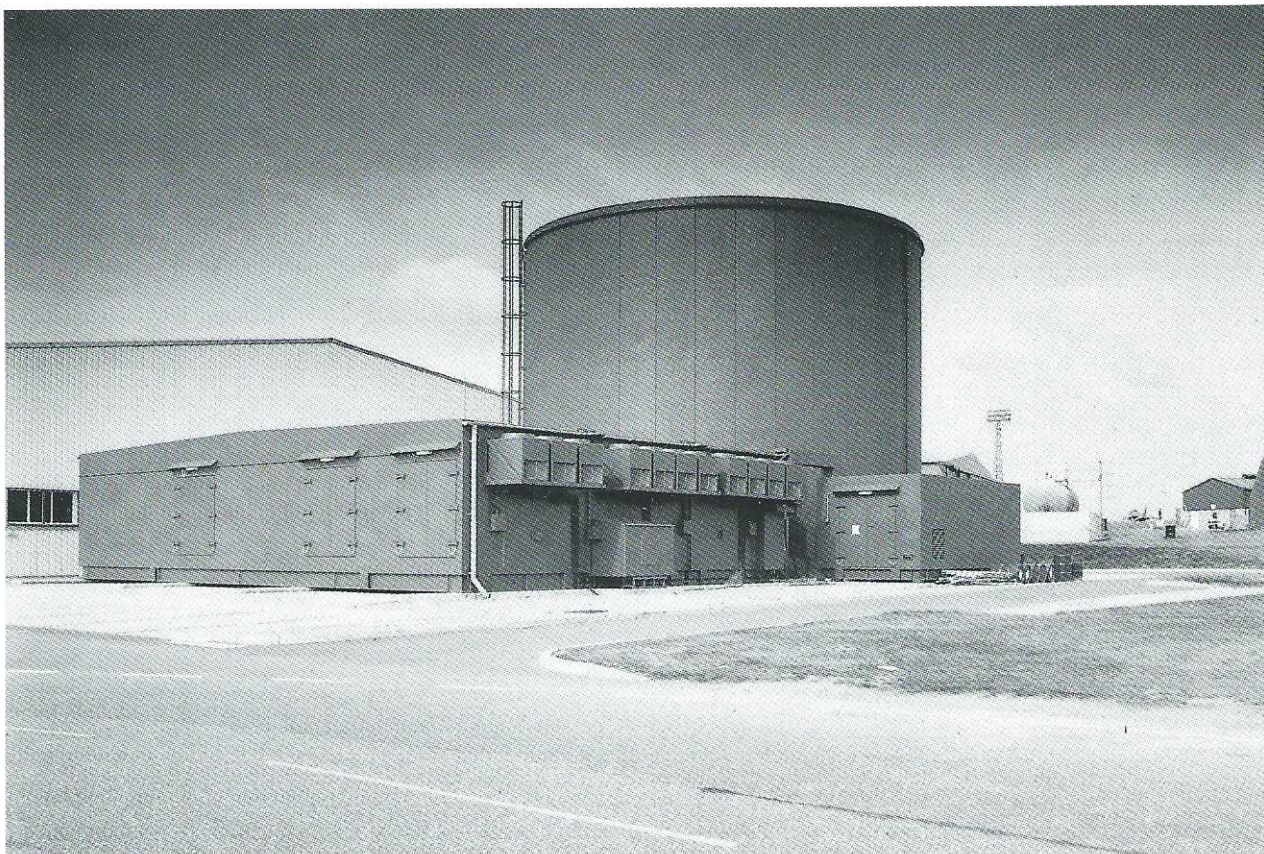
Control by means of a push-button control console allows fast access to

control function page displays from which ambient conditions and malfunctions can be selected, entered and varied. A tactics development facility provides the means to develop tactical scenarios off-line from an expandable target and ground threat library. The resulting scenarios are fully interactive with the relevant simulated aircraft systems and the visual system. During a sortie the instructor can monitor, direct and participate in tactical operations.

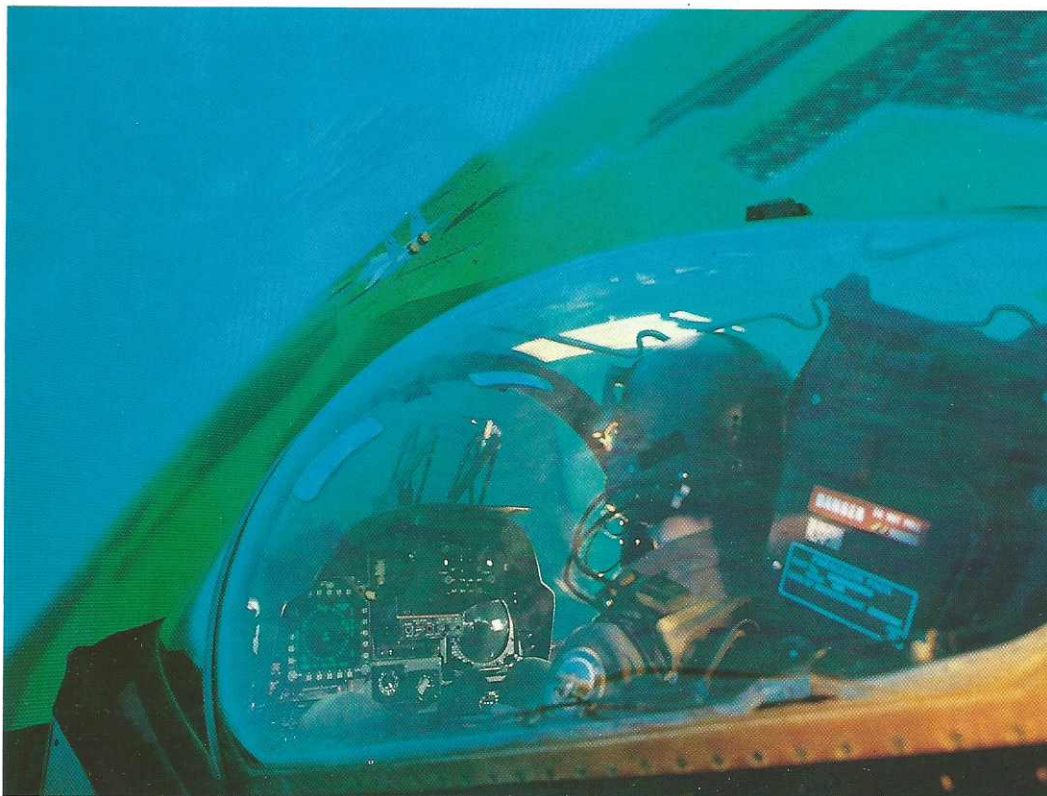
The instructor has a range of additional facilities such as 30 minutes of record/replay, weapon scoring, freeze and reset. There is also a remote debrief facility which utilises recordings on disc and VCR of all major elements of a simulator sortie. These can be played back to provide analysis and debriefing remote from the simulator.

### CONCLUSION

The Harrier GR Mk5 simulator is now in service and the GR7 follows. The final proof of training effectiveness of the simulator as part of a complete training system will come as it is used in its ongoing primary training role of providing a uniquely high proportion of high-speed low-level ground attack training. This international programme at the leading edge of technology has been challenging, demanding and exciting for Link-Miles as prime contractor. The end result is certainly impressive, the fidelity is very high and the operational performance exceeds the latency requirements of the original specification.



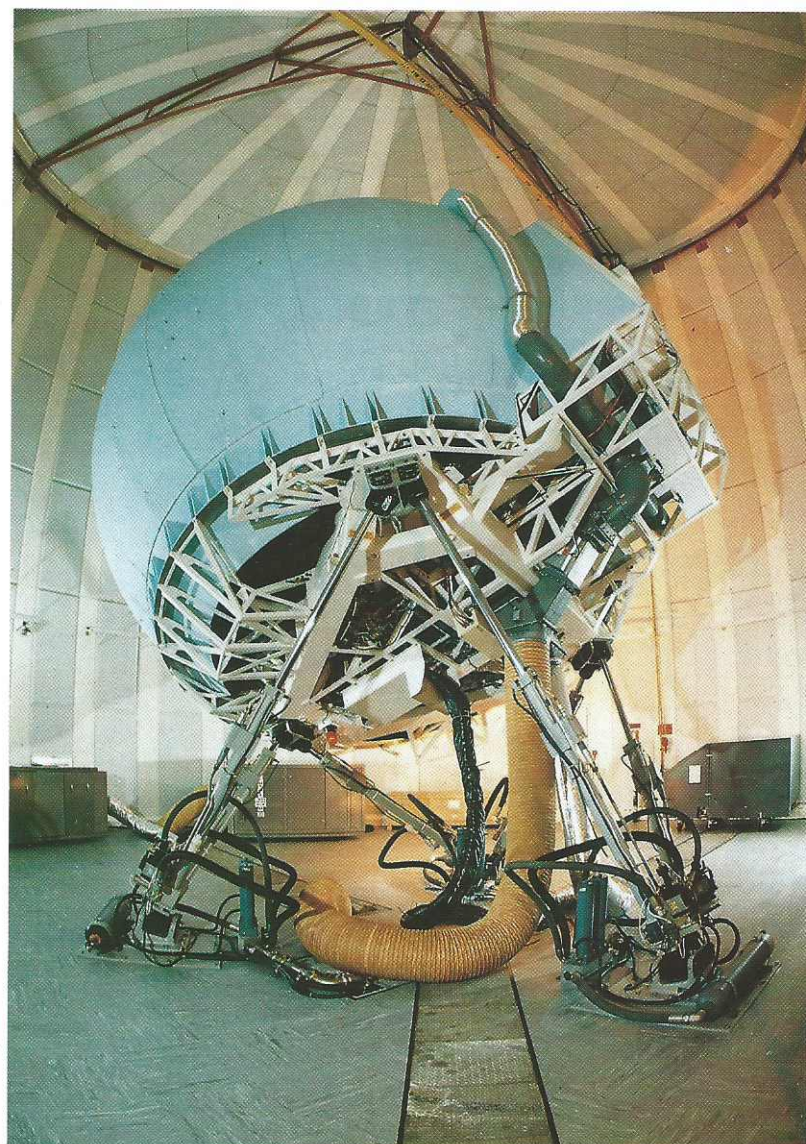




**ABOVE:** "The CAE-Link Eye Slaved (Projected Raster Inset (ESPRIT)) blends a high resolution AOI image subtending 18 degrees at the pilot's eye into a low resolution background image."

**RIGHT:** Something of the range of movement of the Harrier Simulator can be seen in this view from the floor of the main Simulator Hall.

**PREVIOUS PAGE:** External view of the Harrier Mission Simulator building at RAF Wittering.



(All photos courtesy of Walter Gardiner Photography, Worthing).



# Training Flight Engineers

by Eric Myall

## Origins

The formal establishment of the aircrew category of flight engineer within the Royal Air Force was enshrined in Air Ministry Order A/190/41 dated 20 March 1941. This covered the 'provision of Flight Engineers for certain types of heavy bomber and flying boat aircraft'.

Originally, 'Flight Engineers' in the RAF can be traced back to the pre-World War 2 practice of flying boat squadrons of employing engine fitters and flight mechanics from their ground crew complements to assist in monitoring engine performance during (comparatively) long-distance flights and if necessary, to carry out engine repairs in the case of failure or shut-down.

It should be recalled that in the inter-war years, the range and duration of most aircraft was very short compared with modern standards and it was only the larger flying boats of the RAF's Coastal Area and overseas squadrons that were able to carry out long-distance flying. Many of these flights were made into areas far removed from RAF bases, so that some provision for technical assistance had to be made for pilots and observers who comprised the aircrew of that period. In addition, the aircraft engines of the time were far from reliable.

There was one further aircrew category in the inter-war years, one which originated in World War – the Air Gunner.

During that conflict, as soon as flying became an established aspect of war and guns were carried by aircraft for both defensive and offensive purposes, the practice of using groundcrew in the Royal Flying Corps as airborne gunners became widespread. No formal status was given to the volunteers who undertook these duties and they received no promotion or other enhancement.

Even before the outbreak of World War 1 there were pilots, and the well-known 'Pair of Wings' badge was formalised as their insignia in February 1913. The war was only one year old when Observers were recognised with the award of a 'Half-wing' with the letter 'O' at its lower end. This latter badge became the pattern for all other categories of aircrew in due course.

The Air Gunner was eventually recognised, in turn, but not until 1923. At that time arm badges were authorised for both 'Aerial Gunners' and Physical Training Instructors! The Gunners arm badge was a winged bullet. Gunnery training – still for groundcrew volunteers – was carried out at squadron level and on passing out an extra 3d per day was granted, plus 6d per day for each day

spent on airborne operations. This state of affairs, whereby all gunners were in effect 'part-time' endured until 1939.

The event which triggered off the requirements for additional air-crew categories was the decision to build heavy bombers in the mid-1930s. The first of the relevant specifications was B12/36 for the Short Stirling. This was followed almost immediately by P13/36 – the specification which initially produced the twin-engined progenitor of the Handley-Page Halifax and Avro Manchester. These two types were unsuccessful in themselves, but were developed into the four-engined Halifax and Lancaster respectively.

Obviously, these comparatively huge aircraft would require far more crew than the 'heavy' bombers of the 1930s (mainly biplanes) and more than the generation of bombers that were coming into service around this time, such as the Handley-Page Hampden, Armstrong-Whitworth Whitley and Vickers Wellington, collectively known as 'medium' bombers.

The immediate call was for more Air Gunners and in January 1939 the concept of 'part-time' Air Gunners was abandoned. At the same time, the requirements of radio communications were recognised and the commitment for air gunnery training was passed to the wireless trades – leading to the establishment of a 'Wireless Operator/Air Gunner' aircrew category.

A year later the initial meeting to discuss a further aircrew category was held at the Air Ministry. In the introductory remarks, the concept of Flight Engineering was expressed as follows: 'It

is also desirable, with a view to obtaining the best possible performance from engines, to have someone watch the engine instruments ... it is proposed that this duty should be undertaken by an additional member of the crew who would receive special training in the running of engines'. Additional duties for Flight Engineers were also discussed and it was envisaged that they would also be trained as Air Gunners. Although the introduction of the new heavy bombers was a high priority in 1940, the German offensive in Europe which led to the fall of France and the evacuation from Dunkirk all influenced the pace of expansion of commands other than Fighter Command where top priority had, perforce, to be given.

It was not until March 1941 that the formal establishment of the Flight Engineer was enshrined in Air Ministry order A190/41. Even then the position was not entirely clarified. As early as December 1940 the question of a distinctive flying badge for Flight Engineers was raised within the Air Ministry. This would have been a simple modification of the single wing 'Air Gunner' badge which was, in turn, based on the Observer's badge. Flight Engineers were to undergo a three-week gunnery course as part of their training in order that they might take over a turret or gun if an Air Gunner were to be killed or wounded. It was decided, therefore, that the Air Gunners badge would be adopted for Flight Engineers. This decision is difficult to understand and it probably reflected entrenched opposition within Air Ministry to a breach of the 'Pilot/Observer' basic aircrew structure, with any other aircrew members regarded as part-time and auxiliary.



The variety of aircraft used for instructional purposes at St Athan can be seen in this picture of a Lancaster, two Stirlings, Sunderland, Catalina, Halifax and possibly a B-17 Fortress



This outmoded concept could not possibly be allowed to continue and the whole of the aircrew structure within the RAF was changed by Air Ministry order A746/42. While naturally retaining the Pilot category, the Observer role was dropped. The following categories of aircrew were then established:

- 1) Navigator – with sub-categories of Navigator (B) (Bombing); Navigator (BW) (Bombing Wireless); Navigator (W) (Wireless); Navigator (Radio).
- 2) Air Bomber (\*see Note One).
- 3) Wireless Operator (Air Gunner).
- 4) Air Gunner – with sub-categories of Air Gunner (Wireless Operator Mechanic); Air Gunner (Flight Mechanic) (Primarily for Coastal Command Operations).
- 5) Flight Engineer.

This reflects the concurrent decision to do away with a two-pilot arrangement for heavy bombers. This was regarded by that time as being wasteful – with heavy aircrew fatalities, the loss of two pilots was thought to be unacceptable. In smaller aircraft like the Wellington the Air Bomber became a second Pilot 'Pilot's Mate' and in larger aircraft the Flight Engineer would perform this function.

Distinctive badges for the new categories of aircrew were introduced in the latter part of 1942.

## DUTIES AND TRAINING

With the formal establishment of the Flight Engineer as a separate aircrew category it required a clear definition of both responsibilities and the training required to perform them. These were enshrined in Air Ministry order A978/42

dated 15 August 1942 and were as follows:

### Duties and Responsibilities

- 1) To operate certain controls at the Engineers station and watch appropriate gauges as indicated in the relevant Air Publications.
- 2) To act as Pilot's Assistant (as required of Air Bombers – see above).
- 3) To advise the captain of the aircraft as to the functioning of the engines and the fuel, oil and cooling systems, both before and during flight.
- 4) To ensure effective liaison between the captain of the aircraft and the maintenance staff, by communicating to the latter such technical notes regarding the performance and maintenance of the aircraft in flight, as may be required.
- 5) To carry out practicable emergency repairs during flight.
- 6) To act as stand-by Gunner.

### Training

It should be borne in mind that initially all Flight Engineers would be drawn from Fitters and Flight Mechanics. This concept was soon abandoned and direct entrants accepted.

Selected candidates will be required to undergo the following training:

- 1) The Junior NCO course, if appropriate.
- 2) A course of approximately five weeks at an Initial Training Centre.
- 3) A three-week course of Air Gunnery training.
- 4) A course of technical instruction, which may include a course at the manufacturer's works. For Fitters (Airframe), additional instruction in engines would be provided.

Broadly speaking, both Fitters and Mechanics were divided into 'Engine' and 'Airframe' categories with the Fitter having the superior trade status to the Mechanic. For the latter, an additional course would be taken to convert this status to Fitter.

This Air Ministry order also covered the question of Rank and Commissioning. To ensure that all aircrew received reasonable treatment from the enemy should they fall into their hands as prisoners-of-war, a minimum aircrew rank of Sergeant had been established.

