A98-31441

ICAS-98-0,4

EUROFIGHTER TECHNOLOGY FOR THE 21st CENTURY

Erwin Obermeier
Vice President Series Production/Eurofighter
Daimler-Benz Aerospace AG, Military Aircraft
81663 München, Germany

Bob Haslam
British Aerospace, Military Aircraft & Aerostructures
Project Director Eurofighter
Warton, PR4 1AX United Kingdom

History of the Programme

After a number of industrial studies, the first government sponsored investigations towards a future fighter concept to satisfy both, the German and UK Air Force requirements were carried out in the mid seventies. In July 1979 the air staff from Germany, UK and Italy discussed the subject of Tactical Combat Aircraft and initiated the European Combat Fighter study. In December 1983 the air staff of Germany, UK, Italy, France and Spain formulated requirements for a new generation fighter aircraft in the Outline European Staff Target leading to an exploratory study and an agreement for a 9.5 ton single seat fighter aircraft in a delta wing and canard configuration fitted with twin engines.

In August 1985 France decided to leave the joint co-operation and continue a pure national programme which resulted in the "Rafale" development.

Since 1985 the Air Forces and Armament Directorates of Germany, Great Britain, Italy and Spain are co-operating for the definition, development and procurement of a new fighter aircraft. Encouraged thereby in 1986, the four weapon system companies Alenia, British Aerospace, CASA and Daimler-Benz Aerospace (at that time MBB) established a joint management company named Eurofighter GmbH and the four engine companies Fiat Aviazione, ITP (at that time SENER), MTU and Rolls Royce the joint management company Eurojet GmbH. Both are located in the vicinity of Munich.

In 1987 the Chiefs of Staff of the Air Forces of Germany, Great Britain Italy and Spain signed the European Staff Requirement for the Development (ESR-D) of the European Fighter Aircraft (EFA). This document finalised a period of harmonisation of the requirements between the four Air Forces.

The ESR-D defines the operational roles the aircraft has to perform:

- Air Defence
- Air Superiority
- Offensive Counter Air
- Air Interdiction
- Offensive Air Support
- Maritime Attack
- Reconnaissance.

An optimisation for air superiority in both beyond visual range and short range air combat together with comprehensive air-to-surface capabilities were required. Furthermore very stringent demands in terms of availability and supportability were established.

The value of the ESR-D - which really is the foundation-stone of programme - cannot be overestimated.

- The tactical requirements were defined clearly so that industry could base the design and later on the production specifications thereon,

21st ICAS Congress
13-18 September 1998
Melbourne, Australia

- the fact, that one European requirement document - and not four national ones - was to be fulfilled allowed industry to offer a common solution.

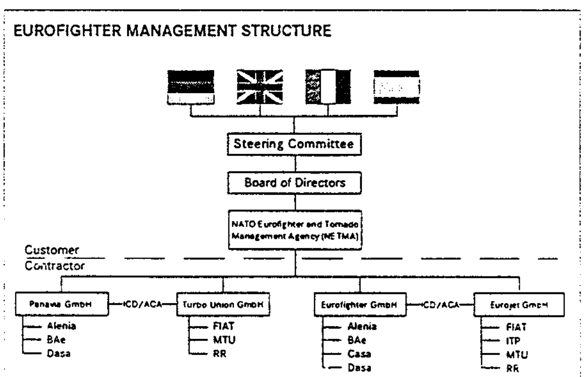
On this sound basis key milestones of the programme could be achieved still in 1987 and in the following year:

- Establishment of a customer agency under NATO umbrella (NEFMA) to handle the programme with industry on behalf of the four nations (in 1996 NEFMA merged with the related Tornado agency NAMMA to become NETMA),

- signature of the inter-government MoU 3 covering the development of the new fighter,

- signature of the two Main Development Contracts between NEFMA and Eurofighter GmbH for the airframe and between NEFMA and Eurojet GmbH for the engine.

