THE BRITISH AEROSPACE EXPERIMENTAL AIRCRAFT PROGRAMME AND THE ROLE OF SYSTEM DEVELOPMENT COCKPITS

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ABSTRACT

There are always two basic requirements for modern military aircraft: it has got to be cheap; and it has got to out-perform its rivals. Although at first glance these appear to be contradictory requirements, it is possible with the advances in airframe design, materials used, and avionic systems employed, to produce higher performance aircraft at a relatively cheaper cost than the last generation of aircraft.

However, many of these advances have only become practical for military aircraft in the last decade: fly by wire systems; the use of colour electronic cockpit displays; digital data bus, distributed processing, etc. The problem faced by the aircraft manufacturer is how to introduce all these advances, which are essential to meet the basic requirement of cost and performance, without introducing too big a risk factor for the customer to accept.

In December 1983 the BAe Experimental Aircraft Programme was initiated with the aim of demonstrating the technology advances that will be introduced into the next generation of military aircraft.

This paper presents an overview of the EAP including a resume of previous work that has been contributory to its success.

Emphasis is placed on the Systems aspects of the aircraft outlining the architecture employed, the design and software production philosophy, finally focusing on the system development and test philosophy. Included in the final section is a description of the EAP development cockpit and other complimentary facilities that played a major role in the design of the EAP cockpit.

INTRODUCTION

Historical Perspective

During the late 70s and early 80s a number of conceptual studies were being carried out with a view to prospective replacements for the current generation of fighters. Notable amongst these were the German TKF90 and the British P110. In view of the similiarties in these configurations and of the size of the potential market, the companies who had previously co-operated on Tornado; MBB, AIT and BAe, agreed to investigate the possibilities of producing a joint specification to meet their individual national requirements. The resultant Agile Combat Aircraft (ACA) was unveiled in mock up form at the 1982 Farnborough Air Show. Originally two demonstration aircraft, based on the ACA design were planned: one was to be built in Britain and the other in Germany. However, as a result of the German and Italian Governments decision to withdraw in December 1983, work on the German aircraft was curtailed. The design of the remaining British demonstrator was rationalised and renamed the EAP: since it still involved the participation of Aeritalia along with many German and Italian equipment suppliers it was still an international collaborative project.

The objective of this programme was to develop and demonstrate the procedures necessary to design, manufacture and test technical innovations relevant to the future fighter aircraft. The technologies chosen covered the fields of,

- Aerodynamics;
- Structures and materials;
- Systems

This paper provides a brief summary of the aerodynamic and structural aspects and a slightly more detailed description of the Systems innovations, since this is the authors particular specilisation.

AERODYNAMICS

Operational studies indicate that manoeuvrability will still be a valuable commodity for the next generation of fighters. The basic layout (shown in Figure 1) embodies a lowly loaded wing and this combined with a high thrust to weight ratio will ensure good sustained and attained turn rates. In addition, the wing is manoeuvre adaptive in that both the leading and trailing edge devices are scheduled with incidence and mach no: the schedules being defined in such a way as to maintain efficient operation of the wing throughout the flight envelope.

The canard configuration chosen can be balanced longitudinally in such a way as to provide minimum trim drag both subsonically and supersonically, hence further improving overall performance. The longitudinal balance defined on performance grounds results in a degree of instability subsonically and therefore necessitates the use of a stability augmentation system. The system selected was a Marconi quadruplex Flight Control System (similar to the one test flown on Jaguar ACT demonstrator). In addition to providing good handling qualities this system allows the implementation of