A single commissioned post on each squadron or operational training unit would be established for an officer of the rank of Flight Lieutenant or below.

### Technical Training, RAF St Athan

A contract for the construction of an RAF Station at St Athan in Glamorgan, Wales, was signed in 1937 and work commenced immediately. The first party of airmen arrived at the camp on 1 September 1938. The initial unit to be based there was No. 4 School of Technical Training (SoTT) which was tasked with the training of Flight Mechanics and Riggers as well as Drivers.

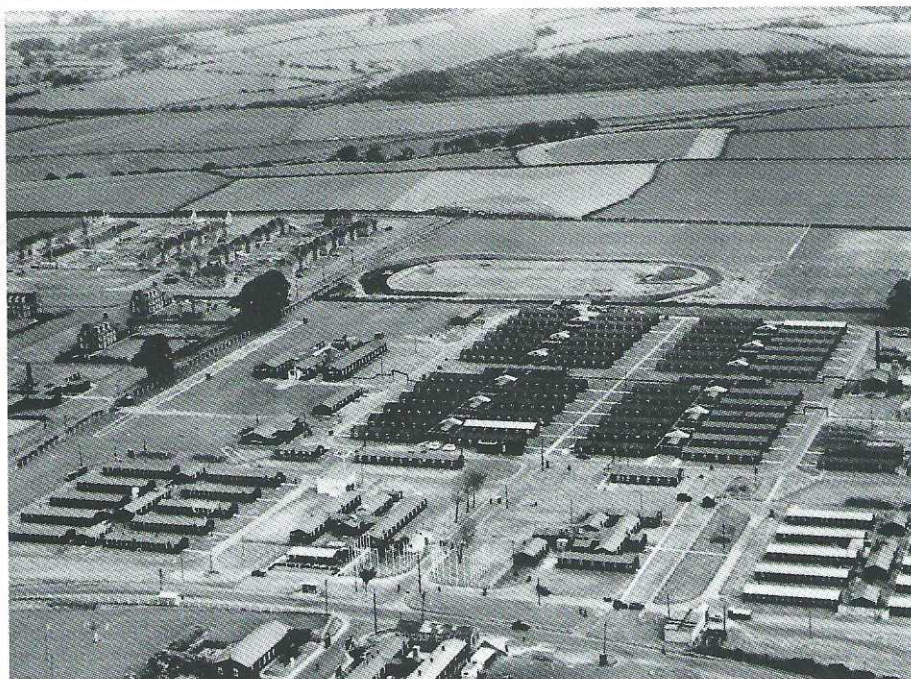
The initial trainees had come from No. 2 (Training) Wing at RAF Henlow from whence came a quantity of Ground Instructional Airframes including Harts/Furies, Fairy IIIFs and Gordons, Avro 504Ks and some Blenheim Is. There was also a flight of 4 Miles Magisters for air experience. The station was mobilised for war on 2 September 1939.

Other tenants of St Athan were Nos. 19 and 32 Maintenance Units, both of which were established during 1939.

In June 1942 St Athan was chosen as the location for the training of Flight Engineers, and No. 4 SoTT as the training establishment. This made sense in that the training of Engine Fitters and Mechanics had been underway for 3 years or more, but Flight Engineers then became the cuckoo in the nest and displaced both Fitters and Mechanics by September 1942. It must be remembered, however, that there were already many 'Flight Engineers' in operational flying duties with the Royal Air Force.

The Short Stirling entered service in August 1940 with No. 7 Squadron and by February 1941 the squadron's operational record book mentioned some Leading Aircraftmen (LAC's) on crew lists as 'Engineers/A.G.'. These were former Fitters who had been given training at Airframe/Engine Manufacturers on the type of aircraft/engine combination on which they were to serve.

For some time the training of Flight Engineers at St Athan was confined to former Fitters/Mechanics, but direct entrants were soon accepted. This partly reflected the vast numbers required due to the continuing expansion of the Royal



No. 4 S of TT at RAF St Athan was the original home of flight engineer training. Thousands of aircrew members passed this way on their way to operational squadrons. In the photo are the East Camp main gate and the wooden huts used for accommodation and as classrooms



Air Force, but also the need to retain experienced Groundcrew, so that not too many of the latter were lost to flying duties.

The first course at St Athan commenced on 30 May 1942 and comprised 60 trainees following a syllabus which had only been drawn up in April! The Initial 2 courses were of 3 weeks duration, the following 2 of 4 and 5 weeks duration and the fifth and subsequent courses took 6 weeks – the planned length. The number of personnel planned for each course was 100, but did fluctuate from time to time. Some delays occurred in the Complementary Gunner School Courses, but this requirement was dropped in around mid-1943 and progress improved thereafter.

On arrival at St Athan, the current requirements for individual aircraft types were assessed and the course was split accordingly, with training following on that specific type alone although some general tuition was also given.

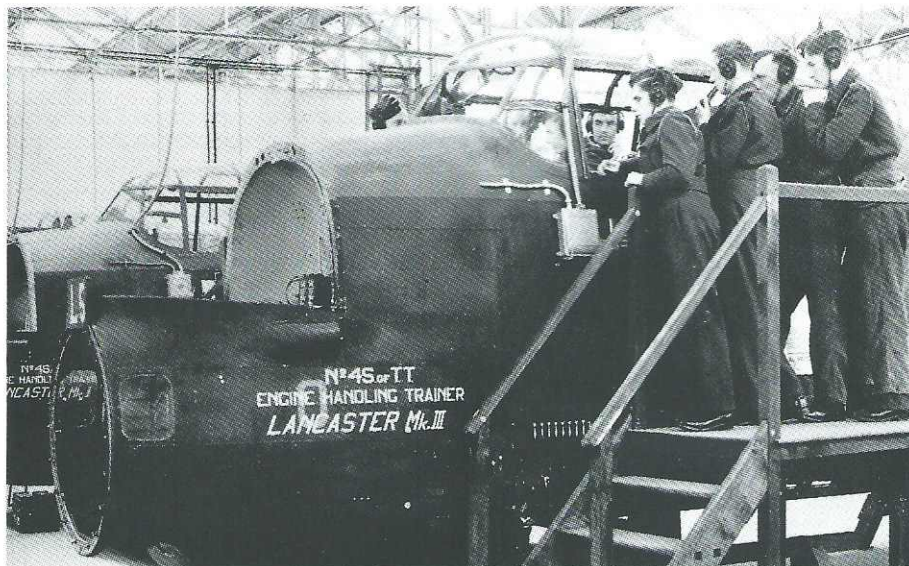
Air Ministry Order A707/42 dated 16 July 1942 allowed direct entrants to be trained as Flight Engineers. Obviously, additional training would be required for those entrants and so a longer course of 24 weeks was established in 1943 when the full impact of Direct Entrant Recruitment was felt. This led at times to an output of over 500 men in one week and a total population at No. 4 SoTT of over 5,000! This level of output was principally aimed at replacing the very heavy aircrew losses of Bomber Command, with Coastal Command requiring comparatively smaller numbers. From March 1943 onwards a new customer was Transport Command, formed on the 25th of that month.

In addition, as the course of the war raged on, the 'Second Front' or invasion of Europe drew closer and it was anticipated that aircrew losses would increase dramatically in the months both before and after that momentous event.

Early in 1944 St Athan could not cope with the sheer volume of training required and the Engineers' course was split into two, with the first 10 weeks being given to No. 5 SoTT at RAF Locking, and the remainder at St Athan. The first course at Locking commenced on 17 February 1942 and the last finished in the winter of 1944/5 – possibly as early as November 1944.

By this time it was realised that D-Day losses were much less than had been feared. Another element in the reduction of Flight Engineer Training requirements was the 1944 decision of the Royal Canadian Air Force to train its own Flight Engineers.

As the war moved to its close in the early months of 1945, the numbers at St Athan dwindled to almost zero but training did not entirely cease with the end of the war. By then, over 22,500 Flight



**Trainee flight engineers being shown the intricacies of the Lancaster MkIII cockpit. Most instructional airframes came from crashed examples that were salvaged in sufficiently complete form for instructional purposes.**

Engineers had graduated from the School and the Station and these had seen active duty on every front.

## POST-WAR TRAINING

In so far as the training of aircrew and, more particularly, Flight Engineers was concerned, the early post-war period was a poorly documented time and can be best viewed as a series of sometimes conflicting developments, for example:

- a) With the conclusion of the war the requirement for aircrew was vastly diminished.
- b) There was a concerted demand by most wartime Aircrew recruits for early demobilisation.
- c) To run down the vastly expanded Air Force took time.
- d) The immediate world-wide post-war commitments of the services were certainly larger than in the early 1930s, before mobilisation had begun.
- e) The air of euphoria of the immediate post-1945 period had begun to be eroded by the gradual realisation that a 'cold-war' with the communist bloc could easily escalate into the real thing. Perhaps the earliest significant evidence of this was the blockade of Berlin in 1948 with its attendant successful airlift.
- f) A certain amount of 'pre-war thinking' began to manifest itself at the higher echelons of the Services. There were many who regretted that the war could not be left to the 'Professionals' alone and that full-scale conscription had been necessary. The sooner the Services returned to a 'proper' peace-time footing with an all-volunteer complement, the better. National Service was a necessary evil in this period in the eyes of many.
- g) The pace of aeronautical progress at this time was enormous and the advent of the jet engine was bound to have an overwhelming influence on all aspects of

military aviation – not least on the next bomber generation which were quickly put on the drawing boards of the aircraft industry.

The outbreak of the Korean War was the catalyst which brought about a major re-think on the part of all the western bloc countries. Thus, from 1946 to 1950, the RAF's aircrew requirements can be seen to fluctuate against a changing political and economic background. This period of austerity and dollar shortages also had its effect on what the Services could afford.

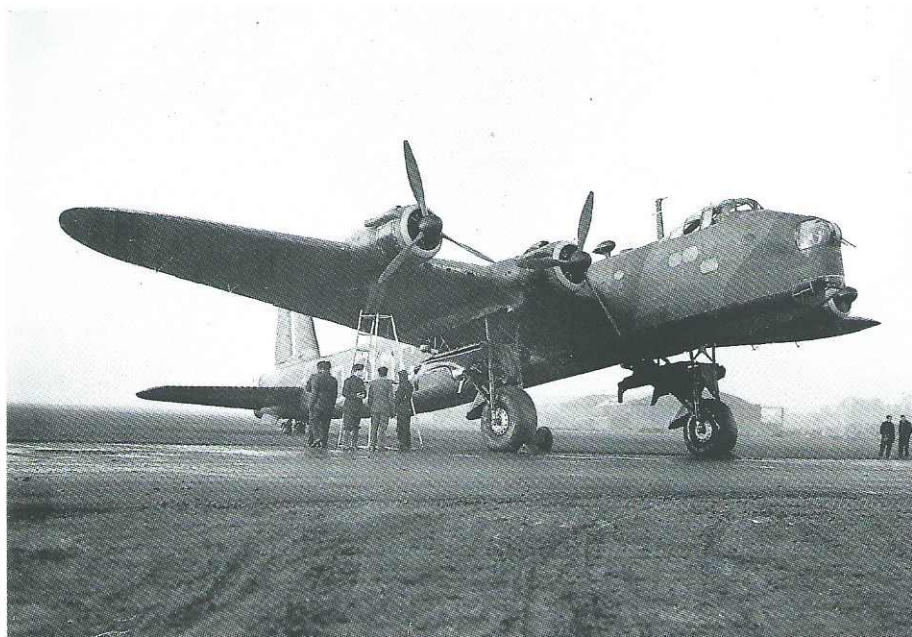
Training at St Athan continued, but on a small scale. Once again the emphasis returned to the training of serving Fitters while direct entrants were few and far between. A certain amount of refresher training was also provided for those who had left the Service at the end of the war and who now wished to rejoin for a peace-time flying career.

Contemporary with this period, a new structure was established for all non-commissioned aircrew. Thus, a Warrant Officer would now be a Master Engineer, while an Engineer 1 would be equivalent to Flight Sergeant, Engineers 2, 3 and 4 covered Sergeant and Corporal ranks and the lowest of the low – the 'Sprogs' under training – were Aircrew Cadets. The simple title of 'Flight Engineer' was actually declared obsolete in September 1946.

Despite this, requirements for them were reflected in a gradual increase in the training workload at St Athan in 1947. From that time on, prospective 'Engineers' were type-trained, initially on the Avro Lancaster from 1947 to 1949, and then on the Avro Lincoln.

In 1948, however, with the immediate post-war fluctuations settling down, the Berlin Airlift episode brought about a re-think and by the end of that year a new direct entrant scheme was started. A separate squadron was established with





**The faithful Shorts Stirling was one of the first multi-engined RAF bombers to employ a flight engineer. These were recruited mainly from fitters and riggers often combining the trade of air gunner with that of engineer.**

**Photo: IWM**

No. 4 SoTT at St Athan to cover this training. The duration of the course was no less than 64 weeks and training was expanded to cover the basic systems of all contemporary large service aircraft. Some Avro Lincolns were operated from St Athan to give practical instruction in the air.

In 1950 the outbreak of the Korean War brought yet another expansion and 2 additional short courses were brought into being at St Athan. The first was for Regular Airmen (12 weeks) and the second for National Servicemen (18 weeks). For both courses, the Engineer's brevet would be awarded at the end of the Operational Conversion Unit Course which followed immediately the training at St Athan. The new non-commissioned aircrew structure was abandoned and all NCO aircrew attained the rank of Sergeant on being awarded their brevet.

## THE AIRCRAFT

The principal types on which Flight Engineers served were the four-engined 'heavies', initially bombers, which were introduced in the early years of World War 2.

In Bomber Command the Short Stirling was followed by the Handley-Page Halifax and then by the Avro Lancaster. American aircraft obtained during the war included the Boeing Flying Fortress (in comparatively small numbers) and the Consolidated Liberator.

The latter 2 aircraft types also saw service with Coastal Command where the Short Sunderland was the principal aircraft for long-range patrol and anti-submarine work. The Consolidated Catalina was also used in this role and was the only twin-engined aircraft to

include a Flight Engineer among its crew complement. It is thought that some Flight Engineers served on the Avro Manchester, but only at Operational Training Unit level.

In 1943 Transport Command was established and in due course acquired its own fleet of four-engined aircraft. A mixture of transport versions of the Stirling and Halifax plus some Liberators were later augmented by the Avro York – the 'dedicated' transport version of the Lancaster, and its lesser modified version, the Lancastrian.

After the war's end, the mainstay of Bomber Command gradually became the Avro Lincoln and, pending the introduction of jet-bombers, the Boeing Super-fortress or Washington as it was known in British service.

While the Sunderland flying boat remained the most prominent immediate post-war type in Coastal Command, the maritime version of the Avro Lancaster came into service and eventually the Avro Shackleton superseded them both.

The first post-war transport 'heavy' was the Handley-Page Hastings, later to be joined by the Blackburn Beverley.

## THE JET AGE

The introduction of jet-propelled aircraft into the Royal Air Force from the late war years onwards was a fairly slow process, but there was little doubt that enormous changes in policies, tactics and aircraft/aircrew requirements would ensue.

Initial emphasis was placed on fighters but the jet-powered bomber was not that far behind. The English Electric Canberra came into service in 1951 and the days of

the Avro Lincoln were soon over. The Canberra was, of course, at best a 'medium' bomber although with vastly greater capability than the medium bombers of the 1930s-40s. Following along behind were the true 'heavies' in the shapes of the Vickers Valiant, the Avro Vulcan and the Handley-Page Victor. It was at this stage that the future of Flight Engineers within Bomber Command came to a fairly abrupt end.

Luckily, a different story prevailed in other Commands. In Coastal Command the Shackleton was replaced by the Hawker-Siddeley Nimrod which remains to this day the mainstay of the Maritime force of Strike Command.

In the transport role the Hastings and Beverley were in due course replaced by a few de Havilland Comets and rather more Bristol Britannias. Later came the Lockheed Hercules and Vickers VC10, and the Short Belfast which had a regrettably short career. Finally, the Lockheed Tristar came into service with 216 Sq.

In the post-war era flight re-fuelling also came into its own with Vickers Valiants, Handley-Page Victors, VC10s, Hercules and Tristars all participating in this part of the modern aviation scene.

Thus, at the present time, Flight Engineers may be found on the following aircraft types of today's Royal Air Force: Hawker Siddeley Nimrod (Maritime Patrol); Lockheed Hercules (Transport and tanker); Vickers VC10 (Transport and tanker); Lockheed Tristar (Transport and tanker); Boeing E-3D (Airborne Early Warning).

It is difficult to see that when a requirement is tabulated to replace the existing Maritime and Transport aircraft, that the Flight Engineer will disappear from the Royal Air Force's Aircrew structure – whatever the airlines choose to do in civil aviation.

## FLIGHT SIMULATION

After the initial period of training at St Athan and the expansion following the introduction of direct entrants, No. 4 SoTT was equipped with single examples of the Stirling and Halifax for pre-flight checks and engine handling/air-frame maintenance. With the increasing numbers of trainees the prolonged ground running of engines posed problems, and obviously flying experience could not have been given on those 2 aircraft alone. The problem disappeared, however, with the advent of the first 1,000 bomber raid when both aircraft were removed from St Athan forthwith for operational duties! The gap that this left in the training sequence was considerable and it was quickly decided that a 'synthetic engine handling device' be constructed at St Athan. The nose section of a crashed Halifax was obtained along with equipment designed to



simulate the operation of Merlin engines. Cockpit instruments were connected and pre-flight drills, fuel supply (always complicated on a Halifax) and engine starting and stopping sequences could be practised, thus replacing to some extent the facilities of the 2 departed bombers.

Following a visit from the C-in-C Technical Training Command to the school, the benefits of this novel 'Flight Simulator' were immediately and formally recognised by an order for 12 improved units and the allocation of a hangar to accommodate them. Permission was given to obtain whatever equipment was necessary from the Aircraft Recovery and Scrap Depot at Cowley.

The initial instructors and, indeed, the creators of this important aid to training were Bob Thompson, J. T. Ford and F. W. Barling. They were later joined by 40 additional skilled personnel.