The resulting basic Customer-Contractor management structure is shown below:



In 1992 the four Ministers of Defence instructed their Chiefs of Defence Staff to carefully review the ESR-D in view of the significant changes in the political and military map of Europe which had occurred after 1987. The requirement document could almost completely be re-confirmed which underlines that it had been compiled in a far-sighted way. Simultaneously industry was tasked to perform a broad-band study on cheaper solutions sufficient to cope with the reduced threat. The result was, that the baseline Eurofighter is still the most cost efficient solution - on the basis of combat effectiveness related to unit cost. The final result of review of the requirements and the reconsideration of the technical solution was the decision to stay with the baseline design and reduce the number of aircraft (from originally 760 to 602; in the meantime the four nations agreed to procure 620 aircraft).

The Concept

Since the mid 1970's national and international air defence studies together with more than 25 000 simulations were performed with the aim to define the air combat scenario and establish the basis for a mission and cost effective air defence and superior fighter aircraft with the additional capability for the air-to-ground role. The evaluations covered the aspects of

- offensive versus defensive counter air systems
- surface-to-air versus air-to-air systems
- quality versus quantity of the systems
- manned aircraft versus Remotely Piloted Vehicles

taking into account the scenario of

- beyond visual range
- within visual range
- effect of flight performance, avionics, armament, combat endurance and pilots capability.

The result was, that

- air attack does not replace air defence.
- only manned fighter aircraft provide the flexibility required for an air defence system.
- the quantity of aircraft is not able to replace the quality in order to achieve sufficient fleet effectiveness.
- future air-combat is not a stand-off problem, but it is highly dynamic in rapidly changing speed and altitude regimes. The ability for 4 g sustained turns at high supersonic speed is important. Avionics and armament are additive but are not able to replace excellent flight performance.
- radar performance with long detection range, large field of view and multi-target capability is required.
- low observability within certain ranges is important.
- short range air combat is dominated by highly unsteady manoeuvres, rapidly changing load factors, shorter firing opportunities, smaller space envelopes ending in low speeds.
- Remotely Piloted Vehicles require highly complex systems in the air and on ground and are very expensive and do still not provide the required flexibility of the total defence system.

Lessons Learned

Continuous monitoring of the programme not just by our customer and the Air Forces shows that the results of the evaluations done during the study phase are still valid and are the basis for the modern fighter aircraft concept.

Whereas the technical results of the studies were very pleasing, their duration (more than a decade) was too long from a programme point of view. As a conclusion there is a clear message for the future:

- Bundle the knowledge and experience of all participants in a collaboration to focus on the final product
- Remove as many interfaces as possible
- Establish a powerful, fully authorised programme management with less as possible national and individual "political" interference
- Don't extend study and concept phases over too long a time, but start early to produce experimental or prototype aircraft.

The Requirement

The Staff Requirement defines in detail the key parameters relating to the combat performance of the aircraft, the equipment it must carry, the ease with which it can be operated and maintained, its mass and its capability to operate in all weather and visibility conditions with minimum support from short runways.

Although the Eurofighter aircraft has been designed to meet the requirements of the four European partner nations, the aircraft will be fully capable of operations world-wide; the use of "European" simply reflects the aircraft's origin.

The Eurofighter has been designed to meet the very demanding requirements by the four Air Forces:

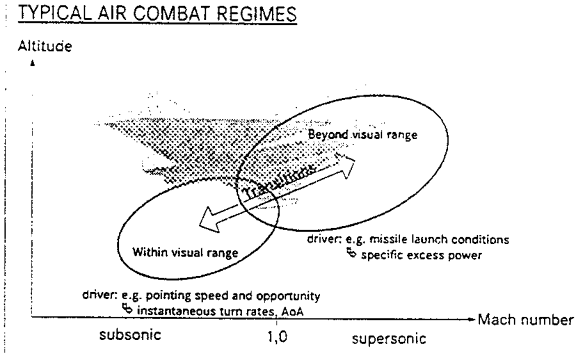
- Single seat aircraft
- Optimised for air-defence at short and beyond visual ranges
- Comprehensive air-to-surface capabilities
- High survivability
- Excellent maintainability and short turn-around time
- Low life-cycle costs
- 25 years / 6 000 flight hours guaranteed lifetime
- Pre-planned growth potential.

The Design Drivers

The challenge for industry is to identify and handle the design drivers, once the important parameters for specific missions are defined. In case of air combat it turned out, that there is a distinct difference between engagements beyond and within visual range.