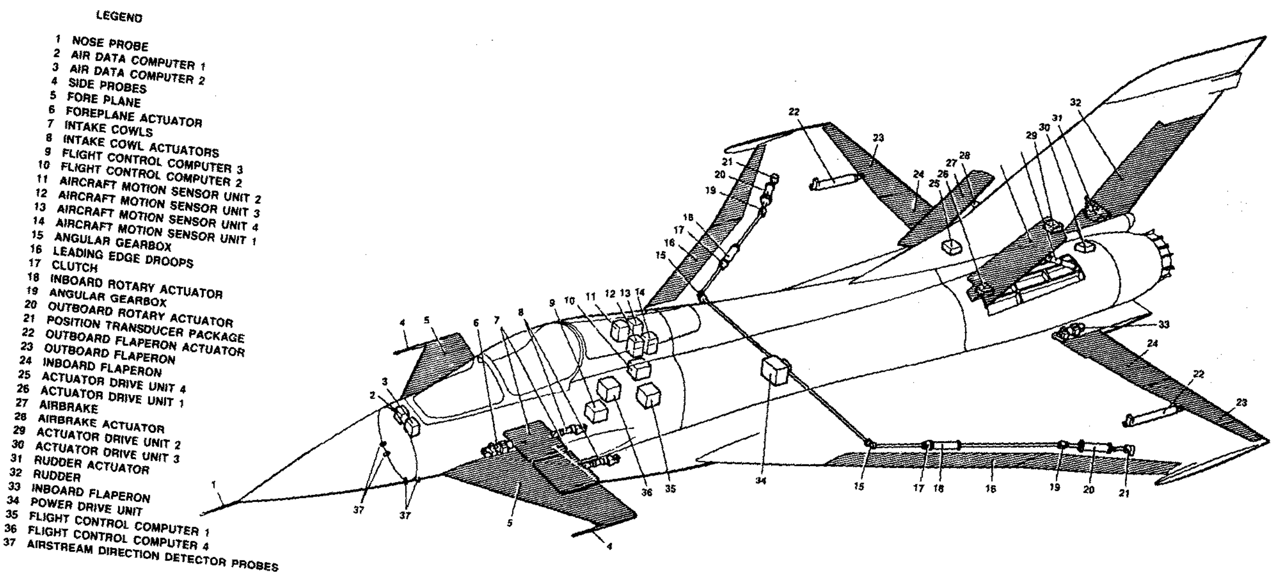

FIG.1 General Arrangement

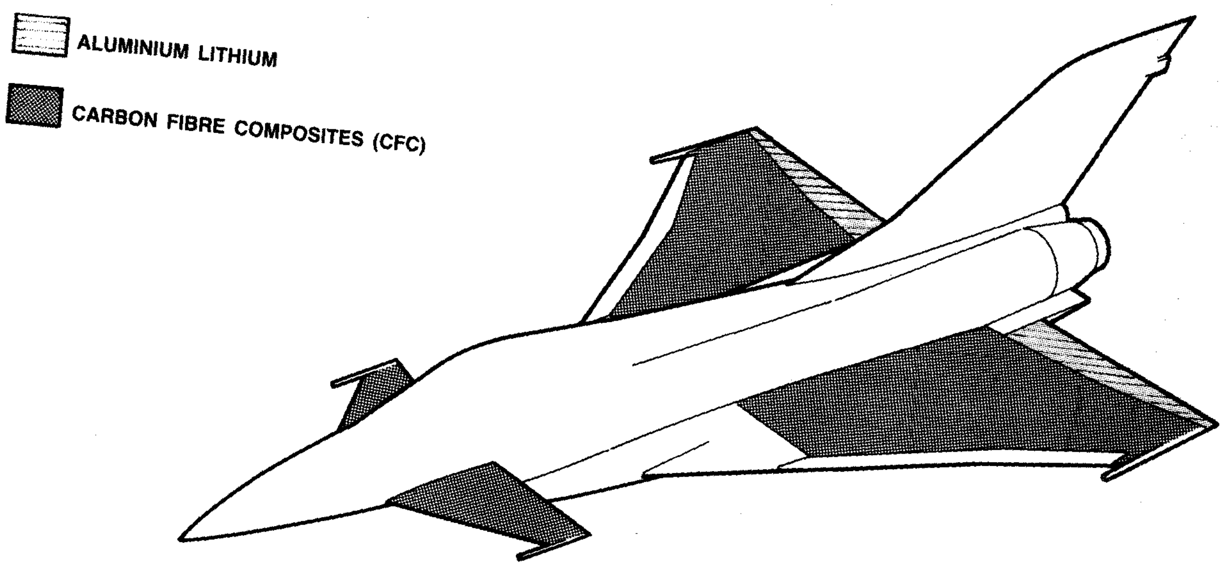

FIG.2 Advanced Materials

aerodynamic and structural limits such that the aircraft can be manoeuvred in a carefree manner. Also, since this system is software controlled it will be possible in future to incorporate control laws required for gust alleviation and fuselage aiming: the gust alleviation system would be used on a production aircraft to enhance the ride qualities during low level penetration; fuselage aiming may be used during close air to air combat for training guns and short range missiles.

Finally, the aircraft has a chin intake and a varicowl lip both of which are designed to ensure that relatively high incidence may be used without the danger of engine surge.

STRUCTURES AND MATERIALS

In order to minimise aircraft structure weight and hence further improve performance, extensive use has been made of advanced composites and alloys.

Carbon fibre composites (CFC) account for 25% of the structure weight: the wing skins and spars are prepreg tape layups as are the foreplane skins (Figure 2). The wing spars are co-cured with the lower skin resulting in an effective bond and reducing the need for conventional fasteners. Computer aided design (CAD) was used extensively on the CFC structures.

Superplastic formed/diffusion bonded titanium structures are used inbetween the engines; aluminium lithium alloy is used on the flaperon skins.

SYSTEMS

The performance of todays military aircraft is not only reliant on its aerodynamic and structural attributes: but also on the aircraft Avionic Systems which are now becoming increasingly important in achieving the demanding requirements imposed. The means by which the pilot controls the aircraft, delivers his weapons, defends his aircraft, navigates, communicates and how he manages the complex systems whilst remaining within an operable work load limit, is the responsibility of the onboard Avionic systems.

A significant feature of the EAP has been to demonstrate the effective use of new technology within the systems areas: Flight Controls System; Avionics; Utilities Services Management System (USMS).

Flight Control System

EAPs quadruplex redundant flight control system is a derivative of the system operated on the Jaguar active control technology (ACT) aircraft, this being the first fly by wire aircraft to fly without mechanical backup controls. Like its predecessor, EAP has four identical flight control computers commensurate with the need to sustain two failures without endangering the pilot or aircraft.

Since EAP will be more unstable than the Jaguar ACT and because 13 surfaces need to be controlled simultaneously, the flight control processors are capable of a higher performance than the ones used on Jaguar. The processors host the flight software that enables the pilot to fly an unstable aircraft and hence how carefree manoeurability and increased agility is achieved. In addition the processors house software for failure management, reversion logic, and built in test.

Also included in the flight control system are four aircraft motion sensor unit (AMSU), two air data computers, and four actuator drive units (ADUs). While the foreplane, intake varicowl, and wing leading edge devices are driven directly from the FCS computers, the wing trailing edge devices and rudder are driven from the aft mounted ADUs which are connected to the computers by serial digital data buses. A digital data bus is also used to connect the Air Data computers and motion sensors to the Flight Controls computers.

The FCS computers pass on air data to the avionics and USMS via the two main MIL STD 1553B data buses. In addition they process motion sensor information to provide data for the standby attitude and heading reversionary instruments.

Avionics

The avionic system consists of a number of integrated subsystems comprising,

- Navigation
- Communication
- Displays and Controls

Communication within and between these subsystems is achieved by using a dual redundant MIL STD 1553B data bus. In doing so discrete links have been avoided except were cost and integrity reasons dictated otherwise.

Navigation The navigation subsystem comprises a Ferranti FIN1070 inertial navigation processor, a GEC Tacan and a radar altimeter. Data provided by the subsystem includes attitude, heading, velocities, track, altitude, present position and time.

Communications Normal communication equipments are available and controlled from an integrated communication and audio management unit (CAMU), supplied by Racal.