Simulators were built for Stirling, Halifax and Lancaster aircraft. They were much more capable than the original training device but an even more advanced machine which fully justified the description of Flight Simulator was built. This involved a Lancaster nose section with full instrumentation and working intercom. The School's staff were given the full co-operation of Mr C. L. Hinings of Rolls-Royce in this development. Engine flight parameters could be realistically portrayed and engine noise was provided electronically. Gradually, other systems were added such as under-carriage and flying control operation, together with authentic instrument readings. Electrical supply was provided by a 3HP motor. A 'snag' panel was soon added from which instructors could introduce problems. If the proper corrective action was not taken promptly, a realistic 'crash' would ensue! Later simulators included Catalina, Liberator and Sunderland aircraft and, as a 'one-off', a Mosquito flight simulator was prepared for RAF Upper Heyford. This was in connection with a high incidence of take-off and landing crashes on that type.

Although patents had been taken out for these Flight Simulators during the war, no further development seems to have been taken by the Royal Air Force after the war ended. The position is not entirely clear, but before the war ended the simulators were demonstrated to the Americans, who showed great interest. It is possible that manufacturing rights were obtained in America and that the subsequent development of Flight Simulators in that country owes much to the innovation and practical expertise that existed at St Athan during the war years. Recognition of the importance of that work was forthcoming by the award of the British Empire Medal to all 3 of the original instructing team.

## THE CESSATION OF TRAINING

In 1951 a decision was taken by the Royal Air Force that training of Flight Engineers at No. 4 SoTT would cease. I have been unable to find any Air Ministry order which covers this decision and it would seem that it must have been taken below Air Council level, possibly jointly between Technical Training Command and Bomber Command.

Training of Flight Engineers was the only aircrew training performed by Technical Training Command and it was therefore something of an anomaly. Bomber Command was by far and away the biggest 'customer' for St Athan and the advent of the jet bomber was, by 1951, well under way with a concomitant reduction in the need for Flight Engineers.

The timing of the cessation of training can be estimated fairly precisely by the fate of the only 2 aircraft used for regular inflight tuition at St Athan. Two Avro Lincolns – RF462 and RF 484 – were allocated to the St Athan Station Flight in July 1950. RF462 arrived on 5 July and RF484 on 27 July. They were primarily used for the training of National Service Flight Engineers, the first course (NSA 1) commencing (initially in Ground School) in the middle of that year. On 4 October 1951, both Lincolns were transferred away from St Athan so the National Service element of centralised Flight Engineer training must have been concluded around that time. New courses arrived at St Athan every 6 weeks and a simple calculation reveals that the total number of NSA courses would have been around 10-12 with a complement of 12 trainees on each course.

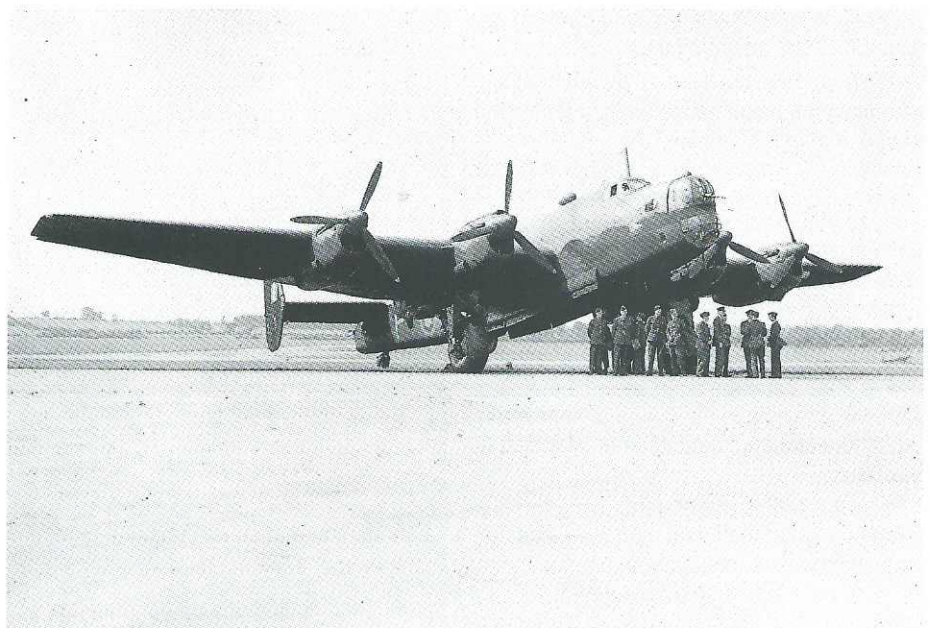
Central training for regulars also ceased at around the same time. Bomber

Command would have been 'awash' at this point with 'spare' Signallers/Gunners/Engineers and any residual requirement for Engineers could have been easily satisfied from existing personnel. In Coastal and Transport Commands, both of which were much smaller than Bomber Command, any immediate requirements could be met from Groundcrew Fitters and the training/conversion process could fairly easily be achieved within the individual Command, primarily at the operational conversion unit stage. This state of affairs was to last for another 9 years, before formal centralised training of Flight Engineers recommenced. By this time, even the name had changed as, from the early 1950s onwards, the term 'Air Engineer' had become common parlance.

**Note One:** *The Air Bomber category is of interest, as one of the duties incumbent upon it was to act as 'Pilot's Assistant, where there is no Flight Engineer, to the extent of being able to fly straight and level on a course.'*

**Acknowledgements:** *The author wishes to acknowledge the assistance provided by Sqn. Ldr. A. F. Hopkins, A. Maydew, BAI (Eng) at RAF St Athan and Ray Sturtivant. Invaluable information was obtained from 'The History of the Air Engineers' by Flt. Lt. D. C. Stringman, RAF and 'Royal Air Force St Athan – A History 1939-1988' by S. J. Bond. Finally, thanks go to Bob ('Tommy') Thompson BEM – one of the original Flight Simulator creators/instructors at St Athan whose history of this episode first appeared in 'The Haltonian' (Editor W. E. Kelley).*

**Acknowledgement:** Eric Myall's article first appeared in 'Aviation News' in 1990 and is reproduced here by kind permission of the author.



Handley-Page Halifax, serial and place unknown.  
Photo: IWM



# Non-destructive Testing of Aircraft Tyres by Shearography

by Ray Fletcher, Retread Technologist, Dunlop Limited

The purpose of non-destructive tyre testing by laser photography is to ensure the tyres supplied to customers are structurally sound and fit for use. It is now taken as a matter of course by airlines (or the military) that advanced NDT techniques are available to manufacturers and retreaders. Without this equipment little or no business would be available. It is required that any areas of reduced adhesion can be identified within a tyre prior to issue. With the recent advances in tyre performance and increase in casing life, it is essential that potential problems are removed during processing before incidents occur.

The new Grant Engineering Non-Destructive Testing equipment installed in July 1992 by Dunlop Aircraft Tyres is the most advanced used by any aircraft tyre manufacturer or retreader in Europe.

Shearography (or L-RAY as the system is patented) testing is technically a simpler process to carry out than other forms of NDT. The equipment is far less sensitive to outside influences such as vibration or wear on mechanical parts. The information provided by the new machine has shown anomalies within the tyre to be much simpler to identify, in comparison with other data such as X-ray. This is because L-RAY data provides a direct measurement of displacement gradient (shear strain is directly proportional to displacement gradient) as a result of the applied stress.

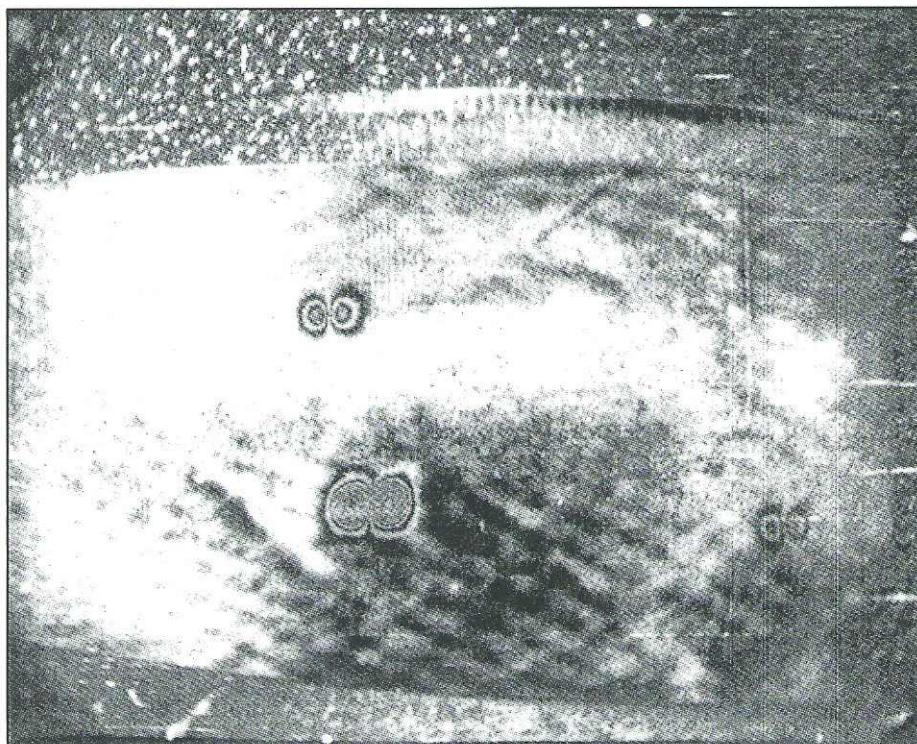
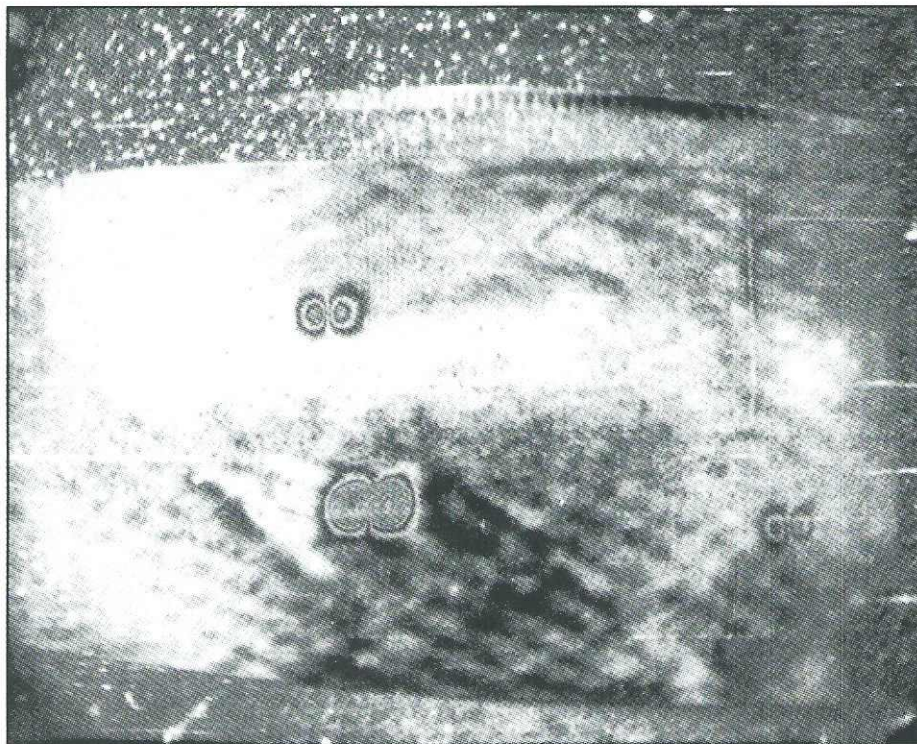
Due to the increased image clarity anomalies can be detected at an earlier stage on L-RAY than was previously possible. The exact size of the anomaly is shown. The main criteria for acceptance or rejection are the number of fringe lines visible at the defect ie the more fringe lines present the greater the movement, therefore the more suspect the area. Data interpretation is greatly simplified as few background fringes are present. These are due to the normal stretch of the tyre and the change in the index of refraction when the second exposure is made in a vacuum.

The L-RAY system is unaffected by vibration problems and can be installed right in the tyre production area without any loss of picture quality.

The control console has facilities for the storage of twenty separate tyre testing programs. Within these programs it is

possible to set up five automatic testing positions in each cycle. This is done by setting the camera co-ordinates using the

hand held remote control. It is possible to move the camera unit forward, backward and tilt through to 45 degrees either up or



Examples of deliberately induced anomalies in a tyre.

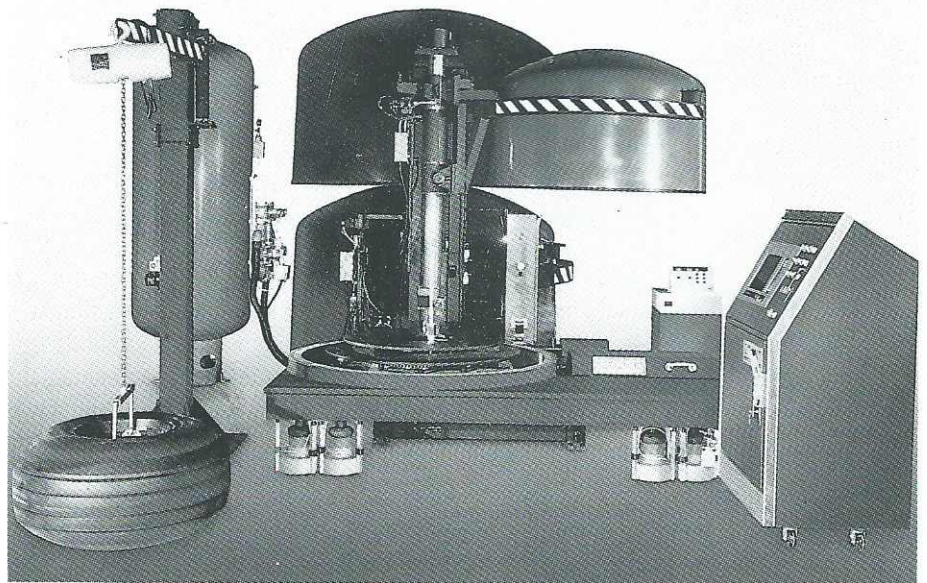


down. The required settings are then transferred into the program memory at the push of a button for instant retrieval when required.

There is no complex setting up procedure needed to supply the laser light to the tyres. The laser will operate at reduced power in an idle mode until full power is required for the exposures. This will help prolong the laser tube life significantly. The beam path requires only three right angle mirrors to transfer the light from laser to camera and is extremely simple to set up.

Using the new machine it is possible to take four pictures, each at approximately 92-95 degrees of the circumference to cover the whole tread area. If testing of the sidewall areas is required the camera can be tilted up or down for examination. A cycle would then be set up to examine these areas in six 65 degree sections. The whole tyre can now be tested from sidewalls to tread in less than three minutes. Interpretation of results has been greatly simplified by the new L-Ray machine. The absence of background fringes has meant that anomalies are easily identified without the need for lengthy operator training.

By building up a data base of results of all tyres tested, it will eventually become possible to predict the maximum retread



Grant Engineering L-Ray System.

life of the casing. It will then be conceivable to replace the expensive and wasteful practice of destructively testing large numbers of tyres by structural examination.

The machine can be used to check the integrity of casings before processing.

However, its main function is as the final quality check on all remould tyres before dispatch, to ensure the customer has confidence in the finished product he receives.



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# Ruslan – The Friendly Giant

by Squadron Leader Phil Coulson, RAF Kinloss



Antonov 124 Ruslan at Pisa. Photographer: Mike Perry

It was a hairy old flyer with a million hours on Beverleys who said of landing that venerable transport "it was like trying to land a 4-bedroom council house whilst looking out of the upstairs toilet window". Future hairy old fliers may reminisce as uncharitably about the view from the massive AN-124 where the crew sit 31 feet agl before they get airborne. Of course, as members of the ex-Soviet republics the Ruslan crews would probably refer to "Kvartira" rather than to a council house, but you get the drift. To assist the pilots in obtaining the optimum lookout, a small prismatic mirror is mounted above the front coaming. Each pilot adjusts his seat until his eyes are reflected in the mirror, and that's it! A suggestion that the mirror is really used for keeping a beady eye on the activities of the 2 flight engineers was firmly rejected!

The fact that an RAF officer can comment at all on the experience of looking out on the world from the flight deck of the AN-124 is remarkable when

one recalls that the aircraft was under constant armed guard during the Paris airshow of 1987. The dramatic dissolution of the Soviet Union and the subsequent necessity to compete effectively in the world market led to the formation, in May 91, of an independent joint stock company, Volga Dnepr, holding its own Air Operator's Certificate.

Based at the Aviation Industrial Complex at Ulyanovsk, Volga Dnepr operates not only a fleet of AN-124s but also Ilyushin Il76 and Antonov AN12 freighters on a network of worldwide operations. Had the company not been formed, explained the UK General Manager for Volga Dnepr, Igor Babenko, some 40,000 people working on the Antonov production line might have lost their jobs. Military spending had ended abruptly and the formation of Volga Dnepr was a lifeline not only for them but also for a further 40,000 or so workers at the engine plant at Zaporozhje in the Ukraine. The new company took its name from the

two great rivers near which the AN-124 Ruslan (Giant) freighters are built.

What Volga Dnepr had in resources it lacked in commercial experience and a partnership with the world's leading outsized cargo market leader, HeavyLift, seemed a natural step. Volga Dnepr gained access to the world market and sorely-needed foreign currency, and HeavyLift gained access to the world's largest freighter aircraft.

In September 91 HeavyLift-Volga Dnepr began operating the Ruslan from Stansted airport where 2 of the aircraft, with crews, are now permanently based. Volga Dnepr operate a further 3 AN-124s and their sixth was rolled out at Ulyanovsk in May 1992. Two of the six aircraft are leased from the military and all are built to the same standard.