This resulted in the challenge to design an aircraft with superior flight performance both in the subsonic and the supersonic regime.

TYPICAL AIR COMBAT REGIMES



In the past combat aircraft have generally been optimised for subsonic/transonic performance or for supersonic performance, unless special measures such as swing wings have been adapted, resulting in mass penalties. This aircraft achieves a good match of performance across the total speed range. In addition with the developing technologies in propulsion, structures and systems allowing high thrust and low mass, together with strong emphasis placed upon keeping the size of the aeroplane small, it achieves a very high level of performance, consistent with its application during the early part of the next century.

To achieve the required combat efficiency the following design drivers have to be taken into account:

DESIGN DRIVERS RESULTING FROM COMBAT SIMULATIONS

Superior air-to-air performance
high Mach number at medium g's
high climb rate
high acceleration and de-acceleration
offensive and defensive manoeuvres
excellent turn rates
fast g on-set
low signatures
} very low drag, high lift, excess thrust, handling quality
Avionics for autonomous and controlled operations
multi-target engangement
all weather day and night capability

Flexible air-to-surface capability
sufficient weapon/store stations
powerful Armament Control System
high accuracy Navigation

Technologies

To achieve all the requirements, the joint expertise of the participating European companies has been combined utilising advanced technologies such as:

- aerodynamically unstable aircraft configuration to achieve the lowest possible aerodynamical drag and the highest agility,
- a specially design engines with high thrust and fast reactions,
- carbon fibre composites, glass reinforced plastics and advanced light weight metal alloys,
- highly integrated structures, using new manufacturing techniques such as superplastic forming and diffusion bonding,
- full authority quadruplex fly-by-wire flight control system including carefree handling,
- a micro-computer controlled integrated avionics and utility system,
- a multi-mode radar with multi-target acquisition and engagement,
- Forward Looking Infrared (FLIR)/Infrared Search and Track System (IRST) for passive target acquisition and tracking,
- optical databus,
- semi-submerged missile installation,
- structural health monitoring system,
- automatic equipment and system failure detection and location,
- low radar cross section and visibility,
- provisions for multi-role capability.

The Configuration and Aerodynamic Concept

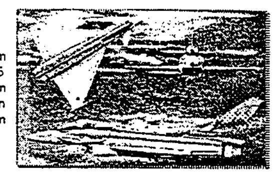
After numerous initial configurational studies of pure delta or strake-trapeziodal wings the final decision was to use the Delta-Canard configuration which was considered to be best suited to meet the challenging requirements.

The delta wing has a number of aerodynamic, structural and configurational advantages. The combined aerodynamic and structural benefit is given by the long root chord which provides large absolute wing thickness together with a high fineness ratio required for low supersonic drag. This allows to build a lighter wing structure with a high volumetric efficiency maximising the internal fuel content for superior mission performance and combat endurance. The large wing reduces undesired aerodynamic effects of external stores and eases their spacing.

The canard greatly contributes to increased aircraft manoeuvrability. The foreplane (canard) vortex interaction with the wing flow increases total lift to more than the sum of both individual lifting surfaces. This effect contributes to better instantaneous turn rates. Furthermore the same vortex interaction is beneficial to the spanwise aerodynamic load distribution, unloading the outboard wing sections and hence reducing wing bending moment and structural mass.

Configuration and Dimensions

Dimensions	
Wing span	10.95 m
Wing aspect ratio	2.205
Length overall	15.96 m
Height	5.28 m
Wings area	50 sq m

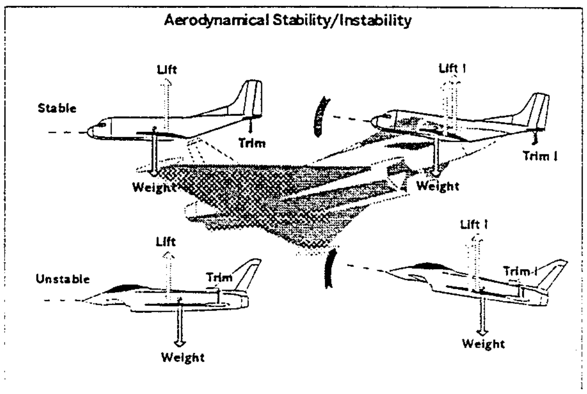


With the given benefits of a delta wing, our early studies have shown that Delta Canard configurations result in shorter, more compact and lighter aircraft than delta wings with tail planes.