Displays and Controls The displays and controls is by far the biggest Avionic bus subsystem and one in which the impact of new technology is most prevalant.

Two identical waveform generators are provided each capable of driving the three multi function colour displays and wide angle HUD.

Raw control data is processed in two identical cockpit interface units (CIFUs) prior to distribution on the Avionic data bus. Inputs to these CIFUs originate from numerous cockpit controls mounted on consoles, throttles, control

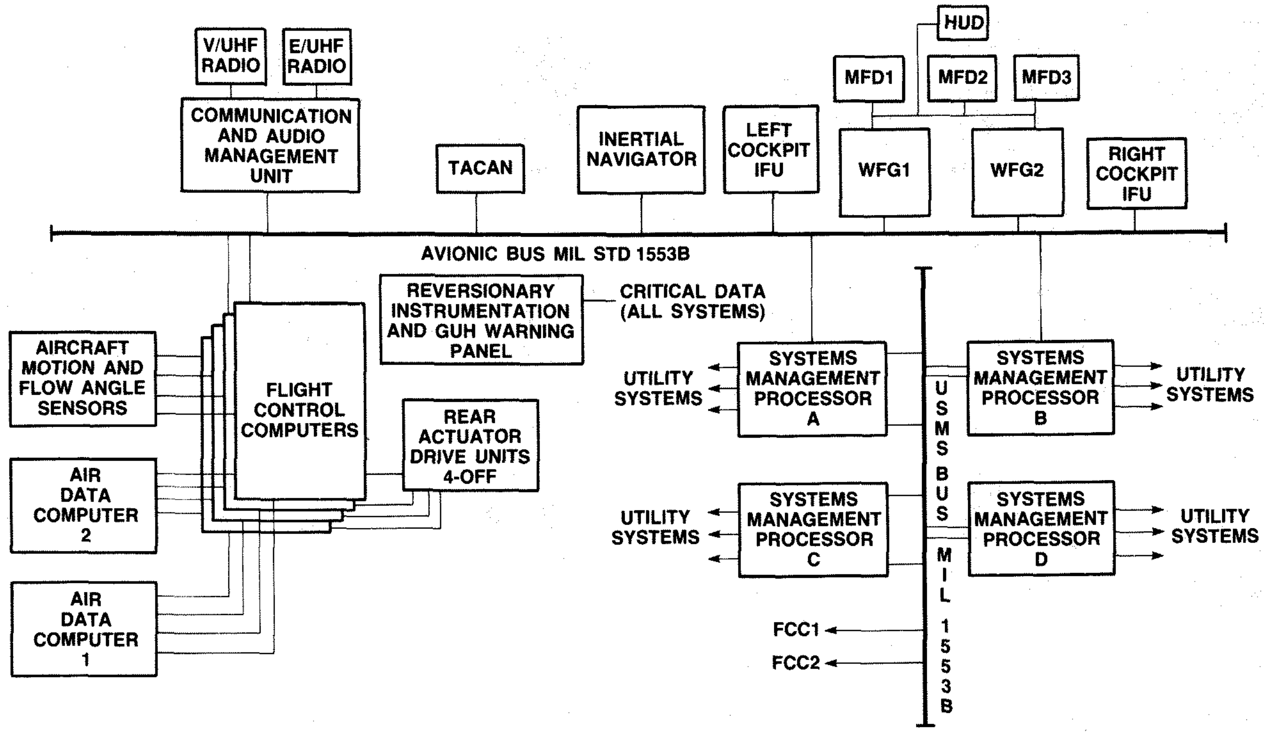

FIG.3 EAP Overall Systems Simplified Architecture

stick and displays. In addition mission data is inserted by the pilot via a Manual Data Entry facility mounted on the left hand glareshield.

<u>Utility Services Management System (USMS)</u>

As a result of a number of years of collaboration between Smiths Industries, British Aerospace, the Royal Aeronautical Society and the Department of Trade & Industry a central management system was installed in EAP for all major utility systems. The major utilities considered where,

- Engine control and indication
- Fuel management and gauging
- Hydraulic system control including undercarriage, wheel brakes and anti skid devices
- Environmental control including cabin temperature monitoring
- Secondary power system
- Miscellaneous systems including,
  - Liquid oxygen control
  - Electrical generation and battery monitoring
  - Pitot head heating
  - Emergency power unit

Many advantages acrue from utilising an USMS not least being the ease in which integration can be achieved with the Avionics system and hence the cockpit displays and controls.

The modular and closely integrated approach adopted throughout all the EAP systems has been an essential ingredient in providing a man machine interface that is capable of performing the highly demanding work load of the advanced military aircraft for the 1990s.

EAP COCKPIT

The most visible area in which the impact of new technology is so apparent is the cockpit. It forms part of an integrated weapon system concept that will permit single crew operation throughout all mission envelopes.

A wide pilot percentile range can be accommodated in a comfortable seating posture, whilst achieving excellent all round external vision.

Flight control is by a limited displacement short stick, which is mounted on a centrally located pedestal, and minimum displacement rudder pedals. Toe braking is incorporated. Thrust control is achieved by a linear displacement throttle box conventionally located on the left hand console. Combat accessible and rapid reaction controls are incorporated into the stick and throttle handgrips to facilitate both "head out" visual combat and "head in" beyond visual range engagements.

Four electronic displays present to the pilot the vast majority of system information during normal conditions. The primary flight display is a GEC Avionics wide angled diffractive head up display, a development from the F16 Lantern programme, offering a 30° horizontal by 18° vertical field of view.

Dominating the panel immediately below the HUD are three colour multifunction displays (MFDs) supplied by Smiths Industries.

Each of the MFDs is capable of presenting any one of 14 formats, the baseline formats being engine instrumentation (left MFD) attitude (centre) and warnings (right). In the event of an emergency these three prime formats can be recovered from other format combinations by pressing one button on the control stick.