The cargo deck of the Ruslan is higher (14.5ft) and wider (21ft) but not as long (118ft) as that of the C-5 Galaxy and is floored entirely with titanium. Although there is a full on-board roller system it is rarely used because pallets cannot be



loaded high enough to use all the available volume. Immobile freight is usually loaded either by forklift or by one of the two twenty-ton combined capacity cranes that travel the length of the cargo deck roof. Large mobile items and cargo on roller pallets can be hauled aboard using either of the large on-board electrical winches and vehicles, of course, can be driven or pushed aboard. The aircraft can be made to 'kneel' to provide a continuous slope and the freight deck floor can be extended by means of a special loading platform so that very heavy immobile loads can be positioned on the platform by crane and then winched aboard. Tremendous versatility and practicality are the hallmarks of the AN-124 and they extend to all aspects of the aircraft's design.

The landing gear is necessarily beefy and there is plenty of it! Five main legs on each side have two wheels apiece with carbon fibre brakes and integral cooling fans, and there are two wheels on each of the two independent nose gear legs. On every main leg there is a hydraulic reservoir and an accumulator that are easily accessible from the cargo deck. Whenever a wheel change is necessary the relevant leg is raised, the wheel changed and the leg lowered once more to the ground. Not all legs are needed for landing and tyre pressure can be altered in flight for paved to unpaved operations. The basic geometry of the gear is fixed, unlike that of the B-52 and C-5 which can be offset for crosswind landings, so drift is kicked off manually for crosswind landings up to the limit of 30kts. The front and rear main legs of the Ruslan are steerable, however, to ease turning circles during taxi.

There are two APUS, mounted one either side aft of the main gear wells. According to Igor Babenko, the air turbine motors that they drive are noisier than the main engines but, again, they are reliable in their provision of electrical, hydraulic and pneumatic air power and can be used in the air or on the ground.

Standing next to the long keel blister that houses the main gear and APU on one side, one looks up a long way to the root of a very clean and efficient wing. Full length leading edge slats and Fowler flaps that would themselves make sizeable wings enhance lift for take off and landing, and 8 spoilers on each wing are used for lift dump. The characteristic Antonov anhedral wings, with their centre section, house in some 20 tanks all the fuel that Ruslan carries – up to 210 tonnes of it (463000 lbs)! Feed to the triple spool engines which can each develop 23.4 tonnes of thrust is from dedicated tanks that are automatically replenished from the centre section out. Typical fuel burn in the cruise with a ZFW of 270 tonnes (594000 lbs) (100 tonnes payload) is about 13 tonnes (28600 lbs) per hour, and the fuel burn in the climb when Ruslan is



lifting her maximum payload is 18 tonnes/hr (39600 lbs) must be astronomical. During one proving sortie the AN-124 lifted 171 tonnes to 35,000 ft, a world record, and broke a further 20 established or available records in the same flight. On another occasion she flew, unrefuelled, for 25 hours and 30 minutes and covered 10,800 nm, impressive performance indeed! For normal operations on a Standard Day Ruslan requires a 10,000 ft runway for a max weight (405 tonnes) take off but can land and stop on only 3,000 ft at its max landing weight of 330 tonnes. The carbon fibre brakes are normally toe-pedal operated but also have a "panic" heel pedal mode for max braking, hence the remarkably short stopping distance, with full flap, spoiler and reverse thrust. Take off and approach speeds fall into the

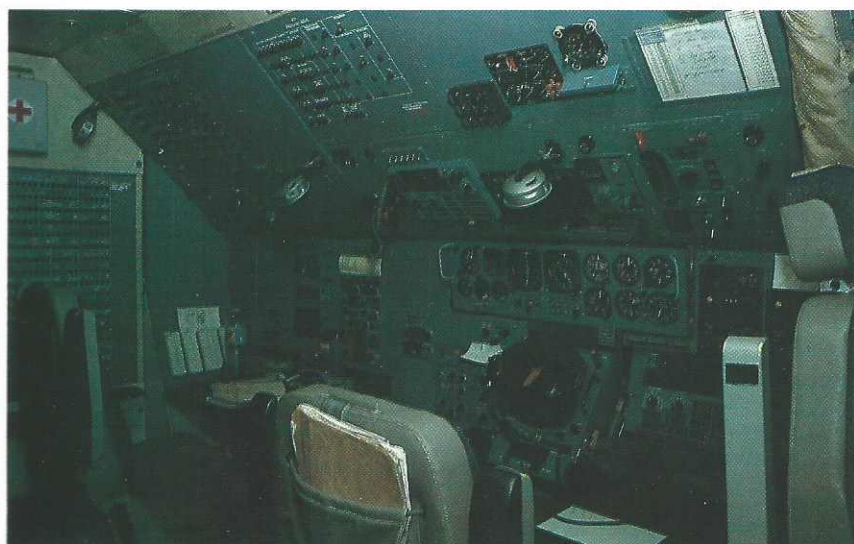
typical multi-engine jet range with a rotate speed of about 150kts at max weight, and typical approach speed of 145 kts. When conditions allow, factored thrust is used for take off.

From the crew entrance door with its built-in access ladder, one turns left to the ladder that rises from the cargo deck to the flight deck. Arrival at that level presents a choice of turning left onto the flight deck itself or right into an access corridor that leads to equipment crates, a galley, two 3-berth bunk compartments and a toilet compartment. Standing at the entrance door to the flight deck, one is about 10 ft aft of the front panel. The immediate impression is one of neat, pleasantly-presented ergonomic design, an impression endorsed by the crews who use it. Ruslan has a 6-man flight crew of 2 pilots, 2 flight engineers, a navigator



Loading one of three 33 tonne excavators for a flight from Stansted to Kuwait. Photographer: Mike Perry







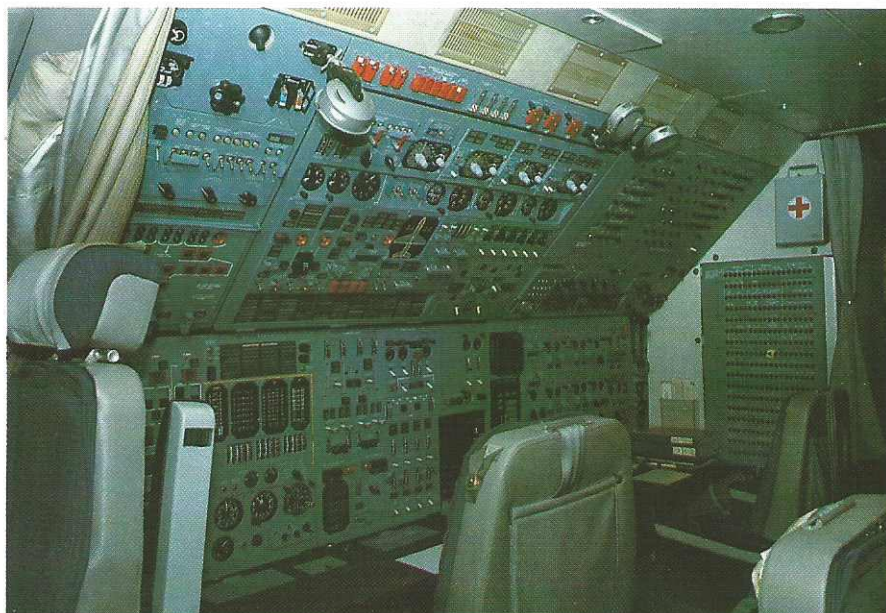


Photographer: Peter Rooley



and a radio operator. Each of the crew speaks "air traffic English" but the radio operator is the main linguist. Had the AN-124 been designed purely for civil commercial operation it would probably have had a 3-man flight deck and, apparently, individual workload for the Volga Dnepr crews is not high. As well as having the MKI self-loading nav, Ruslan has triple INS, dual Omega, Loran, a full suite of radio nav aids and an automatic astro-nav facility which, once locked on to the sun by day, a particular star by night, or a satellite at any time, will happily auto-track it to provide fixes of high accuracy.

The division of labour on the engineers' panel is not completely straightforward. The majority of the job lies with the chief engineer at the front end of the panel whose responsibilities are those common to all 3-crew operation. The second engineer deals mainly with ground related matters such as the APU's, winch power, electrics, hydraulics and cooling. In the air both engineers operate pressurisation and conditioning packs, of which there are four. The flight deck level including the bunks, galley etc stretches as far back as the front spar of the wing centre section and is separately pressurised. The ground servicing crew accommodation, with a max seating capacity of 88 seats, is also above the cargo deck and runs from the rear of the wing centre section to the base of the fin. It too is separately pressurised. Both crew compartments have typical pressurisation settings resulting in a cabin altitude of about 5000', and differential pressure of 8 psi, at a cruising level of FL330. The cargo deck is pressurised as required by the nature of the cargo. The bleed air required to fully pressurise such a cavernous hold degrades performance so, for inanimate freight, a cargo deck altitude of around 18,000 feet is typical. One recent sortie that required max diff on the cargo deck took a large herd of pigs to the US (having recently been on a Nimrod detachment to Florida I know the feeling!) and livestock



Flight Deck – looking aft

normally require more environmental consideration than do people. The fourth pressurization controller is a standby system for the flight deck should the primary controller fail.

The management of all the aircraft systems is aided by a comprehensive computer display at the bottom centre of the engineers' panel. All the data that traditionally was displayed on myriad gauges and dials can now be called up as required. Data vital to flight safety is still permanently displayed on the panel and the blend of traditional and new technology seems to be logical and well thought out.

Looking forward, the instrument panel has all the conventional flight instruments and, on the roof panels, the usual array of comms and radio nav aids. The centre panel is dominated by a radar screen and a moving map display, above which sit the EPR gauges which are the only engine instruments on the panel. The moving map display is not used but the radar

display is extremely useful. Ruslan has two nose-mounted radars, both built to military specifications. The upper system provides the usual "cloud and clonk" facility and the lower system has sufficient power and definition to provide ground mapping and navigation. The display is good enough for the crews to self-position for touchdown in murky conditions or at airstrips that have no approach facilities. By progressively reducing the range of the radar down to 2.5 nm, a nice fat runway is clearly depicted on the radar screen for the latter stages of an approach. The control yokes, fully forward on the ground with the artificial feel systems off, connect to a quadruple fly-by-wire flying control system that has appropriately massive redundancy. Each flying control surface is independently powered and not physically connected to its corresponding surface. Furthermore, each flying control is actually two surfaces so that damage or malfunction does not incapacitate a complete elevator or aileron. Quadruple electro-hydraulic PFCUs drive each moving surface even though one is sufficient for the task. Ruslan will meet a safe standard of control with only one aileron and one elevator in action, and a fifth channel for emergency use that provides mechanical linkage to hydraulic servos adds to the remarkable system redundancy possessed by the AN-124.

Ruslan's military lineage provides overkill for the requirements of an outsized civil freighter, but will help to ensure that any task she tackles will be met with safety, strength and versatility. A friendly giant indeed.

*The Editor is extremely grateful to HeavyLift-Volga Dnepr and, in particular, to Igor Babenko, Capt Kevin Keegan and Peter Rooley for their help and patience in the preparation of this article.*



Antonov 124 – Cargo Hold. Photographer: Kevin Keegan

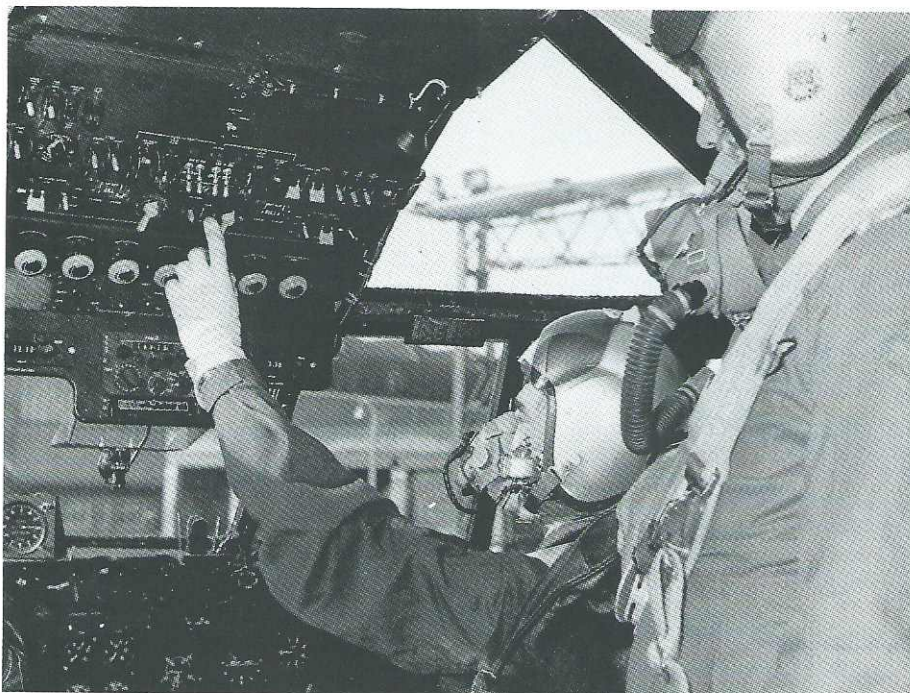


capacity of a co-pilot. Thus Bomber Command severed its final links with its protégé, the air engineer, abdicating responsibility for the branch to Transport and Coastal Commands.

## FEAST AND FAMINE

What followed can only be described as a period of crisis management. The re-equipment of Bomber Command made redundant a number of signallers, air engineers and air gunners. Surpluses became so large that, in 1958, a redundancy scheme was introduced to reduce the backlog. In the meantime, the aircraft industry had firmly embraced the idea of a third flight deck crew member. The Comet came into service with what was to become the standard flight deck configuration with a sideways facing flight engineer's panel on the right hand side, immediately behind the co-pilot. This was a concept perpetuated through the Boeing 707 and its derivatives, the VC10 and numerous other types including Concorde. The Beverley, the antithesis of the graceful Comet, entered service designed for 2-pilot operation. Following an accident in the first year of service and a need to quench the 4x18 cylinder Bristol Centaurus engines' insatiable thirst for oil, the crews which had initially only been augmented on long routes received a permanent air engineer. The highly successful and much loved whispering giant, the Britannia, was also on the horizon. With its innovative and highly complex all-electric flight deck, a skilled specialist was an essential and integral part of the crew. The increasing demand for the air engineer specialization was anticipated by the user Commands but their advice fell on deaf ears. The 1958 redundancy scheme was so successful that, within a year, manning levels of air signallers and air engineers were reduced from surplus to a position of critical shortage.

With no ab-initio training facilities in existence a contingency solution to the crisis had to be found. Ground tradesmen whose records showed a high degree of flexibility and adaptability were carefully selected for direct training by the Operational Conversion Units (OCU). Resources of time, facilities and staff were limited, however, and with the need for a considerable amount of one-to-one tuition, output capacity was severely restricted. The graduates of this scheme were satisfactory but, because of their limited experience and restricted training, they were considered suitable only for employment on the older, more simple aircraft. The arrangement was clearly unsatisfactory as a long term solution. There was a need to be able to cope with a greatly increased throughput and the difficulties experienced by those on the direct scheme clearly demonstrated the need for teaching fundamental airmanship and crew co-operation at an



Flying training on the Vickers Varsity, RAF Topcliffe

early stage. In other words, it was highly desirable that ab-initio flying training be re-introduced as soon as possible. The creation of a staff engineer post at Transport Command headquarters in 1958 finally gave the air engineer a voice at higher levels and direct communication with Air Ministry. The early incumbents of the post, Flt Lt Allan Mundy followed by Flt Lt Dave Nelson, supported by Flt Lt Ken Owen of No 242 OCU, mounted a vigorous campaign. Liaising closely with their opposite numbers on Coastal Command, a joint policy was formulated and presented to the Ministry. Authorization to recommence basic training was quickly given but as the school at St Athan had now been closed for some 9 years no facilities or training resources existed. The need was immediate and, once again, a stop-gap measure had to be found. The best on offer was the V-bomber crew chief course. Run at RAF Weeton and RAF Melksham, and lasting 8 months, the course aimed to provide in-depth theoretical training in the 4 basic aircraft trades: airframes, engines, electrics and instruments. The technical syllabus was more than adequate but the instructors were ground tradesmen who had no concept of the terms of reference of the air engineer. Not only that, the course also did not fulfil the prime requirement of providing basic flying training. Thus the problem of identifying at an early stage of training students who were unsuitable for flying duties remained unresolved. The second disadvantage of the lack of flying training was that flying brevets could not be awarded until OCU training had been completed. This far from ideal solution, however, provided a basis on which to

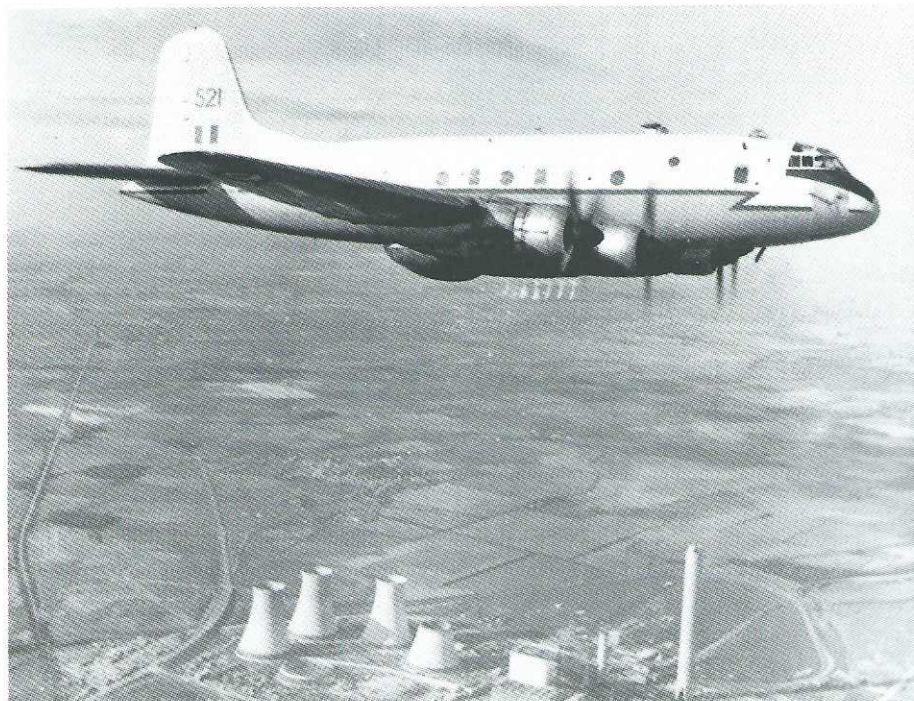
build and, as such, represented the beginning of a new era for the air engineer branch.