Besides of the sample of advantages there are also features which are less attractive. The foreplane has a triggering effect on the wing flow. Thereby aerodynamic non-linear characteristics of the wing itself may be simplified or additional ones introduced by the foreplane. Many aerodynamic studies and windtunnel testing were required to understand the complex flow mechanism and to maximise the benefits whilst keeping detrimental effects as low as possible.

The aircraft is aerodynamically unstable about the pitch axis in subsonic flight and is artificially stabilised by a digital, quadruplex redundant, fly-by-wire flight control System. The basic principle of the unstable design is, that the total resultant of the aerodynamic forces acts forward of the centre of gravity and requires for trimming a downward setting of the flaps. With increasing lift force, the flaps have to be moved further downwards in order to balance the nose-up moment. This is an ideal adaptation of the wing camber to the airflow at varying angles of attack which reduces substantially lift dependent trim drag compared to stable aircraft, where the lift force acts aft of the centre of gravity. The wing camber adaptation is further enhanced by leading edge slats which are also controlled by the Flight Control System and move downwards with increasing incidence.

Sustained and instantaneous turn rates are therefore substantially better than for a stable design.



Although the aircraft becomes aerodynamically stable in supersonic flight, the centre of pressure is still further forward than for a subsonically stable design. The advantage of reduced trim drag and better turn performance is therefore still retained in supersonic flight. However, artificial stabilisation requires more effort in the design of the Flight Control System, in control law design and in final clearance work.

Contrary to other "canarded" configurations the one used intentionally resembled a "long-coupled" canard with the idea in mind to use it for additional pitch control - particularly at high incidence - in addition to the high lift device benefits like on the well known "short-coupled" concept.

A major impact on foreplane location and foreplane wing coupling is the place of the air intake. The chin intake location as chosen for Eurofighter was one of the key configuration features. From an aerodynamic point of view this intake offers advantages at medium and high angles of attack even when combined with sideslip. The airflow quality to the engines remains excellent at angles of attack well above maximum lift. The pre-compression due to the lower forward fuselage shape provides also excellent pressure recovering values for good engine performance at high supersonic Mach-numbers.

The Structural Concept

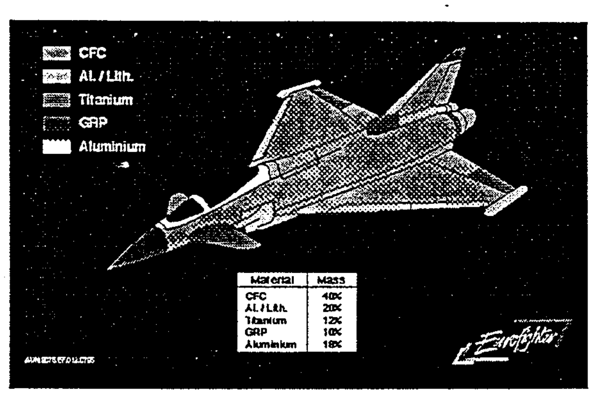
The structural design of Eurofighter has been given to provide the lowest possible mass providing sufficient strength and fatigue life including protection against environmental conditions with an airframe being free of inspection over the lifetime as well as allowing rapid repair of the structure after battle damage.

The airframe structure makes considerable use of

- modern material such as Carbon Fibre Composites (CFC) which enables excellent strength-to-weight and stiffness-to-weight ratio and is free of corrosion and fatigue
- advanced manufacturing methods like super plastic formed (SPF) and diffusion bonded (DB) titanium, which has high strength and toughness and is heat resistant. The SPF-DB process of metal as well as the automatic tape-laying with single shot manufacturing of CFC-parts reduces the number of single pieces, thus reducing weight and manufacturing effort.

Particularly to note are the facts, that

- mass saving in the order of 13% by use of CFC and new manufacturing processes is achieved
- a design envelope from - 3 g to + 9 g with an override option in case of emergency is cleared
- a maximum recovery temperature of 100° C and a maximum stagnation temperature of 117° C are allowed
- the fatigue life of at least 6 000 flight hours against a severe fatigue spectrum will be achieved.