A status format is provided from which the pilot can at a glance assess the health of the aircraft systems. By operation of soft keys mounted around the display the pilot can access formats relating to other systems or navigation displays. Although attack formats have not been programmed the basic controls and displays philosophy would remain very similar requiring only software changes to accommodate the increased number of formats required.

In the event of any system failures, flashing attention getters, mounted on either side of the HUD, are activated together with a speech synthesised voice, channelled through the headphones. The volume progressively increases until the pilot acknowledges the failure by pressing one of the attention getters. At the same time specific failure data is presented on the warnings format. Colour coding is used on the format to differentiate between the severity of faults.

Mounted in the left hand glareshield is another noval multi function device; the manual data entry unit. It is through this device that the pilot can insert changes to flight data such as communication frequencies and channels, waypoint co-ordinates, destinations changes, tacan beacon selections etc. Again adequate capacity has been incorporated to accommodate the additional functions related to combat. Also mounted on the front panels immediately below the outboard MFDs is reversionary instrumentation and a 'get you home' warnings panel.

Careful design of the cockpit ensures that all essential controls and displays are clearly readable and within easy reach. All normal and emergency procedures are kept as simple as possible to ensure that pilot workload is a minimum.

FIG 4 - The EAP Cockpit

SYSTEM DESIGN PHILOSOPHY

During the late 70s and early 80s BAe and various ministry research departments invested significant resources to develop tools and skills that would eventually be essential to a then, future aircraft such as EAP. Projects such as the ministry funded Displays and Controls Rig on which a wealth of experience was gained in using a structured high order language, CORAL 66, and a software design methodology, MASCOT.

The success of these earlier projects was instrumental in deciding the approach to be taken for EAP. Hence the philosophy adopted was an integrated life cycle methodology covering both system definition and software production and test. The method chosen was SAFRA (Semo Automated Functional Requirements Analysis) which is a technique for the development of software featuring a set of tools appropriate to each stage of the software life cycle, from system requirements through to maintenance and support.

For the requirements stage SAFRA utilises a methodology developed by BAe and SDL named 'CORE' (COntrolled Requirements Expression), and a computer based analysis tool termed Problem Statement Language/Problem Statement Analyser (PSL/PSA). A support tool for the production and checking of CORE documentation was provided in the form of a computer based development system known as the CORE workstation.

The methodology evokes the progressive decomposition of high level requirements, in a logical and consistent manner, until a level is reached where the requirement is expressed in sufficient detail to allow software design to commence.

Each level of decomposition consists of a number of logical steps, undertaken by the Systems Engineer which lead to the derivation of the requirements for that level. The information derived at each step is presented in diagrammatic form using a precise, unambiguous notation which can be checked for consistency and completeness across the whole of the systems requirement.

Having produced the detailed high quality software requirements an equally well structured and disciplined approach was applied to the design, code, test and integration phases. The high order language 'PASCAL' was used in all areas where software was produced by BAe. This comprised software for the following equipments,

- All Utility Services Management System processors

- Waveform Generators 1 and 2

- Cockpit Interface Units 1 and 2

The PASCAL software produced was developed using a software development package called PERSPECTIVE, produced by System Designers Limited. The package is configured for host target software development and embodies a MASCOT kernal.

The main features provided by PERSPECTIVE are,

- a methodology to handle the design of complex software and to provide a safe executive environment for sequential programs in a concurrent system, this is based on the use of MASCOT.

- a hosted development tool kit which supports program development and testing, and includes features such as separate compilation of modules, and system construction facilities.

- a comprehensive configuration controls scheme to prevent unauthorised access to software, to ensure different project members interact in a controlled manner, and to provide management information on the configuration of a software system.

- a facility to load application software into a target computer over a serial link which also allows debugging of the software running on the target from a host computer terminal

- a standard run time package which can be tailored by the user to meet his specific requirements.

Throughout the software life cycle a structured and disciplined approach was adopted. To complement the methodology previously discussed (SAFRA), reviews and configuration control procedures were stringently adhered to.

Reviews were carried out throughout the software life cycle to ensure that the software being developed satisfied the requirements, was technically correct, was of acceptable quality and was being organised efficiently.

Configuration management was an essential feature of the software generation process, being the means whereby the integrity and traceability of the software was maintained throughout its whole life cycle.

SYSTEM DEVELOPMENT AND TEST PHILOSOPHY

The philosophy adopted by BAe to integrate and test the EAP systems has been one born from successful major aircraft projects such as Jaguar, Tornado IDS and Tornado F Mk II, all of which relied heavily on the use of ground test rigs. However, in developing EAP, as well as following the course of previous aircraft a further significant stage has been introduced, the use of an 'Active Development Cockpit'.

Before moving into the details of these facilities it is first necessary to understand the reasons why they are essential.

Figure 5 depicts the typical cost profile to introduce modifications or correct errors in a modern day military aircraft. The benefits in producing a good design early in the project is clear to see, and it is primarily for this reason that an Active Development cockpit has been used to support the design of the EAP.

Of equal importance is the need to provide ground test facilities to integrate, test and develop the complex aircraft systems prior to first flight and then in support of the flight test and development programme. Without ground test rigs the cost of developing and testing the aircraft would be prohibitive and even suicidal when fly by wire aircraft such as EAP are considered.

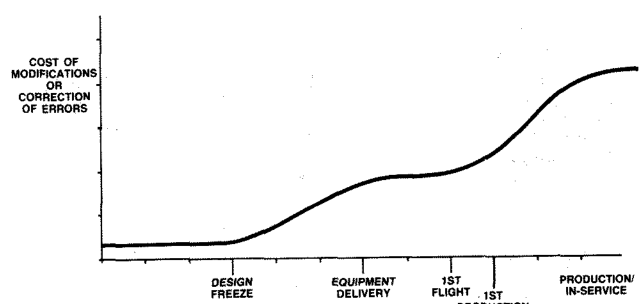

FIG.5 Typical Modification Costs Through Aircraft Life Cycle

History of Ground Test Rigs

Although ground test rigs have remained central to our philosophy, techniques have evolved with each subsequent project. Since EAP is the last project in the evolution of these techniques it is first worth outlining the significant steps, Jaguar The Jaguar aircraft was designed in the mid 1960s and its avionic system was relatively simple by todays standard. The system testing philosophy adopted on the Jaguar avionics rig involved a division of the flight software into manageable sections dealing with specific moding or mathematical equations. Each section was then statically tested on an individual basis.