Recruitment commenced in 1959 and was aimed at Senior Technicians (roughly equivalent to Sergeants) of the airframe and engine specializations. Response, however, was poor with only 6 applicants for the first 30 places available. This should have come as no surprise because terms of service remained unchanged. In return for over a year of intensive training, all that was on offer was 5 years flying with marginal extra remuneration followed by a return to a ground trade to face the problems of re-integration and regaining ground lost against peers in the promotion stakes. No 1 course was postponed and the immediate vacancies in the branch were filled by directly assimilating a limited number of crew chiefs. Terms of service were quickly re-written. The length of aircrew engagement was extended to 6 years, still with the prospect of returning to ground trade, and the field of recruitment was widened to Cpl/Cpl Tech with a minimum of 4 years experience in one of the 4 primary aircraft trades. The prospect of quick promotion and enhanced remuneration boosted by flying pay proved to be the cherry that was needed. No 1 course commenced late in 1960 with further courses being input at 3-monthly intervals.

## MORE NEW TYPES

At about this time a completely new requirement appeared. As carrying capacity increased, the helicopter was introduced in an infantry support role. As such, a rear cabin crewman was required to supervise the on and off load of soldiers





**A Hastings Mk5 of the Radar Bombing School, RAF Lindholme**

and generally be responsible for operations behind the flight deck wall. The newly introduced air quartermaster specialization was well suited to the job but, as yet, insufficient numbers were available. Air engineers were seen as a suitable alternative. Because air engineers could not become fully qualified aircrew until they had completed operational conversion, students were required to complete training on an operational type (Beverley or Hastings usually) to qualify for their brevet before being posted to Wessex or Belvedere helicopters.

More new types began to appear. The Argosy entered service and the Belfast and Hercules were just around the corner. 1963 saw another landmark when Transport Command finally won a long-running battle and permanent re-mustering was introduced by AMO A147/63. Trained air engineers who had returned to their ground trades were invited back and, in 1964, training input was doubled to a course every 6 weeks. As is often the case with any major revision of terms of service, a number of anomalies occurred. While many gained advantage from the new regulations, others were disadvantaged. By and large, however, most irregularities were quickly resolved and, as far as is known, no air engineer returned to a ground trade after 1966. Ground training using Technical Training Command facilities continued until 1967, with the only significant event during the period being the closure of Weeton and Melksham which moved training to RAF St Athan and RAF Newton. The scheme produced students who possessed a consistently high level of technical knowledge but it had the

disadvantage that unacceptably high numbers failed at the OCU stage, largely because of a lack of practical aptitude in the air.

As early as 1963 Flt Lt Ken Owen had pointed out to the Transport Command staff engineer, Flt Lt Dave Nelson, that the wastage rate at a late stage in conversion training was unacceptably high. Basic weaknesses such as persistent air sickness, lack of mental agility under pressure and poor general awareness were not being discovered until more than a year had been spent in training. The situation was unacceptable both from a Service point of view, in that considerable valuable resources were being wasted, and from the individual's point of view in the amount of time and effort wasted pursuing a goal which was unattainable because of a basic lack of aptitude in the air. The pending introduction of 3 more advanced types, the Belfast, Hercules and VC10, planned for 1967, also added weight to the case for specialist aircrew training for the air engineer.

### **AIR ENGINEER SQN FORMED**

Other events which took place in the 60s eventually helped the branch out of its difficulties. Air signaller training recommenced in 1960 after a gap of only 3 years. An expansion of facilities which already existed at RAF Hullavington, where Air Electronics Officers were being trained, was all that was needed. In 1962 the Air Electronics School moved to RAF Topcliffe in Yorkshire. A rationalization of the air signaller, air electronics operator and air electronics officer specializations in 1966 made accommodation and facilities available, presenting the

opportunity to establish an Air Engineer School using conjoint flying training resources. The ground work of a suitable training syllabus had already been completed by a course design team headed by Ken Owen in the early 60s. The proposed course, lasting 52 weeks, included general service and leadership training to prepare students for SNCO rank. The professional course consisted of a thorough grounding in all technical subjects, airmanship instruction and flying training on specially modified aircraft. Aircraft considered were the Hawker Siddeley Dominie modified to incorporate a sideways facing air engineers panel, and the Armstrong Whitworth Argosy with duplicated instrumentation in the freight bay giving a flying classroom facility. On 30 January 1967 Sqn Ldr Ken Owen, tasked with implementing his plans, was named as the first commanding officer of the new Air Engineer Squadron and, on 13 March 1967, the first air engineer course (numbered No 5 course to tie it in with the new conjoint AEOP course, No 1 of which had started training the previous year) commenced training. The syllabus closely followed the proposed format. The year-long course started with 6 weeks of General Service Training which was designed along the lines of the proven Initial Officer Training Course. This was followed by a short course of mathematics and physics aimed to establish a common academic standard. Professional training consisted of in-depth studies of all aircraft systems followed by dedicated flying training. With the exception of the basic academic phase, the student was taught throughout by experienced air engineers, thereby ensuring that the principles of airmanship and airborne operations became an integral part of the instruction from the earliest stages. The only departure from Ken Owen's original plan was in flying training. Financial constraints made the cost of using specially modified aircraft prohibitive. The task was assigned to the ubiquitous Vickers Varsity. Unpressurized and powered by Bristol Hercules radial, air-cooled piston engines, it was far from the ideal vehicle but it was already being used by the air electronics operators. Thus the concept of conjoint flying training was born. Flying in the right-hand pilot's seat, the student was introduced to the principles of airmanship and crew co-operation. He was taught basic flying skills, systems handling, fault diagnosis, engine handling and radio procedures. Results were startling. The OCU failure rate which had been the catalyst for the re-introduction of basic training fell to a negligible level very quickly.

### **GRADUATION**

The re-introduction of flying training presented the opportunity to resolve other anachronisms. A flying brevet cannot be awarded until basic flying training has

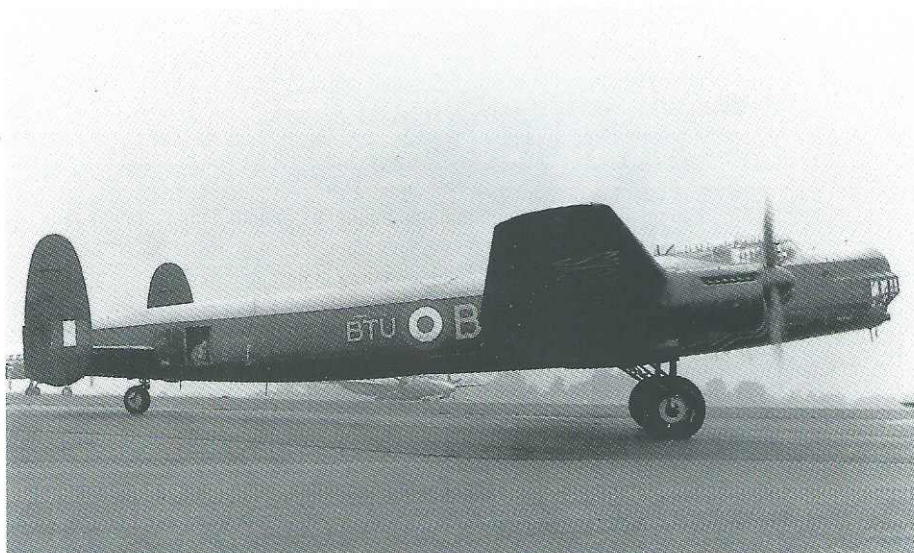


been successfully completed. Unlike other aircrew specializations, this qualification had not been satisfied in the air engineer's case until after operational conversion ever since training ceased at St Athan in 1951. Now, at last, students were able to celebrate their success by taking part in a formal graduation parade and having their brevets awarded by an air rank officer. The usual culmination of these occasions was a flypast by a diamond 4 formation of Varsitys.

### A COMMON STANDARD

The other thorn remaining in the side of the branch was its acrimonious division into Air Eng(A)s and Air Engs, colloquially known as Air Eng (B)s. Although initial recruitment to the new course was restricted to serving aircraft trade technicians, this limitation was quickly lifted. Eligibility was extended to all, including direct entrants, who held 3 suitable GCE 'O' levels and were medically fit for aircrew duty. The decision that all would graduate as Air Eng(A), irrespective of background qualifications, finally forced the issue of agreeing a solution to what was seen as the division of the branch into first and second class citizens.

Many ex-WW II air engineers and those who had completed the St Athan All Through Course were being paid on a lower basic pay scale than the graduates of the new course. Discussions had been taking place between the Transport Command Staff Engineer and MoD since 1963 without agreement being reached. Basically, the gnomes holding the purse strings refused to sanction what amounted to a pay rise for half of the branch without a demonstration of equal technical expertise. As those affected were highly experienced and, in many cases, the senior members of the branch,

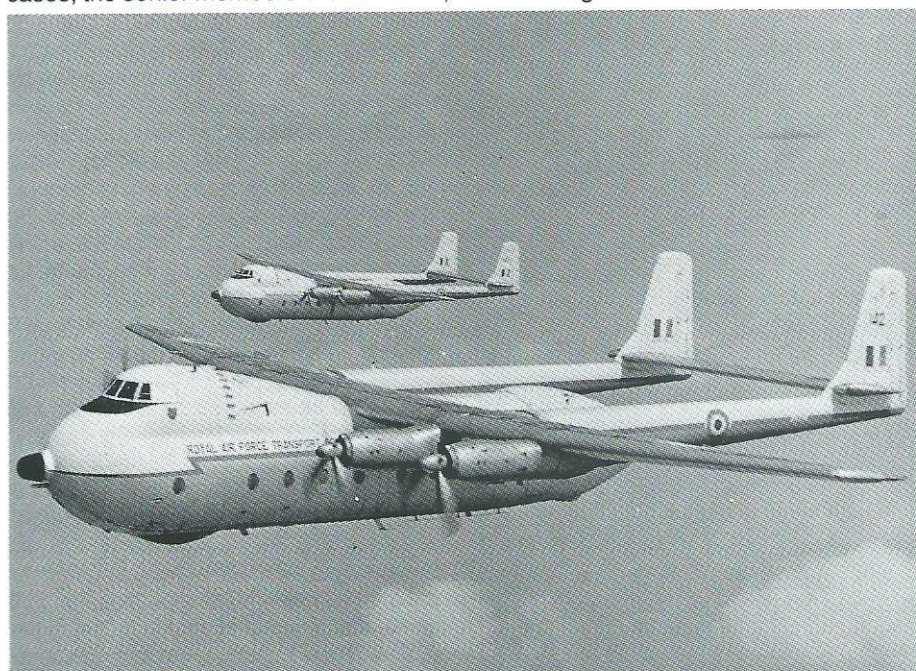


Avro Lincoln SX930 at Bovingdon 7 Oct 1957

this idea was not favourably received as it amounted to questioning their professional standards. Various options were considered including a written examination or the completion of a 2-month fitters course in one of the basic aircraft trades – a completely superfluous qualification. The situation rumbled on without solution until 1968 when agreement was reached that all Air Eng(B)s would sit a single written examination in order to be recognised for the higher qualification. The exam set was by no means a formality, but most sat it and passed without a great deal of complaint. Some held out for a while before submitting grudgingly, and the final few needed gentle, purposeful persuasion. Eventually, the invidious two tier system which had lasted for 18 years was brought to an end.

### THE MOVE TO FINNINGLEY

In September 1973, as part of a policy to centralize all non-pilot flying training, RAF Topcliffe closed and the Air Engineer and Air Electronics School moved to RAF Finningley. Initially training was established alongside, but independent from, the existing navigator school. Plans were afoot, however, to combine all flying training at RAF Finningley using a single aircraft type. The airframe selected was the Argosy modified to become a flying classroom, the scheme originally envisaged by Ken Owen in the early 60s. The procurement of a specially fitted Argosy, however, never happened. A single aircraft was seen around RAF Finningley for a while, but its purpose was cloaked in secrecy. Eventually, the project was scrapped in favour of conjoint flying using the Hawker Siddeley Dominie.



Argosy Aircraft of 115 Sqn, 1974

### FIGHTING FOR RESOURCES

The Dominie option fell well short of the flying training envisaged in the original course design. The aircraft had advantages over the Varsity in that it was jet-engined and pressurized, but the proposal to modify the flight deck to incorporate a sideways facing panel was a non-starter. Students would occupy the right-hand pilot's seat and operate as pilot's assistants. Not only that, the aircraft were funded for navigator training and, as such, the navigator school determined the sortie profiles and the availability of the right-hand seat, their own syllabus frequently reserving its use. The case for an adequate allocation of flying hours with a suitable exercise content for air engineer training was fought long and hard but it was a losing battle. At the end of the day only 20 hours per student were authorized, an amount considered inadequate to achieve a satisfactory graduation standard. This



limitation catalysed a radical re-think of the course design. The Argosy simulator was still operational at RAF Benson and, with the run down of No 115 Sqn, was available for use. As the flying available fell short of what was required it was decided that the accepted convention would be reversed. Flying training would precede simulator training, and the final simulator exercises would be deemed the graduation standard. Thus was born the 4-phase course format which continues today: basic academic and systems instruction; flying training; advanced systems instruction; simulator training. In the preceding article, Eric Myall described the resourcefulness of the St Athan instructors in designing and producing a number of flight deck simulators in the 1940s, some of which were extremely sophisticated and, historically, the forerunners of today's flight simulation industry. The tradition for self-sufficiency did not end there, however. In the 1960s, instructors at the Maritime OCU, No 236 at RAF Kinloss, designed and constructed a Shackleton air engineer's station with fully active instrumentation and an instructor's panel which allowed fault simulation. When the Nimrod replaced the Shackleton, a replacement "Bamboo Bomber", as these rigs became known, was a top priority and, again, self-help provided the answer. There were others also. A VC10 panel was produced by No 241 OCU at RAF Brize Norton, while at RAF Topcliffe in 1973 the instructors produced a complete, open plan mock-up of the Argosy flight deck. The art reached its zenith in the early 1980s when 2 flight deck trainers, a Dominie and an Argosy, were built by the staff at RAF Finningley.

### THE DOMINIE TRAINER

The need for the Dominie trainer was brought about by the lack of aircraft for ground instruction because of the intensive nature of the conjoint flying programme. Unlike most previous cases, there were no broken aircraft or redundant spares to work with. A fibre glass Dominie nose section was fabricated in station workshops and then the basic shell was fitted out by instructors from the school. The need for a useable trainer was urgent and, with limited resources, MEng Rick Williams initially produced hand drawn panels with dummy instruments fitted with manually positioned pointers. A throttle box as well as flap and undercarriage levers were hand manufactured and, as they became available, various switches and instruments were fitted to replace facsimiles. FS Chris Baker supervised the final stages which included wiring up and fitting an instructor's control panel. This excellent trainer is still used today.

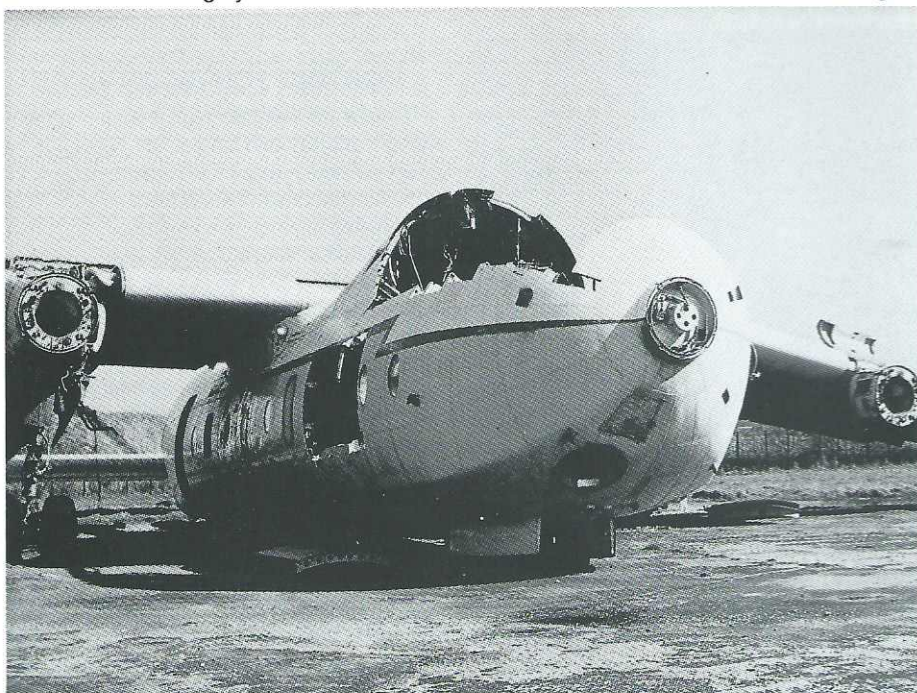
### THE ARGOSY TRAINER

The second project, the Argosy Flight Deck Trainer, was even more ambitious. When the Air Engineer Squadron inherited the venerable Argosy simulator at RAF Benson it had already achieved its service life expectancy. An engineering survey, however, indicated that with careful use a further 5 to 10 years and some 5000 operating hours might be squeezed out of it. The planned student intake was 4 every 16 weeks, a throughput that made the use of the simulator a reasonable prospect for a considerable time to come. What was not foreseen was the rapid expansion of civilian airlines that took place during the mid to late 1970s. The prospect of a lucrative second career encouraged

considerable numbers of serving air engineers to exercise their option to leave the Service. Suddenly, from a situation where the school was barely ticking over, the intake was increased to between 10 and 12 students every 8 weeks. At this pace the extended working life of the simulator was quickly going to run out. In 1978 a second blow was struck against the training facilities. A redundant Argosy aircraft, maintained in a ground training role and used for pre-flight inspections and engine ground runs, was declared electrically unsafe by the ground engineering authorities and condemned. Potentially, this action was going to throw an even greater load onto the Benson simulator. In the long term, the answer was to bid for a new simulator with complete training support facilities. The immediate problem, however, demanded novel and innovative thinking. Fortunately, at that time, there was one instructor in the school who had the vision and inventive expertise to conceive a bold and far-reaching solution. MEng Tony Bateson approached the then commanding officer, Sqn Ldr Denis Crowson, with the promise that if he could arrange for the flight deck wedge to be cut from the top of the scrap Argosy fuselage and moved into the school demonstration hall, he would construct a functional Argosy Flight Deck Trainer.