The aircraft structure is built in six main sections:

- Front Fuselage including cockpit area, canopy/ windscreen. The material is mainly carbonfibre with the major internal frames manufactured from aluminium alloys,

- Centre Fuselage, including fuel tanks, chin intake, secondary power system, part of the main undercarriage bay, the nose undercarriage, the major wing pick-ups and the internal cannon. The airbrake is mounted on the spine behind the cockpit. Mainframes are of aluminium alloy with extensive use of carbon fibre for external skins.
- Fin and conventional rudder are manufactured from carbon fibre with aluminium alloy on the leading and trailing edge.
- Rear Fuselage with two major metal frames supporting the engines. The rear frame also incorporates fin and arrestor hock attachments. The vertical shear web separates the engine bay and is manufactured from superplastic-formed / diffusion bonded titanium. Two large engine bay doors are fitted. Where temperature permits, carbon fibre is used for external panels.
- Wings with integral fuel tanks as multi-spar CFC construction. There are full span inboard and outboard flaperons and leading edge slats. Wing tip pods house the Defensive Aid Sub Systems and are an integral part of the wing design.

The Electronic Systems

The Eurofighter Electronic Systems are highly integrated. The functional structure at the first level distinguishes

- the Flight Control System (FCS)
- the Avionic System (AVS)
- the Utility Control System (UCS).

The FCS ensures stabilisation of the aerodynamically unstable aircraft configuration, commands the aircraft control surfaces to exercise steering inputs, provides "carefree handling" and includes a wide range of autopilot functions. The AVS comprises and integrates the mission oriented equipment to enable communication, navigation, displays and controls, target detection, tracking and engagement, weapon control, threat detection and countermeasures.

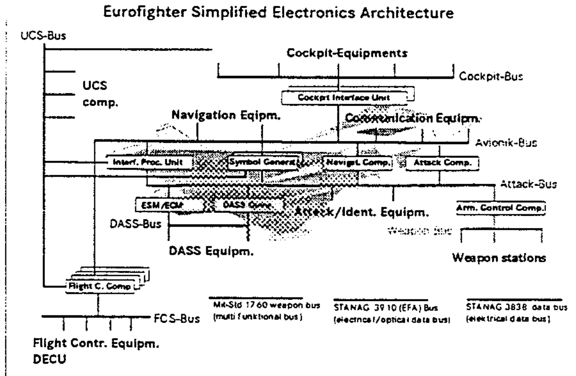
The UCS provides monitoring and control of the aircraft general systems such as Hydraulics, Landing Gear, Fuel System, Electrical Power Generation, Distribution, Environmental System, Secondary Power System etc.

Although FCS, AVS and UCS perform different task within the Eurofighter weapon system, their design is based on common considerations and features:

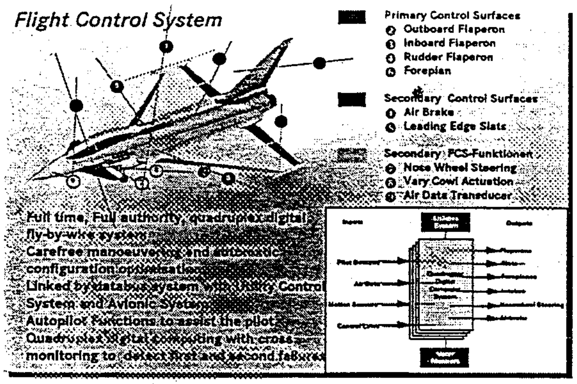
- redundancy in equipment and functions is widely implemented to ensure flight safety and mission effectiveness
- reduction of pilot's workloads and optimised man-machine-interface
- type of databuses and their architecture to provide a large growth potential
- wide use of standard processors to reduce development and maintenance cost
- common software development methodology and software tools.

All three systems are connected by databuses and dedicated links.