Since this testing was essentially static in nature only selected points of the operational envelope were covered. To exercise the software in a truely dynamic manner it had to be flown and consequently the aircraft had to be used as a software development tool.

Tornado IDS This aircraft was designed during the early 1970s and like the Jaguar its avionic system was built around a main computer. However, the Tornado avionics system was both more extensive and complex than that for its predecessor. The test philosophy adopted for the Tornado was essentially the same as that for Jaguar, hence, the system development timescales expanded beyond those previously experienced. The Tornado aircraft had to be used to assist in the development of the flight software since this was the only way to dynamically exercise it.

Tornado F Mk 2 The advent of the Air Defence Variant of the Tornado brought about a significant change in the avionic systems development testing philosophy. Since its primary role was air to air the emphasis in weapon aiming was different and more complex in content. Consequently development of the avionic system using established techniques with inherent increases in timescales and manpower was considered unacceptable.

Experience of the Tornado IDS programme had generated the idea of dynamic testing on the rig, however, it was realised that this could only be achieved by enhanced simulation and data acquisition capabilities. It was at this stage that the established mathematical modelling technique of driving an aircraft aerodynamic model from representative flying controls, together with the ability to produce avionic system simulation when required, were essentially integrated with the avionics rig facilities.

This integrated approach resulted in the development of a much enhanced Data Acquisition and Simulation System (DASS) for the Tornado F Mk 2 avionics development rig, which gave the rig a fully dynamic capability. This made it possible to actually fly the avionics system on the ground test rig executing navigation tasks and operating the facilities of the weapon aiming system.

System Development Rigs

In order to prove the aircraft systems they have to be flown and exercised throughout their entire operational envelope. Before this can be attempted, however, sufficient confidence in the system design, its operational performance and its integrity must be achieved to comply with a safe to fly standard. To reach this standard the systems are subjected to a pre-flight ground test programme on the avionic system development rig. This has been the central tool used on all projects previously discussed and on the EAP.

The rig plus suitable support equipment provides a facility on which the following objectives can be achieved,

- Validation of equipment interfaces
- Development of the system to a safe to fly standard
- Flight back up
- System familiarisation for aircrew and ground crew
- Support for the continuing system development and enhancement.

The design of the rig is such that single equipments, subsystems or the complete aircraft system can be exercised. This is achieved through a modular construction technique. Each module or bench houses the aircraft equipment, interfacing wiring, break out panels for monitoring purposes, and were necessary simulation electronics to allow stand alone operation,

FIG 6 - EAP System Development Rig

Each bench or equipment is interfaced with other system benches to allow the complete aircraft system to be established and exercised.

To facilitate rig testing a Data Acqusiition and Simulation System (DASS) is provided which forms the fundamental tool by which the test engineer accomplishes his task. The main functions of the DASS are,

- Monitoring and recording of a variety of different types and quantity of signals ie analogue, discrete, serial digital highways, MIL STD 1553B data bus, etc

- Display of signals and attributes to the user

- Test control

- Running of static and dynamic simulations to allow the rig to be operated in a fully dynamic manner.

- Fault injection.

EAP System Development Rigs

Aircraft systems were separated into four major parts each requiring a specific ground test rig or rigs to perform integration and test. The areas concerned being,

- Avionics
- USMS
- FCS
- Utilities

The short timescales involved, (18 months testing in comparison with 4 years for a similar proportion of previous aircraft) together with a very limited budget, dictated that wherever possible testing philosophies should be adopted that took full advantage of the advances in aircraft architectures and test facilities.

However, since the FCS and aircraft utilities were similar to the systems used on previous aircraft; JAG ACT and Tornado, existing facilities had to be used which precluded any significant changes to the test philosophy.

The opportunity to apply a new test philosophy was however, available on the Avionics and USMS rigs.

Avionics and USMS Rig Although fundamentally separate rigs were used for the Avionics System and USMS, the testing philosophy for each was identical. Both system architectures are based on a federated processor concept with a large proportion of the inter processor and system data being conveyed via MIL STD 1553B data buses. It is primarily because of these features that the opportunity for parallel testing presented itself. Whilst the techniques pioneeered on previous projects were fully utilised, the ability to perform parallel testing was a significant factor in the success of the overall test programme.

From the outset the individual equipment benches were designed to support parallel testing, providing power supplies, monitoring panels and interfaces to a DASS processor in which appropriate dynamic simulations were hosted.

The design of the DASS facility had equal importance in supporting parallel testing. Unlike previous designs a multi processor architecture was used, each processor being capable of working in isolation providing all normal comprehensive functions. The schematic shown in Figure 7 depicts how the Avionic and USMS was divided and how the DASS architecture supported parallel testing.

Having comprehensively tested individual subsystems progressive integration testing took place culminating in the final integration of Avionics, USMS and FCS.

