Eurofighter: Aerodynamics within a Multi-Disciplinary Design Environment

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Abstract

The art and science of aerodynamics have been developing continually to meet the changing needs of aircraft of all types. in many cases, combat aircraft design drives this development farther and faster in the search for improved combat effectiveness. One result has been that an ever broadening of the individual but heavily integrated aspects of aerodynamics into a set of interdependent, diverse fields, covering fluid dynamics, structural dynamics, solid body mechanics, ballistics, acoustics and more recently electro-magnetics. Together, these individual disciplines are combined together into a term sometimes referred to as aerodynamic technology, as described in a recent Royal Aeronautical Society edition (1).

This paper will examine the requirements placed upon these disciplines in the light of the multi-disciplinary design optimisation process that took place on the Eurofighter project, specifically highlighting the roles of the aerodynamic technologies within that process and the lessons learned from their application in this environment. The paper will also provide some recommendations for improvements in the design capabilities based upon the experience gained and lessons learned from the design of the Eurofighter Weapon System.

Introduction - The Need for an Integrated Design Environment

The first air to air conflicts occurred in the Great War. Here, aircraft were, for the most part marginal with regard to performance, stability and controllability. Indeed, many combat losses could be attributed to these shortcomings rather than the action of the enemy. However, some of the aircraft were regarded, and still are, as models of the agile fighter, particularly in the hands of an expert pilot, or "ace". The basic skills required were the ability to remain in control and shoot accurately.

For subsequent conflicts, the same basic skills were required, although airframes were better stabilised and controlled and had increased power available, resulting in higher speeds. With radar and radio, it became possible to receive guidance towards the targets that the ground control perceived as the prime threat. Weapons remained visual range, however, but regardless of this, the increased speeds and the added information changed the difficulty of the pilot's task due to the implications on his situational awareness and choice of tactics. Increasingly, the combat results became more clouded by the interaction of the systems available to the pilot and his ability to assimilate the information provided.

The advent of jets, airborne radar capability, missiles and counter offensive equipment have all tended to complicate the picture whilst attempting to improve the ability to perform the same basic tasks, i.e. finding the opposition and shooting him down. Korea demonstrated the benefits of high performance combined with good handling, to the detriment of the Communist forces. However, some lessons were forgotten, and had to be relearned in later conflicts.

Effectively, the processes described above have resulted in individual areas developing their capabilities for the goal of increased effectiveness, all with the aim of making the task of the pilot or crew easier to perform. However, what resulted was a management problem within the cockpit, i.e. each time a system improved to make it easier to use, another one or two were added.

In the case of Eurofighter, the decision was made to make the management of many of the systems automatic, such that they should look after themselves and allow the crew to concentrate on his tactics and operation, whilst the on-board systems do all the housekeeping. All of this was

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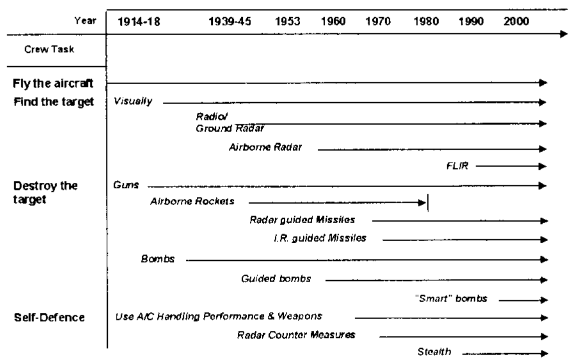
required whilst achieving new levels of performance and handling of the aircraft, thereby ensuring that the crew always have the upper edge in any combat or other task.

The environment in which a fighter pilot operates is subject to continual change due to technology advances and the altering world situation. The only prediction that can be made with confidence is that profound change should continue to be expected.

The Growth in Complexity of Crew Tasks in Combat



The Eurofighter, now known as Typhoon for the export market, was designed into an age where this statement was never so true. The aircraft was conceived during the latter stages of the Cold War, where the primary threat was still considered to be the Soviet Bloc. Late in 1989, the Berlin Wall fell and the whole scenario changed politically across Europe. However, the various programme delays allowed for a re-assessment of the aircraft and its requirement, with experience of the Gulf War and early operation in the Balkans feeding into the military awareness. The result was that the need for the design was re-affirmed with relatively minor changes to the requirement being defined and accepted by the contract reorientation.