### THE "BATESON SIM"

Understandably, this audaciously ambitious project was looked upon with some scepticism by authorities outside of the branch but, nevertheless, approval was given. The piece of scrap-yard junk was duly delivered to the school. Using analogue techniques, Tony Bateson modified instruments and designed circuits which, with the exception of the flight instrument system, brought the whole cockpit to life, including realistic engine noise. Aided by 2<sup>nd</sup> corporal electricians the project which had been estimated as a year's work was completed in 9 months. The results were outstanding. So faithfully did the Trainer reproduce the Argosy that, in addition to pre-flight checks and engine running procedures, it was possible to transfer the first 3 exercises from the Benson simulator to the new Finningley based trainer. By easing the critical work load it was possible to extend the working life of the Benson simulator until 1984, by which time it had been in use for 22 years and accumulated well over 65000 running hours. MEng Bateson's magnificent achievement was to be the last in the long line of cockpit trainers built by the branch. The advent of the Health and Safety at Work Act and the implementation of stringent safety regulations, together with the rapid advance of digital technology, made such projects no longer practical or allowable. In modern times, all such training aids must be procured from



The Argosy from which the Bateson Sim was cut.



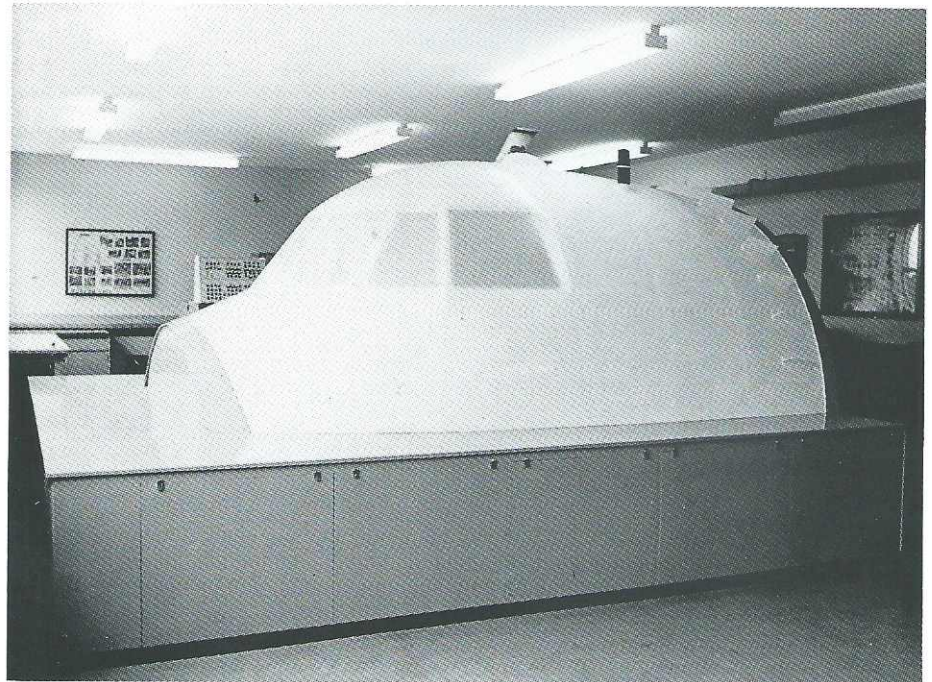
industry at great expense. Fittingly, as a lasting tribute not only to Tony Bateson's ingenuity but also to those who have been involved in similar projects over the years, the Argosy Flight Deck Trainer is now exhibited at the Newark Air Museum.

### AEPT

Once the immediate crisis was solved, work to define a suitable replacement training platform was begun. In order to establish syllabus credibility, training needed to be based around in-service technology. However, because the school's remit was for broadbased training in preparation for entry into a variety of OCUs, it was considered undesirable to concentrate teaching around a single in-service type. The ideal answer was to develop a generic 4-engined jet trainer supported by a suitable inventory of training aids. Outline approval was given by the command authorities with the proviso that, to reduce costs, use was to be made of Service owned equipment wherever possible. A redundant Nimrod Mk 1 air engineer station was available, thus dictating that the new system would be designed about it. Once again, this time working in close liaison with civilian industry, MEng Tony Bateson went to work. Rediffusion built a fixed-base simulator, with a dynamic colour visual system, around the Nimrod panel and incorporated a unique feature – the flight deck was designed to split along its centre-line and hinge open, thereby fulfilling a secondary role as a classroom training aid. As the policy was to train students for entry to a range of OCUs, the new trainer was named the Air Engineer Procedure Trainer (AEPT) in order to give it an individual identity separate from the Nimrod. A series of computer controlled systems training panels were designed and built by Pennant. In addition to a dynamic schematic display, each trainer incorporated the relevant cockpit control panel allowing operating procedures and fault diagnosis to be taught and practised independent of the simulator. With the training syllabus re-written and updated, the revised course was introduced in July 1984. In use today and for the foreseeable future, this training system has proved most successful as, nowadays, failure at operational training units is almost unknown.

### FUTURE PROSPECTS

The air engineer branch today consists of some 287 SNCOs and Master Aircrew, and about 56 Officers. The introduction in recent years of the Tristar, VC10 tanker aircraft and the E3A Sentry makes the immediate future look fairly prosperous. In the long term, however, a reducing requirement for the services of the air engineer is evident. Hercules and Nimrod are due to be replaced at about the turn of the century and, with the "glass cockpit"



External view of 'The Bateson Sim', the Argosy Procedures Trainer

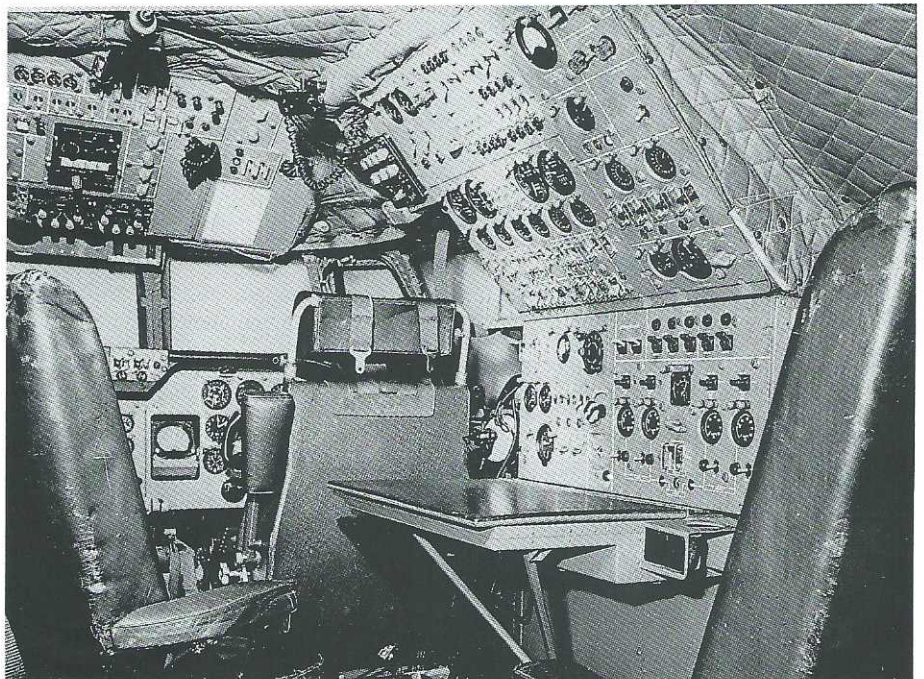
becoming a firmly established concept, the introduction of types with a 2-man flight deck is a strong possibility. The position of the flight engineer in civilian aviation has already begun to erode with the introduction of the 747-400 series and others. Arguments still rage about costs versus safety and the interface between human reactions and a computer but, undoubtedly, in the end it will be the financiers who win.

### 50 YEARS ON

That is the future! Last year the air engineer branch proudly celebrated its 50th birthday. Unbelievably, particularly in the light of the period in the 1950s when

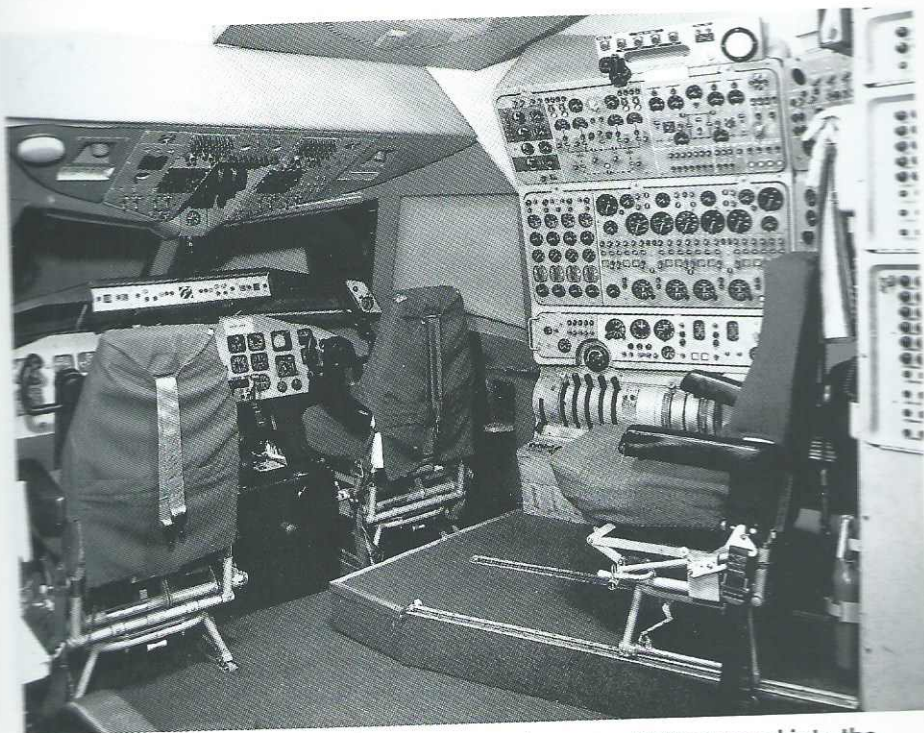
the branch languished in the doldrums, 1992 marks the 25th anniversary of the air engineer training squadron. Since its establishment in 1967, some 900 air engineers have been trained by the school, many of whom form the core of the specialization in civilian aviation today. While the number pales into insignificance against the 22,599 trained at St Athan between 1941 and 1951, it is an achievement with which all those associated with the squadron over the years can be justifiably pleased.

As time goes on, some things change while others remain the same. The branch is now open to serving airwomen and the first 2 female air engineers have recently



Internal view of the Argosy Procedures Trainer, 6FTS





The Air Engineer Procedure Trainer – shown partially opened into the classroom mode

commenced their Hercules OCU training. The first DE female air engineer has started her basic training at 6FTS. In addition, air engineers still fly on the Lancaster. Instructors from Air Engineer Squadron are selected to crew City of Lincoln, the Battle of Britain Memorial Flight Lancaster. At any one time, 3 air engineers share the display duties, each man normally completing 2 display seasons. Understandably, there is great competition for this highly prestigious and much sought-after duty.

The 'E' brevet lives on in both historic and modern aircraft – and long may it continue to do so!

#### Acknowledgements

I am indebted to Flt Lt Derek Stringman(deceased), on whose book "The History of the Air Engineer" this article is based. My thanks also to MEng Tony Bateson (retired) for providing photographs of the Argosy Flight Deck Trainer.

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## TECHNICAL TALK

# PROPULSION CONTROL A Changing Scene

by Mike Joby, Manager – Advanced Controls  
Lucas Aerospace Ltd, Electronic Systems, Birmingham

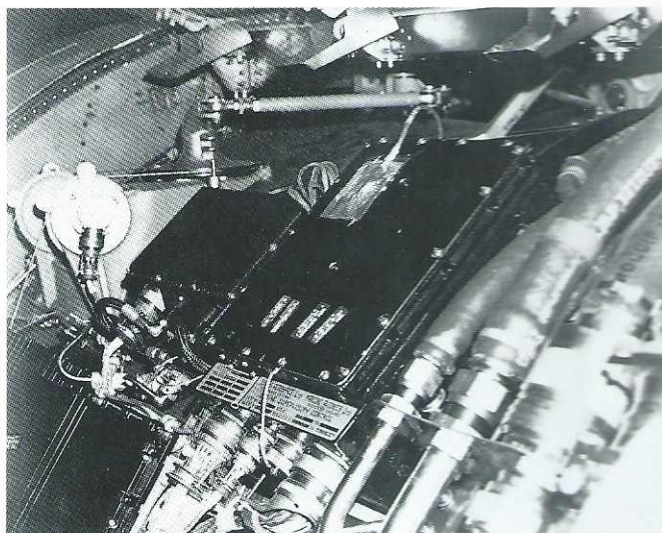
### PERSPECTIVE

The history of control systems for gas turbine engines goes back over 50 years, to the pioneering work of von Ohain in Germany, and Whittle in the UK. The first systems developed for these early engines in the 1940's were purely hydromechanical, and relatively simple. The efforts of the engine designers however, to increase thrust and improve efficiency, while allowing the aeroplane to operate over an ever wider flight envelope, led to a progressive growth in control system requirements through the late forties and fifties.

Engine developments such as twin-spool configurations, variable geometry compressors and modulated reheat, were placing increasing demands on hydromechanical systems. New solutions were needed, capable of providing a wider range of control functions, and at the same time allowing the hydromechanical systems to be progressively simplified. The availability of transistors provided the key to managing this problem, and opened the way to rapid advances in control technology and capability.

### ANALOGUE CONTROLS

The 1960's saw the development of complex, full-authority, analogue electronic controls. Without these advancements it is probable that Concorde could not have been developed into a practical, operational aircraft. Yet even as these new technologies were being exploited, their potential shortcomings were also becoming apparent. In particular their dependence on hardware to define the control function, to provide adjustment capability, to monitor the system and even anticipate future requirements, was a significant constraint. In fairness, modification was much easier than on hydromechanical systems, but nevertheless still a significant overhead in the development process.



### DIGITAL CONTROLS

In 1965 the first digital control evaluation tests were carried out in the UK by Bristol Siddeley Engines on their BLADE rig. This facility provided a core engine, which was used primarily for turbine blade evaluation. These tests were followed over the next 10 years by the development of increasingly practical equipment, culminating in the flight trial of a Lucas Aerospace Full Authority Digital Engine Control (FADEC) on Concorde in 1976. The development of this control involved the solution of a number of critical technology issues. A complete flightworthy hardware package, including a powerful digital computer specially developed by Sanders Associates, was designed and flight cleared for the programme.

At that time Engine Designers regarded electronics as being more suitable for wireless sets rather than flight critical control system components. The reliability and failure modes of electronic systems were regarded with suspicion; electronic components most frequently fail catastrophically in contrast with hydromechanical systems, which exhibit wear-out. This difference demanded a system design approach, which addressed the failure modes and effects within the electronic control. Thus a twin-channel redundant architecture was employed, similar in its basic concept to the analogue system already used on the

Olympus 593 engines fitted to Concorde. A software system, with sufficient design visibility for flight clearance purposes, was developed; an innovative safety scheme, involving both hardware and software, was implemented. The system underwent a successful 50 hour flight test programme, demonstrating conclusively the viability of the FADEC concept.

Since the mid-1970's twin-channel digital controls have moved from the demonstrator phase to production on a wide range of civil and military aircraft. Applications include:

Turbo Union RB189  
Pratt and Whitney 2037  
Rolls-Royce Pegasus 11  
Pratt and Whitney 4000  
CFM International CFM-56  
GE CF6-80C  
IAE V2500  
Rolls-Royce RB211-524H

The list is by no means exhaustive, but serves to show the concentration of such technology on the larger, more complex engines. Where smaller engines have exploited digital control technology, there has been a tendency, up to the present time, to adopt limited-authority Supervisory Control or single-channel FADEC solutions with hydromechanical back-up. This situation is now changing. Systems for Regional, Executive and Commuter aircraft are adopting twin-channel architecture, as this ensures the greatest compatibility with modern fly-by-wire, glass cockpit aircraft.

### TODAY'S SYSTEMS

The most complex FADEC systems in service today are those used on large civil transport aircraft. The electronic controllers are engine mounted (see photographs), and are designed to meet the highest levels of safety and reliability, in the severe operating environment of the engine fan case. A typical Propulsion Management System comprises the following principal elements:

- Flight Management Computer



- Autothrottle
- Engine Indicating and Crew Alerting System
- Full Authority Digital Engine Control

Communication between the FADEC and the airframe systems is via serial digital highways. Engine thrust may be set automatically through the Flight Management Computers, or manually by the pilot. The twin-channel FADEC configuration lends itself to the use of dual-redundant serial digital data links, allowing a much more efficient transfer of pilot command, engine parameter display and maintenance information. Redundancy is necessary to ensure that the probability of loss of any particular parameter, in this scheme, is no greater than with hard-wired instruments and controls. It also ensures that no single failure in the FADEC or its data links will cause loss of function, so that the aircrew cockpit operations remain unaltered. This is a major benefit in the two man cockpit, minimising the failure management task.