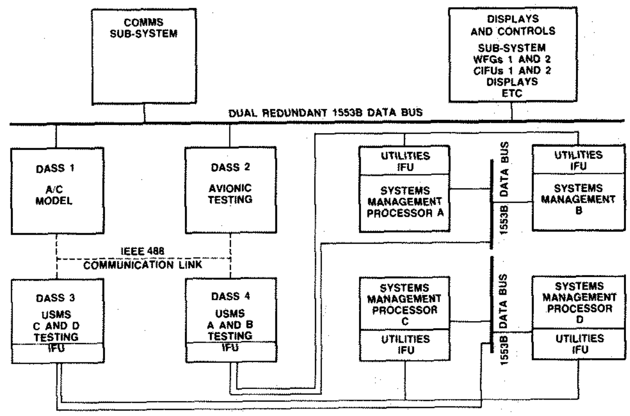

FIG.7 Typical Test Configuration and DASS Utilisation

DEVELOPMENT COCKPIT FACILITIES

The final part of this paper concentrates on the facility used during the period proceeding the EAP design freeze date and which were used extensively to design and develop the EAP cockpit. A brief history is given starting with the Ministry funded Displays and Controls rig, through P110/ACA, finally focussing on the development of the EAP cockpit itself.

Displays and Controls Rig 1978-1982

This was a very signficiant programme of work which for the first time on one project addressed the areas of technology that would be used on then future aircraft. The work was funded by a Ministry contract with the following objectives,

- To carry out an investigation into and build up experience in the implementation of a Mil.Std.1553B Data Bus. At that time, apart from small demonstration rigs transmitting a few words there was no experience in the UK of building a complex system using a data bus. The rig was to be the first functional data bus in the UK.

- To examine and gain experience in the use of a high level software language CORAL 66 and of MASCOT (Modular Approach to Software Construction Operation and Test).

  MASCOT is a formal method for the design and development of real time software and at the start of the project very little was known about its application to realistic problems.

Similarly, at that time, there was little experience in a real time environment, using CORAL 66.

- To develop management techniques and understanding of the control of a complex software task. The design of the rig placed a heavy reliance on software and demanded a formalised approach to its production and control right through from software requirements to basic design, detailed design, coding and test.

- To examine the control requirements of a federated system.

- To examine the viability of an 'Electronic' cockpit.

- To investigate whether multi moding of displays and controls was feasible - whether such multi function techniques were acceptable to the user (pilot) and easily engineered.

- To determine the requirements for display reconfiguration under failure conditions - to establish a logical reversionary sequence.

- Overall system management - such a large research programme required rigorous control from concept to fulfilment and needed a 'formalised aircraft' type of project control.

The experience gained on this project provided to be the foundation for the subsequent projects leading to, and including the EAP.

P110/ACA Cockpit

Feb 1982 - Jan 1983 Early in 1982 the first project development cockpit was provisioned for the P110/ACA (Figure 8).

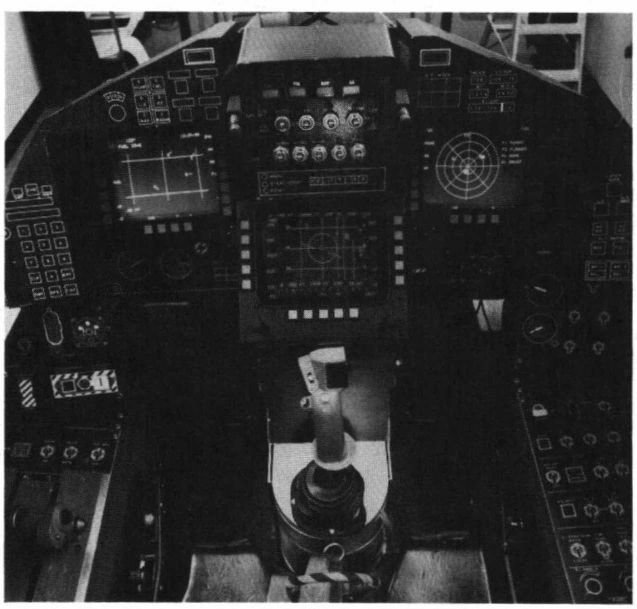

FIG 8 - P110/ACA Development Cockpit

It was furnished with 3 monochrome multi function head down displays, HUD, manual data entry facility and various flying controls, seat and switches.

During this period aircrew and design engineers were involved in exercises to assess the following aspects of the cockpit,

- Static displays and moding. Since there were 5 phases of flight incorporating 80 different display formats it was essential to develop a sensible moding philosophy to minimise pilot work load.

- Assessment of single crew operation of a radar to quanitify problematic areas

- Evaluation of Manual Data Entry facility

Feb 1983 - Feb 1984 Towards the end of 1982 the decision was made to build two ACA demonstrator aircraft. As a consequence, work undertaken on the development cockpit was directed towards the demonstrator aircraft which resulted in a number of changes and the initiation of relevant assessment work.

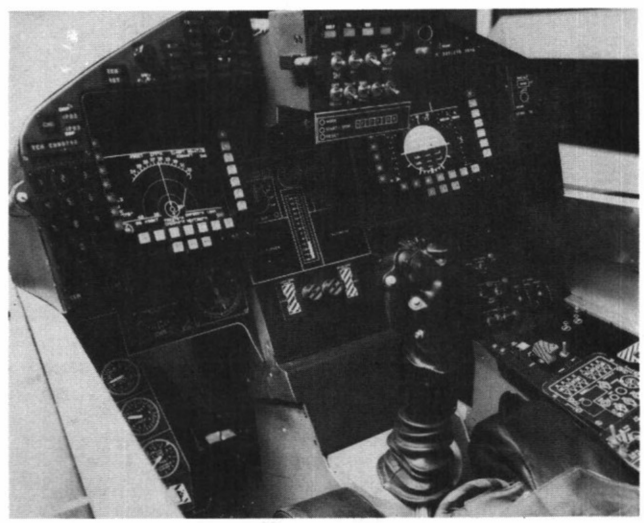

FIG 9 - ACA Demonstrator Development Cockpit

The major changes consisted of,

- Replacement of 3 monochrome MFDs with 2 colour MFDs.

- Installation of a new representative Manual Data Entry facility

- Reduction from 5 to 3 programmed phases of flight

- Reduction from 80 monochrome formats to 42 colour formats

- Changes in the warnings and display control philosophy

Numerous assessments took place during this period of time, but the introduction of colour displays presented a whole new set of potential problems that needed to be addressed, typical examples being,

- how many colours should be used
- how would colour impact on the warning philosophy
- should colour differences be used to carry data
- what effect would the harsh lighting conditions, experienced by a fighter aircraft, have on the colours chosen.