Eurofighter Simplified Electronics Architecture



Eurofighter has full authority digital quadruplex fly-by-wire system, which provides artificial stabilisation, carefree handling ensuring that flying limits cannot be exceeded by the pilot, excellent control and handling characteristics and autopilot functions. Direct pitch control is provided by all moving foreplanes together with full span flaperons. Roll control is obtained by flaperon and rudder movements. The leading and trailing edge devices optimise the aerodynamic characteristic of the aircraft over the full angle of attack envelope whilst minimising drag at all times. An airbrake provides deceleration and accepts pitch control for the aircraft. Control of nose wheel steering, the vary cowl intakes and several autopilot functions are additional tasks of the FCS.



The FCS operates in response to information received from sensors provided on the aeroplane. These are the pilot controls, inertial sensors, flow angle sensors, pilot static, intake pressure and total temperature probes.

The FCS software is also arranged to ensure good aircraft response and handling in all cases and to properly calibrate sensor signals.

The FCS provides a number of functions to assist the pilot including pitch and bank hold, barometric altitude acquire and hold, Mach-hold, IAS-hold, heading acquire and hold, track acquire and hold, automatic approach and autothrottle. In addition tactical autopilot modes have been implemented (e.g. Auto Cap or Auto Attack).

A primary consideration in the design of the flight control system was the provision of an appropriate level of integrity to ensure flight safety. There has been designed in failure tolerances and graceful degradation in cases of malfuctions.

The flight control system allows to deal with the non-linear aerodynamic characteristics of the configuration, particularly important at subsonic/transonic speeds. It allows refinement of handling qualities, endowing a good measure of carefree handling - extremely important for intense single crew air-to-air combat.

The protection from electromagnetic interference was an important consideration for the flight control system and resistance up to levels well above hundred volts per meter is accommodated by the design and verified in extensive tests.

In the event of pilot disorientation the FCS allows for rapid and automatic recovery by the simple press of a button. On selection of this autorecovery facility the FCS takes full authority (including of the engines) and fully controls and automatically stabilises the aircraft in a wings level gentle climbing attitude at 300 knots until the pilot is ready to retake control.

High mission effectiveness and survivability is ensured by an integrated avionic system comprising the following seven functional subsystems:

- displays and controls
- attack and identification
- navigation
- monitoring, test and recording
- armament control
- communications
- defensive aids.

The Eurofighter avionic system architecture makes extensive use of STANAG 3838 electrical and STANAG 3910 electrical/optical databuses for avionic data transmission. A MIL-standard 1760 weapon bus is implemented in the armament control. The STANAG 3910 fibre optics databuses are essential to Eurofighter as they allow the massive amounts of data used by the various systems to be transmitted around the aircraft at the required rates.

The high level of integration and sharing of information between the various subsystem computing centres gives the pilot autonomous ability to assess rapidly the overall tactical situation from both his onboard sensors and via data links with other airborne or ground-based systems. Based on this situation awareness he can respond efficiently to identified threats during air-to-air or air-to-service attack missions.

The entire system is designed to minimise workload in the cockpit. In case of failures, graceful degradation is designed into the system. There are pre-flight and in-flight built-in tests to monitor systems and equipments and provide for rapid failure diagnoses.

The system is designed with growth potential that is to say at the completion of the original development contract only about half of the memory and processing capacity will have been used. This gives great potential for introducing new weapons without equipment change and tailoring certain parts of the weapon system to customer needs. Rapid change systems and processors are being considered to offer high response to customer requirements.

Nevertheless due to the planned long lifetime of the weapon system continuous monitoring of obsolescence components and solutions on how to replace them over the time have to be implemented.

As far as the cockpit is concerned, a high level of system integration and automation has been adapted to allow safe and efficient single seat operation in the multi-role environment. Significant attention has been given to the man-machine interface. Advanced digital technology not only enhances operability and survivability but also simplifies aircraft maintenance. The main interaction between the pilot and the aircraft systems is via the manual data entry facility, the head-up display, multifunction colour head-down displays, throttle and stick controls and direct voice input.

The advanced cockpit design and layout has arisen from a series of formal assessments by operational pilots from the customers Air Forces carried out in a rapid prototyping facility.