The primary reason for the success of the aircraft design concept lay in the inherent flexibility that could be achieved from the combination of the technologies employed in the aircraft and the integrated nature of the aircraft-weapon system design. From the outset, the aircraft was designed around air-air and air-ground roles, and this latter role has been strengthened in the recent past without requiring major upgrades to then design.

The whole weapons system design is driven by the need for agility, flexibility and availability, and rather than adopt a traditional approach, the vehicle and the weapon system has been designed to be blended and integrated to make this achievable.

A concise definition of agility is provided by the report from AGARD on agility [2], which states

"Operational Agility is the ability to adapt and respond, rapidly and precisely, with safety and poise, to maximise mission effectiveness."

This addresses the whole weapon system, but Operational Agility can be considered as being made of three essential components, i.e. the Airframe, which we will take to include the Flight Control System, the Mission Systems and the Weapons. Our concern within this review is the Airframe and the place of the Aerodynamic technologies within this design process.

The role of aerodynamics in this design optimisation was one of enabling the levels of performance required with the stability and control characteristics required for the generation of agility combined with carefree handling, which has proved to be a major engineering activity to ensure that this is achieved satisfactorily.

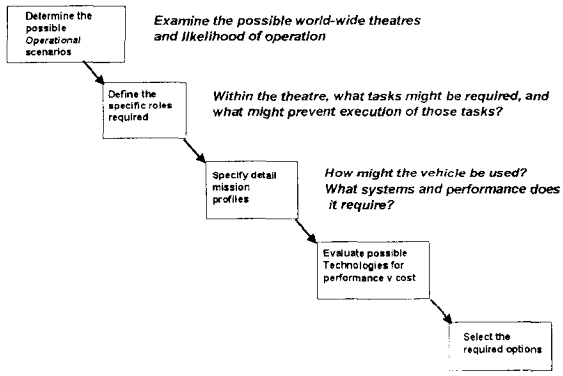
Whilst the work on the control system development is ongoing, the level of manoeuvre capability and airframe agility that has been demonstrated already is breath taking.

The Weapon System Specification

Traditional combat aircraft specifications and requirements were not really appropriate for the complex, integrated vehicles that have to result from attempting to meet the requirements. The more traditional processes often arrived a set of aircraft systems that had to be managed individually, rather than having an integrated management. The very complexity of the vehicles often means that decisions relating to the design options may not take into account all the influences, leading to engineering difficulties and expense later in the processes of development and procurement.

There was a need to change the way in which Weapon Systems were formulated. The concepts involved in total mission system engineering and simulation have assisted in the process of determining what the Weapon System Specification should contain and in the design and subsequent evaluation of the vehicle that results. Eurofighter, as a project, has followed this integrated approach and has been deeply influenced by the transition from a more serial process to one of extensive parallelism.

Process for Determination of the Vehicle Roles and the Integration of the Technologies to be applied.



What was required was a method of defining the intended role of the vehicle, then breaking this down into a series of missions, then mission tasks, then mission task elements. From these, it should be possible to establish the interactions of the various technologies that can be applied to the aircraft. One of these technologies relates to the vehicle aerodynamics.

In the case of Eurofighter, this process resulted in a Weapon System Specification being agreed and contracted in 1988. This Specification has been subject to continuous review, particularly during the period of reorientation of the contract, culminating in a re-signature of the contract in 1994 and the subsequent placements of the Production Investment and Production contracts during 1998 and 1999. The result is a total Weapon System, i.e. an aircraft, its sensors, processing and displays and weapons package, that is flexible, highly integrated and supportable, with low life cycle costs and high availability. Indeed, the specification places as much emphasis on these latter aspects as it does on overall performance.

Aerodynamic Technology in the Initial Design

From the very outset of the project, aerodynamics played a very significant part in determining the nature of the vehicle that would fulfil the requirement to be met. Whilst a considerable data base had been constructed from the previous aircraft projects, such as TKF-90 in Germany, the tri-national ACA study and real projects such as X-31A and EAP (Experimental Aircraft Propgramme), the Eurofighter requirement also added something new. By changing the balance of the design requirements, changes to the configuration were allowed with a different optimum solution resulting.