Complementing the work undertaken on the development cockpit to address these problems parallel activities took place in an Ambient Lighting Facility that could simulate the diverse lighting conditions experienced by a modern military aircraft. Much of the work conducted in the lighting facility was funded under a Ministry contract and in close collaboration with specialists at RAE Farnborough.

EAP Development Cockpit

Feb 1984 - EAP Design Freeze In December 1983 the German and Italian Governments decided to withdraw from the ACA demonstrator. To compensate for the inevitable increase in the BAe workload a reduction in performance was accepted in some areas without prejudicing the basic objectives of demonstrating the use of new technology. As far as the cockpit was concerned the following changes were introduced,

- A 3rd colour MFD was introduced to simplify the cockpit moding philosophy and hence the software.
- Major simplifications of the warnings philosophy, display moding and format content
- Number of formats available was reduced to 14

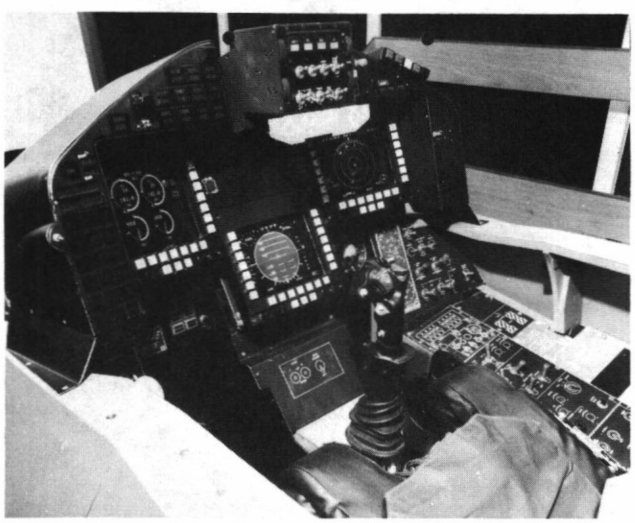

FIG 10 - EAP Development Cockpit

To accommodate and assess these changes the ACA development cockpit was replaced by a more representative mock up. This in turn was furnished in a similar manner to its predecessor but including the changes required for the EAP demonstrator.

From this point on, no further changes were introduced apart from format changes that resulted from the ongoing assessment by aircrew and design engineers. This continued until the EAP design freeze in July 1984.

Post Design Freeze Activities Although the development cockpit continued to support cockpit changes that became essential after the design freeze, there were few, and consequently the role of the cockpit became biased towards other support activities, the most significant being,

- as a demonstration tool for aircrew, design engineers, managers, prospective customers, partner nations, equipment suppliers, etc. The ability to demonstrate a fully active and representative cockpit well in advance of any aircraft equipment was of immense value to all concerned. To quote the words of one senior manager "half an hour in such a facility provides a better appreciation of the implications and impact of new technology than does days, and even weeks, of reading and studying descriptive literature".
- As a training vehicle for aircrew ground crew, and specific equipment manufacturers
- As an early development tool for the Euroepan Fighter aircraft.

Facility Description

Although the active development cockpit has been the focal support tool for the design and development of the EAP cockpit a number of other complementary facilities have been developed. These together with the development cockpit are described in the following paragraphs.

Anthropometric Seat During the early stages in the design of a cockpit, the basic geometry determining the position of the pilot with respect to various consoles, switch panels, displays, flying controls etc, must be optimised to suit the percentile range of pilots that need to be accommodated. Other factors must also be considered, for example, the pilots external vision; ejection lines (ensuring they are not compromised for any of the percentile range of pilots); and seat design in terms of back angle, squab angle and ejection clearance.

Although most of this work can and is done by the design engineer using conventional and computer aided design techniques, the anthropometric seat complements these methods by providing the means by which the percentile range of pilots can assess the proposed geometry in a flexible cockpit shell. Changes

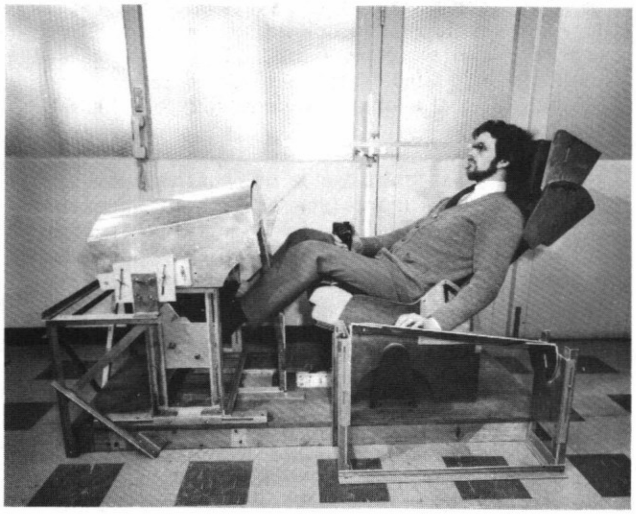

FIG 11 - Anthropometric Seat

to all parts of the cockpit can be quickly implemented to optimise angles and position with respect to the pilots eye position.

"Quick Look" Format Generator A very powerful facility has been produced that will allow engineers and aircrew to quickly produce static display formats and to then manipulate and modify all aspects of the format at will.

FIG 12 - "Quick Look" Format Generator

A graphics processor forms the central core of the system executing all the drawing commands and control functions necessary to provide the flexibility required to change attributes such as colour, character formats, symbol position, symbol shape, background colour, etc.

The graphics processor is interfaced to a host computer which houses the user interface software. This software, produced by BAe, allows the operator via a BIT PAD TABLE and visual display unit to develop formats in an extremely user friendly manner. The operator interfaces to the facility using English commands and typically can generate a full colour format from 'scratch' in less than 1 hour. Changes to the format being accomplished in seconds.