The attack and identification system performs the detection, acquisition, tracking, identification and engagement of targets and includes air-to-air features with look-up/look-down capability, multi target track and prioritisation, offensive manoeuvre and weapon release computation. The air-to-surface features contain ground mapping/ranging, terrain avoidance, weapon release computation and sea surface search. The European collaborative radar (ECR 90) is being developed by the Euro-Radar consortium. This fourth generation multimode pulse doppler radar is the first airborne radar in NATO with three as opposed to two receiving/processing channels.

To compliment the radar a dual mode forward looking infrared sensor is mounted on the port side of the fuselage forward of the windscreen. In the air-to-air role the sensor is used for passive search, detection and tracking of targets. In the air-to-surface role the forward looking infrared is used for target acquisition and identification. It also provides a landing and a night flying capability.

The defensive aid subsystem (DASS) is internally housed. It provides an all-round prioritised assessment of air-to-air and surface-to-air threats with fully automatic response to single or multiple threats (manual override being available).

The high integrity armament control system manages store selection fuzing/arming, gunfiring and the release/jettison of all weapons. It monitors weapon status and controls the primary weapon modes. It is designed, so that no single fault in the armament control system will cause or prevent the release or jettison of any store.

The basic navigation system incorporates a ring laser inertial equipment with an accuracy of better than one nautical mile per hour with full alignment time of four minutes or less.
The integrated monitoring and recording system plays a key role in ensuring high aircraft availability and low life cycle costs. All aircraft systems, the airframe and the engines are continually monitored for status, damage and exceedance of parameters. The system provides a means of rapid onboard fault diagnoses and manual or automatic recovery to maximise operational capability.

The Eurofighter Utility Control System is a digital integrated control system, consisting of seven computers, connected to a dual redundant STANAG 3838 databus. The system is designed to provide primary control and monitoring of the aircraft, general utility systems, comprehensive built-in test functions and interfacing with other aircraft systems including avionics, flight controls and indirectly with propulsion. The UCS reduces pilots workload by providing increased automation of basic system functions and by continuously monitoring system performance to provide status warnings and automatic reconfiguration to safe conditions as and when required. The maintenance data panel, which is easy accessible by the ground crew, provides in plain language display any line replaceable unit failures on board of the aircraft. It further incorporates removable data storage module and facilities for connection of a printer for immediate hardcopy as well as connection for detailed bus analysis equipment if desired.

Logistics

Design for the logistic support is inherent in the Eurofighter engineering design process. It has therefore been applied from the outset on the Eurofighter programme. Right from the beginning of the development of Eurofighter there has been given equal priority to

- safety
- weapon system performance
- cost
- reliability, maintainability and testability features.

Influence on design and development by well defined reliability, maintainability and testability programmes have led to

- low defect rates
- reduced maintenance man-hours per flying hour
- improved fault isolation / location by built-in test capabilities.

Eurofighter is designed to have a defect rate not exceeding 400 defects per 1 000 flying hours for the single seat aircraft.

In parallel with the development of the aircraft itself there are developments of the aircrew synthetic training aids and the ground support system to ensure sufficient system support right from the beginning of the in-service phase.

The Engine For Eurofighter

The engine and its cycle were designed and optimised in a highly integrated joint effort with the aircraft manufacturer in order to meet all weapon system requirements of the four nations.

The EJ200 engine is a two-spool turbofan with modular construction for ease of maintenance and support. The broad blades of its wide chord fan with integral blade/disc in all stages are light and aerodynamically efficient as well as possessing a high level of resistance to foreign object damage. The fan has no inlet guide vanes, which reduce mass and complexity and improve birdstrike capability without compromising operability. Both the high pressure compressor (five stages) and low pressure compressor (three stages) are driven by single stage advanced air-cooled turbines featuring the latest single crystal blade technology.

Brush seals are used instead of labyrinth seals in the air system throughout the engine. Low smoke and emission characteristics have been designed for the main annular combustor which incorporates airspray fuel injections.

The key cycle parameters overall pressure ratio, turbine inlet temperature, fan pressure ratio and the resulting bypass ratio were defined as follows:

The overall compression pressure ratio was set to the highest level possible within the constraints of engine and airframe materials which dictate the maximum acceptable level of compression exit temperatures within the Eurofighter flight envelope.

The choice of turbine inlet temperature and fan pressure ratio and the associated bypass ratio resulted from the integrated aircraft engine design study and optimisation.