## SAFETY AND RELIABILITY

In the design of a FADEC system, safety and reliability are of paramount importance. In particular, for a large civil transport, the engine control must be compatible with the following:

- Life – 100 000 operating hours
- Operation – 5000 hours/annum
- Probability of failure leading to In-Flight Shut-down –  $<10^{-5}$  per hour
- Probability of uncontrolled parameter exceedance –  $<10^{-9}$  per hour
- Probability of common mode failure affecting more than one engine –  $<10^{-9}$  per hour

The reliability and operating life of control system components has improved over the years under the influence of the twin imperatives, safety and the marketplace. For a twin-engined civil transport with medium/long range capability, it is essential to achieve ETOPS (Extended Range Twin Operations) clearance as soon as possible after entry into service. This currently requires the engine control system to equal or better the In-Flight Shutdown rate given above for a period of operation defined by the Regulatory Authorities. This will be typically 12 months for 120 minute clearance. Clearly the acquisition of ETOPS rating is of the greatest importance to the Airline Operator. Indeed, airframe manufacturers are seeking ways in which sufficient reliability 'credits' can be obtained during development to allow ETOPS to be granted on entry into service. This can only occur if there is the highest confidence in the reliability of the control system and engine components.

## System Architecture

The system architecture is normally based around a twin-channel electronic controller, with independent overspeed protection, as shown in fig 1. The fuel control system comprises an engine-driven fuel pump, compressor guidevane actuation system, a main fuel metering valve and a separate overspeed control valve. Such an arrangement is necessary to meet the stringent overspeed protection requirement. Power is derived from a dedicated permanent magnet alternator, which enables engine starts, even when there is no aircraft power available, and gives an interrupt-free source of electrical power for the propulsion system.

Fig 2 shows the main electronic control architecture as currently applied in a number of Lucas Aerospace FADEC systems. The control comprises two essentially identical, self-monitored channels. Each channel receives a complete set of command signals and engine parameters, and is capable of controlling the engine in its own right. Inter-channel data links provide the computer in each lane with access to the other lane's signal inputs and outputs. By this means the lane in control can tolerate any combination of single input/output faults without loss of function.

The twin-channel configuration, now being used on many engine controls, has been adopted as it represents the most cost-effective way of achieving the operational reliability levels required for aircraft certification. A triplex-redundant solution would involve significant system cost and weight penalties. Broadly similar architectural features are shared by all the systems now in service.

## FUNCTIONS AND FEATURES

FADEC systems are required to interface with a larger number and variety of sensor inputs than other control systems on the aircraft. By way of example, on one current large engine system, the FADEC accommodates more than 120 individual signals. These include

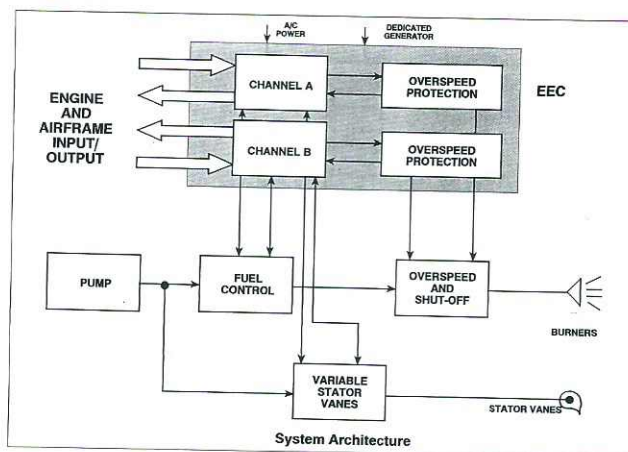


Fig 1.

not only the speed, temperature, pressure and position sensors on the engine, but the thrust control levers (to control forward and reverse thrust), and the serial data links to the Integrated Display System, the Air Data Computers, the Flight Management Computer (via the Autothrottle System), the Central Maintenance Computer and the Air Bleed System (for air conditioning and anti-icing).

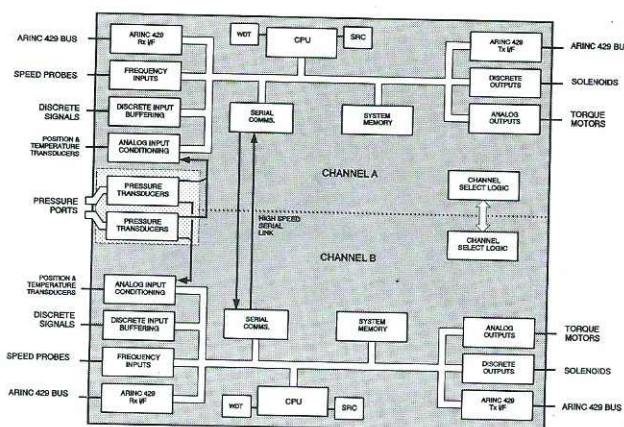


Fig 2.

In a typical control scheme only the critical airframe signals, such as the pilot's thrust command and fuel shut-off valve, are hard-wired to the FADEC. Parameters required for despatch, and non-critical parameters may be transmitted between the FADEC and airframe by databus. ARINC 429 is the standard currently used on large civil transport aircraft. In some military applications, the total airframe interface has been reduced to a triple-redundant, bidirectional MIL-STD-1553B databus. This approach minimises the engine/airframe harness weight and complexity.

The engine sensor interface comprises a mixture of engine mounted transducers used for both control and health monitoring purposes. Pressure transducers are frequently built into the FADEC itself, and used to measure ambient, intake and internal engine



pressures. For high accuracy each sensor is calibrated by the manufacturer, to obtain the relationship between pressure, sensor temperature and output signal. This calibration data is stored in the FADEC memory. The highest level of accuracy and performance is essential in the case of the main thrust control parameters used on large turbofan engines, where fan pressure ratio and Mach Number are measured using sensors with air data computer levels of performance.

The test interface is primarily intended for interrogation of the unit at a maintenance facility, and also for programming the computing system. Loading new software into the FADEC is increasingly becoming accepted as an on-wing operation.

## SYSTEM MONITORING

The FADEC is designed to provide comprehensive system fault monitoring. The computer in each channel of the electronic control is designed to be self-monitoring. In a typical self-monitoring scheme the computer executes a self-check routine, designed to detect any faults in the computing system hardware. The tasks divide into power-up checks and continuous checks. Power-up checks include tests which can be carried out while the control is running the engine. One example is the setting of the Watchdog Timer, which is the main hardware monitor for the computing system. Continuous checks divide into foreground and background tasks. Foreground tasks are executed within the control sample period and include instruction checks, read-write memory checks and addressing the Watchdog Timer to confirm satisfactory system operation. The main background task is executing a sum check of the fix-odd-parity memory. The purpose of the checks is to ensure, with a high level of confidence, that all computing system faults are detected.

As long as the computer in the controlling lane remains fault-free, then it can be used to check the other parts of the electronic control and external system components.

In a well-designed control, the input/output monitoring capability can be made very effective, so that the only source of undetected single faults leading to loss of thrust control is the computing system. Again, within the computing system, the checks described above cover all the elements with the exception of a subset of processor faults. A typical design target for single failures leading to loss of thrust control is:

Probability of single failure leading to loss of thrust control  
 $- < 10^{-7}$  per hour

Thus the aim of the system design is to ensure that the electronic control

contribution to loss of thrust control is negligible.

The computing system and associated safety circuitry form the heart of the FADEC. The computer is designed to be self-monitoring. It is then used to check out the other functions of the system. This typically gives better than 95% fault coverage overall and close to 100% for flight critical functions.

## CONSTRUCTION AND PACKAGING

FADEC systems are normally designed to be engine mounted. Thus the electronic controller is placed in a more hostile environment than perhaps any other unit on the aircraft. Particular threats arise from ambient temperatures which can swing from  $-55^{\circ}$  to  $100^{\circ}\text{C}$  during engine operation, high levels of vibration, high intensity radio frequency interference (HIRF) and lightning strike. The increased use of composite materials has generally increased electromagnetic compatibility (EMC) problems. The evolution of a satisfactory and reliable FADEC, capable of withstanding this environment is critically dependent on circuit integration and packaging.

The 'black box' in which the control circuits are housed is designed to provide the best possible environment for the electronics. The box is usually anti-vibration mounted. The mounting system resonant frequency is selected to be well away from any engine steady state running condition, and well below the fundamental natural frequency of any circuit board or module. This ensures that only small amounts of vibrational energy reach the boards, typically 2g rms. The effects of HIRF are minimised by designing the box to provide a conductive enclosure for the circuitry, with apertures only where connectors are fitted. The circuitry within the unit is protected against interference imported via the harness by filters, which may be chassis mounted or built into the unit connectors. Signal and power lines are protected against the effects of lightning strike by transient suppression diodes or varistors, which divert the energy to ground.

Thermal management is of major importance. Many components are only specified for  $125^{\circ}\text{C}$  maximum operation, and component failure rate increases exponentially with temperature. Thus circuit modules are designed to conduct heat efficiently to the casework, being fitted with heat planes, which are bolted or clamped to the cold walls. By this means components can be maintained at temperatures between  $15^{\circ}\text{C}$  and  $30^{\circ}\text{C}$  above ambient, hence keeping components as cool as possible.

Contaminants and moisture must not be allowed to affect the system, and so the box is designed to be environmentally sealed. Boards are given a protective

acrylic or polyurethane conformal coating for added protection. The box is allowed to breathe to prevent build-up of moisture within the enclosure.

*Integration brings multiple benefits. Modern CMOS integrated circuits consume and dissipate little power, whilst at the same time allowing greatly increased functional density. Current FADEC's make extensive use of both standard and custom large scale integrated circuits. This reduces system size and weight. Temperatures inside the unit are minimised and reliability maximised. A typical large engine FADEC, the Lucas Aerospace FAFC 2000, used on the Rolls-Royce RB211-524 engine incorporates features of the kind described above. This unit has accumulated over 1,600,000 engine-mounted flying hours to date, and is outstandingly reliable, with better than 62,000 hours per channel mean time between confirmed defects. This record has made FAFC consistently the most reliable FADEC in service.*

## NEW DEVELOPMENTS

The FADEC shown in the photograph is the latest Lucas large engine control, the Trent FADEC. This unit is due to enter service on the Airbus A330 in early 1995. With features including the ability to provide fault messages in English, it represents the current upper limit of function and sophistication.

A somewhat different approach is being adopted for smaller and less complex engine applications, where cost is the major driver. In a recent exercise, Lucas Aerospace used a pair of automotive engine management units to control a 15,000lb thrust turbofan engine on a test bed. A simple buffer box was added to handle the engine thermocouple and the fuel metering valve position sensors. The units were reprogrammed and used in a successful series of tests, with the engine starting first time.

The success of this exercise demonstrated graphically how automotive and aerospace systems are coming closer together, both in terms of requirements and capability. Designs are now under development, which combine the best features of automotive and aerospace technology, to provide a new generation of controls for mid-range and small engines. These controls will contain all the necessary functions for propulsion system management, including glass cockpit and vehicle management system interfaces, providing large engine standards of performance at an affordable cost.



# Just Another Night-stop Palermo

by Flt Lt Cliff Foggo, 101 Sqn Eng Ldr

"Just another night-stop Palermo" were the optimistic words that started the involvement of 101 Sqn in Operation Granby.

On 7 Aug 90, 2 VCIOK aircraft landed in Palermo to be told not to return home the next day as planned but to wait for further instructions. At the same time one aircraft was being recovered from the USA and, on 9 Aug, 5 VCIOK aircraft arrived in Akrotiri.

Various trails were flown out of Akrotiri to deploy aircraft in theatre and after 4 days 2 VCIOK deployed with 8 Jaguars to Thumrait in Oman. Over the next 18 days various training sorties were flown with the Jaguars and also with the Oman Air Force Jaguars, as well as being a taxi service for dignitaries visiting the Gulf. After an incident where both main undercarriage legs failed to lock down normally and had to be operated on the free-fall system because of sand clogging the grease in the downlocks, it became obvious that the constant 45kt winds were having a detrimental effect on the aircraft. It was then decided to move the tankers again, this time to Seeb.

At the same time it was decided that more tankers were required in the Gulf and so, after much searching for dispersal space, 3 further VCIOK aircraft arrived in Bahrain. This meant a split detachment for 101 Sqn with 3 aircraft in Bahrain and 4 aircraft in Seeb. By now the groundcrew

were very proficient at acquiring ground equipment because most of the Sqn equipment was still trying to catch up with the Sqn's moves.

Most of the training sorties were now at night with Tornado GR1 aircraft and there was also a daily task to mount a towline for the Tornado F3 CAP. During this period the US Navy were very keen to train with the VCIOK and a number of sorties were flown with F14, A6, EA6B and A6K aircraft. One of the more interesting of these was a night sortie into the Gulf from Seeb. The mission details gave the VCIOK 4 receivers, but when orbiting overhead the aircraft carrier it was found that there were 8 tankers, all at 2000ft spacing and each with 4 receivers. This proved to be foretaste of things to come, where the ability to think quickly and be flexible was essential.

During this period, September to December, most of the 400 sorties were accompanied cross-countries with Tornado GR1 aircraft, to cast them off at a pre-arranged spot and time so that they could make their time on target, and wait for their return. These sorties did not always work out as planned as, on one occasion with 3 tankers in formation, the pre-planned allocation of receivers to tankers did not work out correctly, and a few minutes of chess type movements were required to achieve the desired formation.

In December 90 it was decided that for best operational efficiency 101 Sqn should be located together at Riyadh in Saudi Arabia, so everyone packed up and moved again. The first night at Riyadh was a picture, seeing the faces of the Sqn members as they sampled their first alcohol free beer.

Early January 91 saw a first for 101 Sqn when it was decided to have as many tankers as possible in Riyadh. The ground engineers did a marvellous job in getting all 9 aircraft serviceable and lined up together.

On January 16, while most of the crews were sitting down to an evening meal, the call came to return to the airport ASAP, and so the Air War started. It was a strange feeling to taxi out for the first mission, 1 hour before the war started, behind a 747, 737 and an Airbus which were still flying their normal schedules. As the aircraft transited towards Tabuk for the rendezvous nothing seemed different. But as time went on more and more red lights could be seen in the sky around. One light was high in the 1 o'clock and after a few minutes it looked like 2 or possibly 3. Eventually it could be seen that it was in fact 3 KC135 aircraft, each with 4 chicks. The AWAC people earned their pay that night and also the respect and appreciation of all the crews. The rendezvous was carried out just like a







normal training sortie and the GR1s cast off as usual on time.

The tanker then set up a towline to wait for the GR1s to return and also listen for any response from the Iraqis. No hostiles were called by the AWAC threat advisory and the GR1s returned for their fuel and we all set off for base. On return the aircraft was turned round and the crew went into rest to wait for the next mission. Initially, the flying rate was very high but after a few days it slowed and settled to a regular pattern.

During the Gulf War 101 Sqn flew nearly 400 sorties, aborting only one for an airborne problem and losing no missions for ground unserviceability. The groundcrew achieved a marvellous serviceability rate throughout.

By the end of the Ground War the flying rate was very low and the planning started for the recovery of all the aircraft to UK. Over a period of 5 days, all 9 aircraft were involved in trails, some doing a shuttle between Riyadh and Palermo. On Mar 11 the Sqn was back where it started from, in Palermo, but this time with all 9 aircraft.

The final leg home was on Mar 13 when the Sqn arrived home at Brize Norton to a marvellous welcome from relatives and Station personnel.

#### CAPTIONS:

Page 41: Some of the mixed trade: F-14, F-18 and a pair of A6.

Left: A VC10K with a 3-ship formation of RAF Jaguars

Below: All 9 of 101 Sqn's VC10K aircraft on the dispersal at Riyadh





# "THOSE WERE THE DAYS"

## The Saunders-Roe SR45 "Princess" Flying Boat

by R. B. Stratton, CEng FRAeS FSLAET  
One-time Chief Flight Engineer, Saunders-Roe Ltd (Saro)

The Brabazon Committee's recommendations for the United Kingdom's development of post-war civil aircraft included a flying boat with transatlantic capability.

In 1945 Henry Knowler, Chief Designer of Saro, began project design work on such a flying boat. Although 12 Rolls-Royce Tweed turbo-propeller engines were initially proposed, the final choice was that of 10 Bristol Proteus. A gross weight of 315,000lbs was chosen.

I joined Saunders-Roe at Cowes in 1949 from the Royal Air Force, having served as a Flight Engineer on Sunderland Mk Vs in Coastal Command. My first assignment at Saro put me into the "deep-end" of design and development, a subject of which I had little prior knowledge. Henry Knowler tasked me with getting our own Sunderland, RN297, "off the water" as a

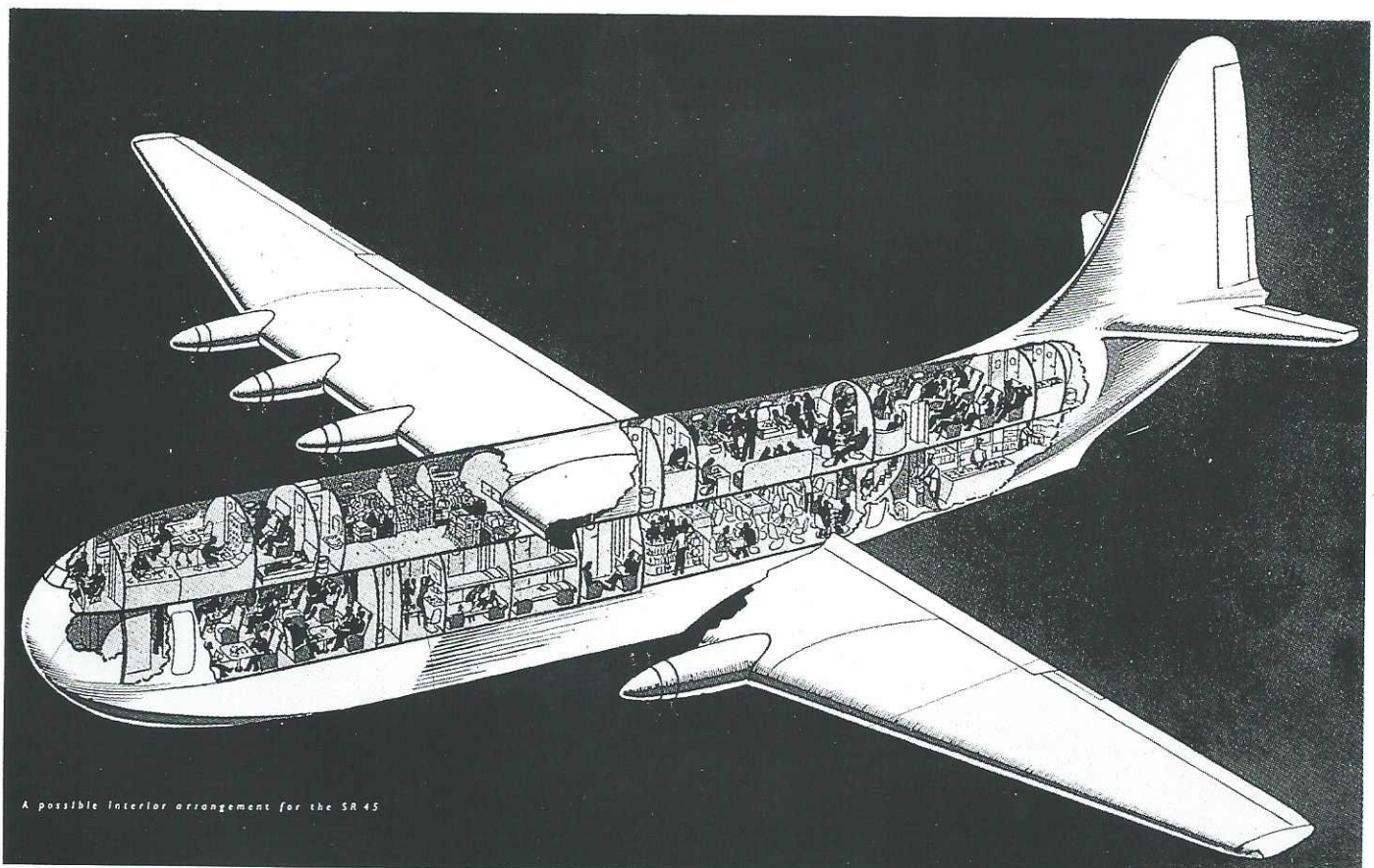
flying test bed for the powered flying control (PFC) systems.