Since the first stage in the development of a suite of cockpit display formats is to determine the basic make up of each individual format in terms of information content, symbology size and shape, positioning, colour usage etc; it is possible to make significant progress in each area by first producing static formats.

The format generator provides this facility and has proved invaluable in the development of both EAP and EFA formats.

Ambient Lighting Facility Although a large amount of cockpit development work can be performed in laboratory lighting conditions, to ignore the implications of the lighting conditions experienced throughout the flight envelope of the aircraft, is a recipe for disaster. With the advent of colour displays the importance of developing colour philosophies under realistic lighting conditions was of paramount importance.

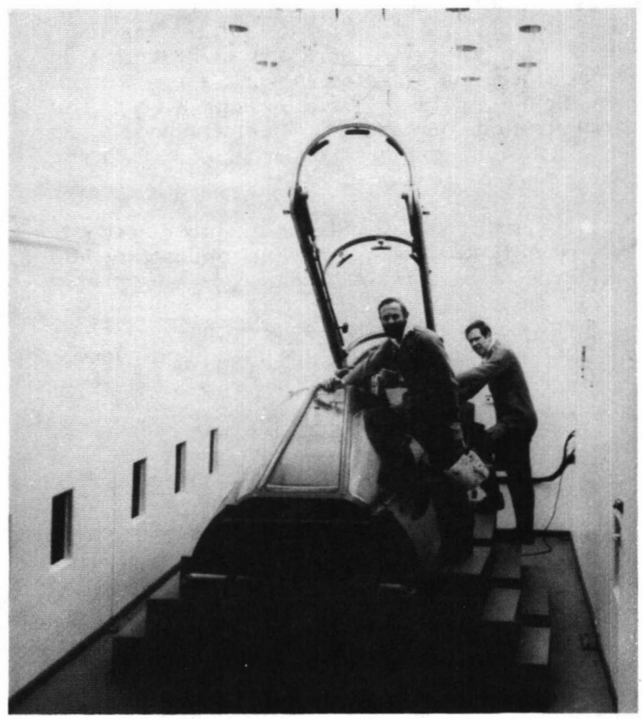

FIG 13 - Ambient Lighting Facility

Over the last five years BAe have developed a facility in lighting conditions can be simulated realistically for both day and night spectra. To achieve the high illumination levels, pressurised Xenon lamps are used since they have a relatively flat spectral response over the visible range , extending into the UV and IR regions.

Low level illumination is achieved using a balance of orange, green and blue electro luminescent panels, 100 in all.

EAP Development Cockpit In designing the processing architecture required to support the EAP development cockpit consideration was given to secondary tasks that could be undertaken if an architecture similar to the aircraft was chosen. Consequently a federated processing scheme was adopted with inter processor data being passed using a MIL STD 1553B Data bus. In doing so not only was data bus experience gained at an early stage but useful evaluation work was undertaken to assess such things as bus loading, bus controller retry sequences and transaction table formatting options.

Display Generation The three head down raster displays were driven from a Ferranti Programmable Display generator (PDG). The PDG was not only capable of driving three displays but also of updating the symbology in a representative real time manner.

Head up display symbology was generated by a Smiths cursive Programmable Graphics Generator (PGG).

System Simulation Navigation functions and various utility systems; engines, hydraulics and fuel, were dynamically simulated to a level necessary to exercise the cockpit display formats and controls in a represetnative manner.

A cockpit processor was used to interface all cockpit controls to the rest of the system via the MIL STD 1553B data bus. In addition it hosted the control logic software for the manual data entry facility.

Plessey MIPROC processors were used throughout, programmed in CORAL 66 and interfaced to the 1553B data bus via Marconi LSI remote terminals.

Outside World Simulation To allow assessment of the cockpit under realistic flight conditions an outside world simulation system was provided. It consisted of an aircraft model, again resident in a Plessey MIPROC, that generated dynamic data to the system simulations and display formats. Additionally, data was passed from the aircraft model to a commercial computer generated scenario simulator. The image generated by this unit was video mixed with Head Up Display symbology before being presented to the pilot using a SONY large screen projector unit.

Fault Injection A comprehensive fault injection control unit was installed to allow assessment of the pilot/cockpit interface even under single and multiple fault conditions.

All of these cockpit development facilities have been the culmination of many years of commitment by British Aerospace to provide a family of tools that can be used to support the evolutionary design of military aircraft cockpits.

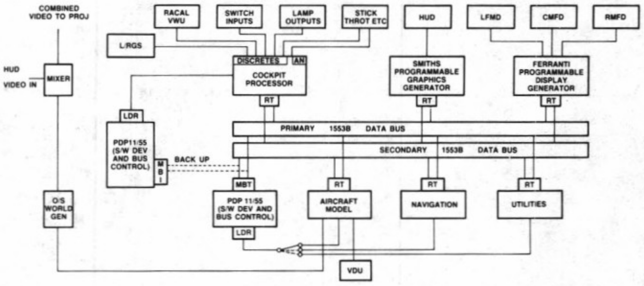

FIG.14 EAP Development Cockpit Architecture

The importance of such facilities has been plainly evident in the successful development of the EAP cockpit and will now provide a strong foundation for the design of the European Fighter Aircraft.

CONCLUSION

This paper has presented a summary of the EAP programme with emphasis on the Systems and development cockpit aspects.

The purpose of the EAP has been to demonstrate BAe's ability to successfully utilise new technology and thereby establish a corner stone for the European Fighter Aircraft. The project has been an unequivocal success both on a technical basis and in meeting extremely short timescales. A significant milestone in the programme was on 16 April 1986 when the EAP was officially rolled out in the presence of the Defence Minister, Mr G Younger and other national and international VIPs.

FIG 15 - EAP Roll Out

ACKNOWLEDGEMENT

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