A convergent/divergent nozzle was chosen because a higher reheated thrust at supersonic Mach numbers can be obtained due to the better nozzle expansion. Of more importance, this higher thrust at a given fuel flow improves the reheat SFC even more and is a very important parameter for maintaining combat at supersonic speeds. The detailed study shows that the nozzle can be designed for negligible loss at subsonic missions and in particular for ferry and low speed loiter missions.

The reheat system features a radial hot stream burner, independent cold stream burning and the hydraulically operated convergent/divergent nozzle. All accessories including the full authority digital engine control unit are self-contained and engine-mounted. An auxiliary gearbox on the underside of the engine provides drive for the accessories.

The engine embodies mature engineering technologies with designers able to draw up a knowledge already available within the various participating companies.

Engine control is by an advanced light weight full authority digital engine control unit. The hydro mechanical element of the fuel system is of a new advanced type with minimum size and mass.

Eurofighter's Growth Potential

The overall technical concept of the Eurofighter, which is defined in the contractual weapon system design and performance specification, turns out to be very successful and stable. However, in view of the long planned in-service life of the weapon system, the need for modifications and upgrades may rise due to the developing threats and to continually strive for low cost of ownership. Areas of future upgrades may be

- integration of new weapons
- enlarged spectrum of external store configurations
- further enhancement of the flight and mission performances
- integration of forthcoming generations of avionics
- adaptation of the weapon system to new or updated threats.

Studies are already on the way to consider further extensions to Eurofighter 2000 system capabilities, such as

- thrust vector control,
- terrain following through enhanced ground proximity warning systems,
- continued life cycle cost reduction,
- reconnaissance capability,
- further developing potential for beyond visual range and short range weapons,
- increased carriage capability.

The Eurofighter is in an unique way prepared for these later upgrades by its high growth potential in term of electrical power and cooling capacity, computing power and high performance fibre optical databuses. The engine is also designed for pre-planned production improvements, for significant future thrust increase.

Eurofighter Programme Status

On March 27th, 1994 the first Eurofighter prototype made its maiden flight at Manching, the second one only a few days later (April 6th) at Warton. The first Italian development aircraft (and the first one with the newly developed engine) flew first in June 1995. The first Spanish prototype (and the first one in the double seated trainer version) took to the air in August 1996. Since March 1997 all seven development aircraft are in flying status.

Flight envelope expansion has been achieved very rapidly. Up to now more than 80% of the envelope have been covered with an airspeed up to Mach 2 and more than 40 000 feet altitude.

In the last weeks of 1997 some major flight test events took place, like first-in-flight launch of a Sidewinder, first jettison of an AMRAAM and first air-to-air refuelling.

The use of advanced flight test instrumentation and data-gathering methods allows detailed evaluation in real-time or within a very short time period. Out of flight tests performed up to now there are no indications of problems, which would require major modifications or changes to the design.

Also extensive ground tests (e.g. the important Major Airframe Fatigue Test, which has in the meantime (status March 1998) completed more than 16 000 simulated flying hours, i.e. more than 2.5 times the required structural life) have provided the necessary confidence in the aircraft design.

The Customer was given a great deal of visibility by reports, witnessing of test, assessments at the Active Cockpit and by the two "Previews" for the Official Test Centres (OTC's) which already took place (some more will follow). During these Previews OTC pilots have the opportunity to perform ground tests, taxi runs and test flights. The first OTC Preview took place in spring 1996 at Manching, the second one in May 1997 at Turin. All pilots, which have flown the aircraft, rated the product from good to excellent and as exactly the fighter aircraft required by the European Air Forces. Up to now we have completed some 700 test flights successfully.

Encouraged by these results on December 22nd, 1998 the defence ministers of the four participating nations signed MoU 6 and 7 covering the production of 620 Eurofighter and the related product support. On January 30th, 1998 the related frame contracts and the production investment contract were awarded to industry.

Conclusion

This presentation has not set out to be highly detailed in nature but merely to give a picture of what Eurofighter's weapon system looks like, how it is being developed and what some of the key technology issues being addressed are and finally about the growth potential which is inherent in the total weapon system.