The Saro Princess had been designed to incorporate power operated controls without manual reversion. A full-scale "fly-by-wire" system was being tested, based upon World War II artillery synchronous (electrical) transmitter systems, to signal the PFC units. The Smiths SEPI Mk.IX electric auto-pilot constituted the triplication. In the event, we installed flexible steel cable controls to signal the PFCs. The PFC units were derived from well-proven Boulton Paul swash-plate pump and motor systems, well known in aircraft gun turrets of those days. These self-contained units were driven by individual electric motors. In the case of the Princess, 120v DC was to be the main source of electrical power so it was necessary to install an Austin industrial engine with back-up batteries in the Sunderland.

The PFCs installed in the Sunderland incorporated manual reversion systems of great complexity, and it soon became

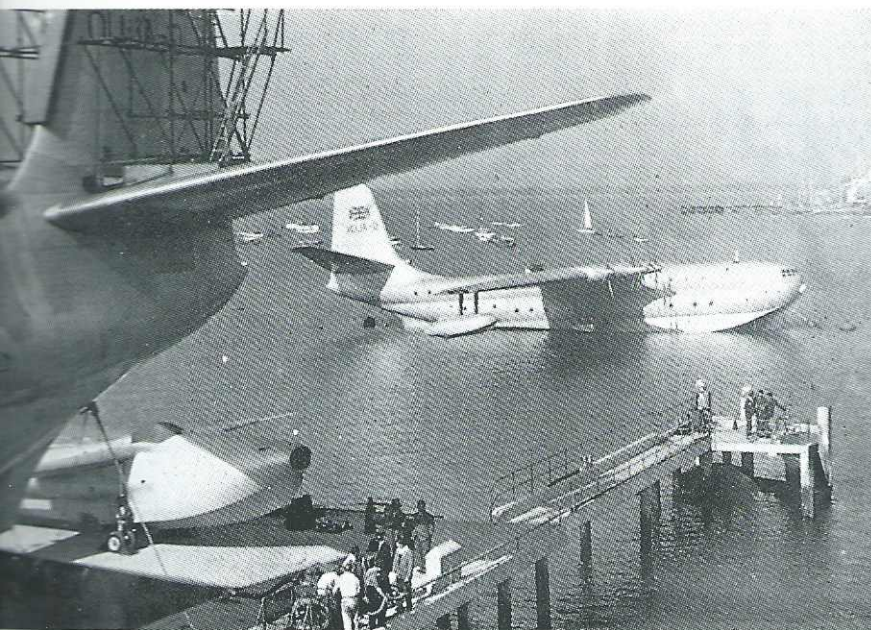
apparent to me that manual reversion might prove to be more hazardous than powered flying controls! This was proved to be true when, on the first flight of the elevator system, on reversion to manual for landing we ended up with the elevator itself in power and the pilot's controls disconnected! By reverting to "power" we regained control and this single incident (repeated some time later when demonstrating to the Test Pilots from the Aeroplane & Armament Experimental Establishment), probably put an end to manual reversion as an essential safeguard. RN297 operated out of Cowes Harbour between October 1949 and March 1953, accumulating some 400 hours of very useful PFC indoctrination. The output from the PFC hydraulic motors was by shafting to close-tolerance screw-jacks so that no mass balancing was required.

By superimposing the SEPI auto-pilot on the power operated controls of the Sunderland a "fly-by-wire" take-off, circuit



A cutaway drawing of the Princess Flying Boat





G-ALUN at Cowes, 1952

landing was made, from the Solent, in 1952.

The design of the Princess was strained dimensionally by the size of the Columbine hangar, erected in 1953 for the construction of Saro Londons and, later, the Lerwick. The inner wings (with floats installed), could be fitted once the hull had been positioned in the centre of the hangar. The fin tip was neatly positioned within the hangar roof structure and could only be extracted by tilting the installed water-ballast to tilt the hull on to a tail trolley for removal from the hangar. Only then could the outer wings (with tip floats) be installed. The inner wings were also the fuel tanks, with a capacity of 15,000 gallons. Of the 3 built, only G-ALUN was flown. The scenes, scale models fitted with Desoutter airdrill motors to drive their propellers were used for both aerodynamic and hydrodynamic testing.

Hydrodynamic tests showed that the wave was likely to impact with the outer propellers (as it did on the board propellers of Sunderlands). This prediction was proven when we bent all the centre blades 3" forwards on G-ALUN. Since the bends were both symmetrical and beautifully radiused, we achieved them that way.

The ingestion of sea water into the intakes on take-off was also a function of propeller performance, in that the wing intakes of the reverse flow Proteus "sucked" the vortices generated by the propellers. Spring loaded hinged doors were installed in the top of the intakes and the take-off run was initiated with the main intake doors closed by electrical actuators. As soon as "prop-speed" was reached, the intakes could be opened and full power achieved.

Electrically, the Princess was in a world of its own. There were four 39KW 120v generators driven off the propeller gearboxes of each coupled Proteus. The

"coupling" of 2 Proteus engines was a mechanical means of using 2 engines to drive a common contra-rotating prop unit. Each turbine shaft, as well as driving its own compressor, drove a common gearbox which then, via the same translation unit as that used on the Shackleton, drove the propellers. There were two 11KW 24v DC generators on the centre coupled engines, and a proliferation of rotary inverters for 26v AC and 115v 400 cycle AC.

The tragedy of this "all-electrical" aeroplane was that there was no installed APU! Historically, this decision was taken following the sinking of the Short Shetland at Felixstowe when its Rotol APU caught fire through lack of safety precautions in its ventilation system.

The Princess was totally dependent upon an APU tied alongside in a motor-launch until such time as one of the centre coupled engines was brought up to

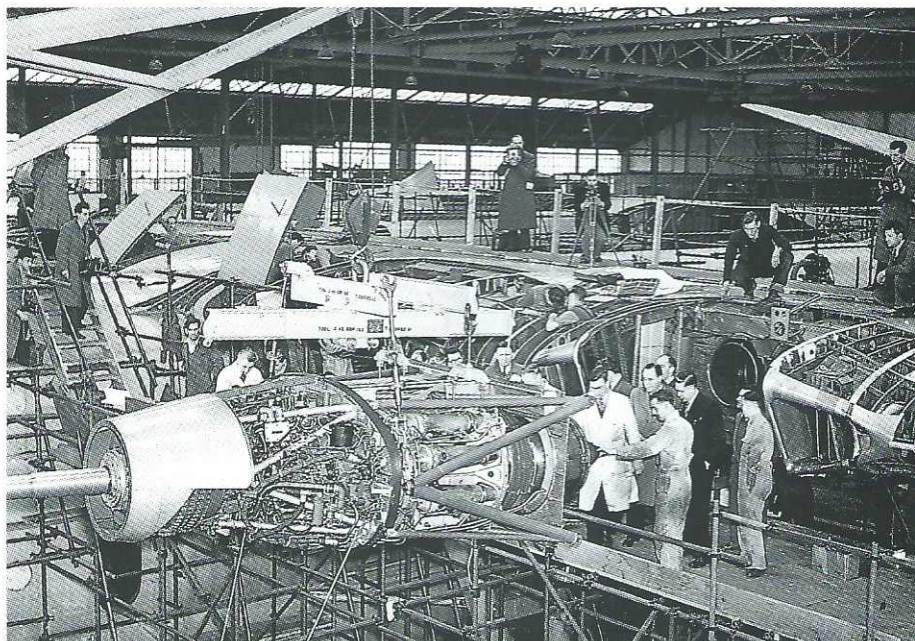
high propeller speed! By the time all 10 engines were operating at flight idle speed, the speed over the water was judged to be of the order of 16 knots. Although the Rules for the Navigation of Ships at Sea require power to give way to sail, the absence of an APU on the Princess made this somewhat of an academic requirement!

Although FADEC had yet to be invented, the Proteus did have all-electric engine controls. A "deal" was done between Ultra (who produced the engine controls) and de Havilland Propellers to interconnect the throttle signals, via a microswitch and a cam secured to a (coupled) propeller blade by a jumbo-sized jubilee clip, to activate the feathering solenoid in the constant speed unit. The flight fine pitch stops were cut back, and the blades allowed to assume superfine pitch, at which pitch no thrust was generated. Thus propeller "prop-dwell", so well known to Britannia crews, whereby the propeller blades "motored" around fine pitch but would accelerate to take-off power without overspeeding, was invented. (This system was a big improvement on the technique of starting the take-off run with the "minimum" RPM selected, to avoid overspeed, as we had to do in the early flights.)

Unlike for the Bristol Brabazon, the only modifications we had to make to the local real estate was some modest dredging of Cowes harbour (which was of benefit to local inhabitants) before gaining access to almost twenty miles of natural alighting area stretching from Lee-on-Solent to the Needles.

Having attempted to launch G-ALUN at midday on 21 August 1952, a summer gale delayed the operation until high tide at about midnight.

The first flight took place on 22 August 1952 and without any preliminary high-speed runs Geoffrey Tyson taxied out towards Lee-on-Solent, poured on the



A Coupled Proteus



power, and we lifted off after a very brief run.

Although we were scheduled to make a fairly extended test flight, I was bound to advise our Chief Test Pilot that the temperature gauges in each of the 4 inter-propeller gearboxes on the coupled engines were "in the red". After only 32 minutes we landed and the problem was subsequently resolved by disconnecting the gauges.

We managed to fly to Farnborough on one day that year, returning prematurely from a second attempt with engine failures. The early Proteus had light alloy compressor blades, and these kept shedding. It was whilst making a spectacular low-level flypast from the Black Shed end at Farnborough that the hinge-moment limiting relief valves on the aileron PFCs made their presence felt by refusing to roll the aeroplane into a turn! I remember throttling back all 10 engines so that, at reduced IAS, the ailerons would operate as they were designed to do!

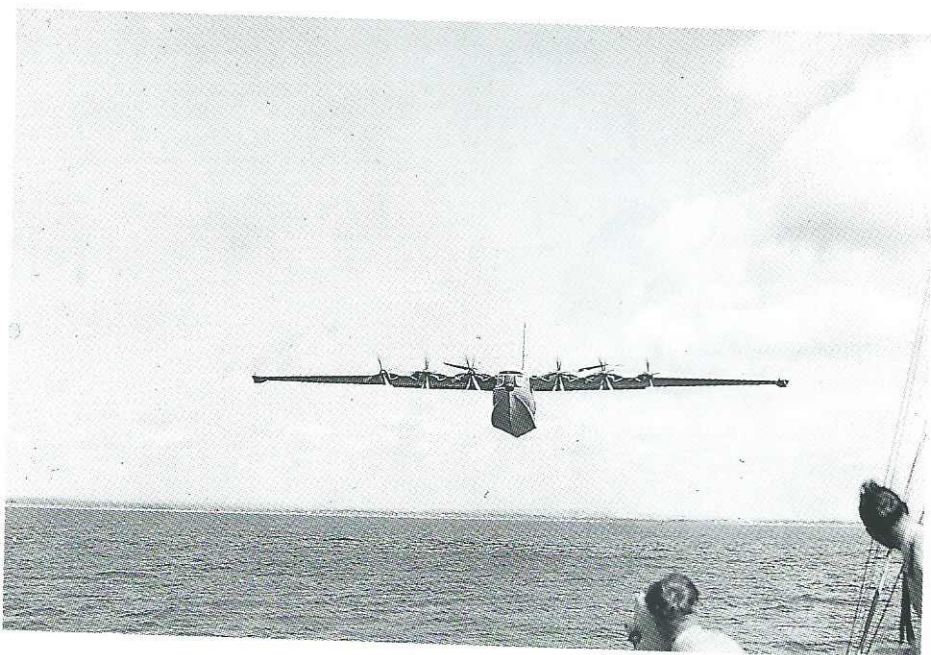
Not one minute of flight testing time on G-ALUN was wasted. The instrumentation of the day was based on real live instruments and real live cameras. Notwithstanding so much spray, we succeeded in strain-gauging both a coupled and single propeller using open slip rings!

After some 80 hours of flying, G-ALUN was withdrawn from active service on 27 May 1954. We had flown to 30,000 ft at a

weight of 320,000lbs. We had investigated the flight envelope and performance in sufficient depth to formulate a data-base. What we needed next was a set of engines meeting their full specification of 3,200 shp.

On the subject of engines, I may be unique in having experienced more engine failures and fire warnings than almost anybody else. By far the most spectacular was that of a coupled engine

at 30,000 ft over Cherbourg on 24 February 1954. An oil feed pipe had failed to the power turbine of one half of a coupled (No.5) engine. The coupled gas generators continued to put power into the system, and the constant-speed governor was attempting to maintain the pre-selected propeller rpm. Eventually, the power-turbine shaft broke in 5B engine, the propeller oversped, and the torque reaction damaged the engine



**Airborne!**



**Launching, 21 August 1952**





The Cockpit Layout

mountings. I managed to shut down the right combination of engines, and we returned safely to Cowes.

Politically the future looked bleak. The Bristol Britannia had been delayed in entering service with BOAC because of intake icing problems with the Proteus. Top priority was given to that version of the Proteus. British South American Airways were keen to put 7 Princesses on their routes but, after the disappearance

of the second BSAA Tudor, BOAC took over BSAA.

BOAC had ordered the Handley Page Hermes, and the Boeing 707 was coming over the horizon and over the Atlantic!

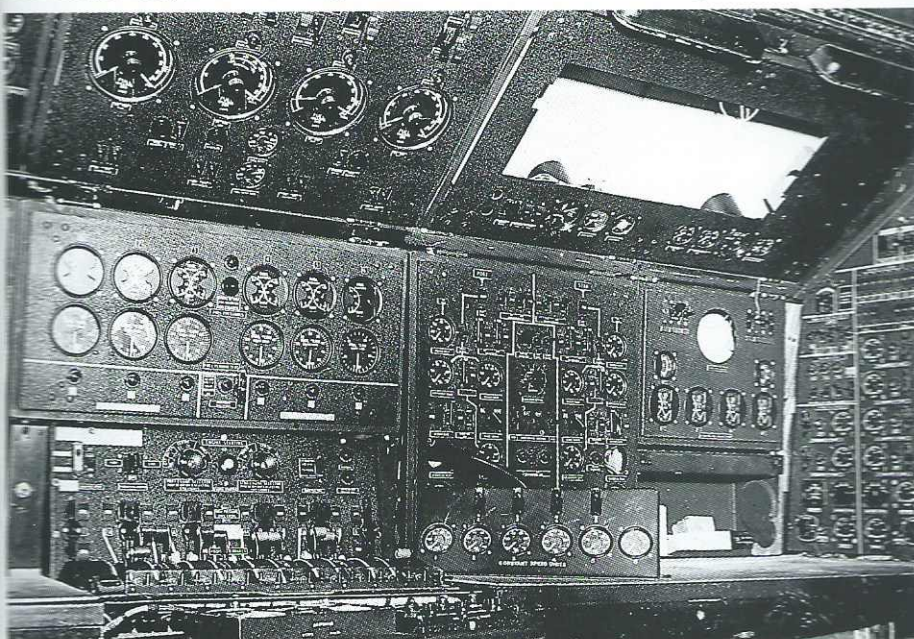
The Royal Air Force took a look at the Princess as a long-range troop ship. The US Navy Bureau paid Saunders-Roe to complete a nuclear power-plant project, and there was talk of converting the nose, the tail and the wings into a "Guppy". A

multi-bogie wheeled landplane version was also proposed. All came to no avail and the aircraft were cocooned for a while before being scrapped in 1967.

The technology has existed since the days of the first metal flying-boat hulls of 1924 to control corrosion by anodising and chromate painting. However, there remains the unresolved problem of salt water ingestion by gas turbine powerplants, mostly from the point of view of degraded compressor performance, and raised turbine temperatures.

The versatility of Saunders-Roe knew no bounds. My next Project was that of Chief Development Engineer on the SR53 (Mixed Powerplant) Interceptor. Subsequently I fulfilled the same function on the Saro Skeeter and Scout helicopters. Saro went on to develop Black Knight and the hovercraft. Now they are part of Westland Aerospace.

So ended the flying-boat era!



The 2nd Flight Engineer's Station

*The Editor would be delighted to hear from any serving or retired Flight Engineer who has material suitable for 'Those Were the Days'.*