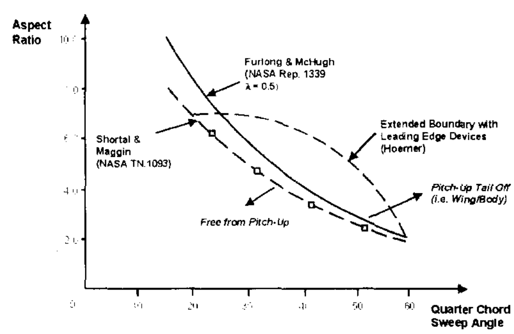
A number of examples can be shown where this integrated design approach was required and in which the aerodynamics team played a significant role.

Aircraft Configuration and Wing Design

The requirement emphasis on a combination of agility, low and moderate speed manoeuvrability and supersonic sustained performance directly resulted in the choice of the delta-canard configuration. Extensive use was made of wind tunnels and CFD methods, as an integrated design activity, to ensure that the design met its particular requirements in terms of the aerodynamic performance.

Wing Planform Optimisation (1)

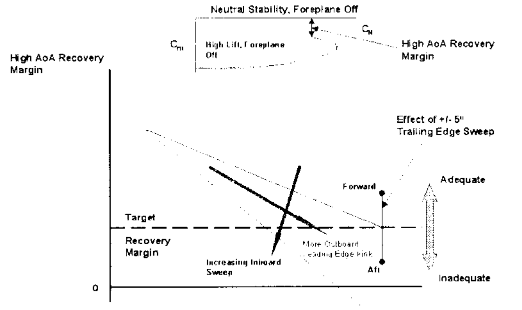
Approximate Pitch-up Boundaries in relation to Sweep and Aspect Ratio



The design process required a closely integrated study with the aircraft structural designers, with information being regularly passed back and forth between the two areas. Key decisions for both disciplines resulted from the need to ensure that the aeroelastic stiffness of the wing was achieved, whilst being able to tailor the stiffness such that the required aerodynamic shapes were maintained for both cruise and manoeuvre conditions.

Wing Planform Optimisation (2)

Effect of Planform Parameters on High AoA Recovery



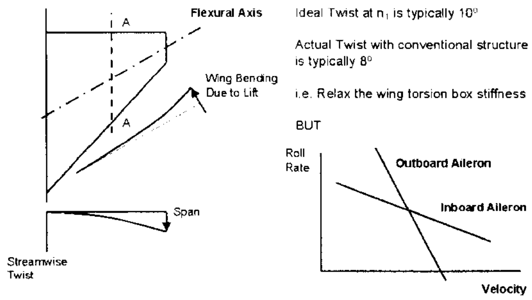
Wing trailing edge angle, flap position and sizing, including the size of the powered actuation system all result from the trade studies that were performed. This required the integration of the structural model, available via versions of Nastran, with aerodynamic models that existed in a number of different aerodynamic tools. The Nastran aerodynamic packages were not used as they were not sufficiently advanced to cope with some of the transonic and separated flow conditions that were of prime interest.

Significant effort was placed in correlating the results of the different aerodynamic design methods with experimental data from early wind tunnel tests to ensure that consistent results were being obtained, and that the overall aerodynamics of the wing matched the performance requirements and the needs of the flight control system. This latter demand placed significant burden on the aerodynamic designers to achieve as linear a design, in terms of pitch stability, as possible. Past experience from many previous projects with similar configurations indicated that some level of non-linearity was inevitable, however.

The demand for linear aerodynamics for the flight control system is always present with every aircraft design. However, there is also a view that, because the FCS is clever, it can cope with very non-linear aerodynamics. The phrase often heard was "never mind, the FCS will take care of it!" In the case of Eurofighter, the level of instability that was required for the overall aircraft was such that linear aerodynamics became a much firmer requirement, together with good aerodynamics from the flying controls. The whole success of the aircraft concept relies upon the aircraft being controllable in a carefree manner throughout its envelope of normal operation.

Wing Planform Optimisation (3)

Optimisation of the wing torsion box determined by aeroelastic efficiency - wing bending v torsional stiffness for rolling



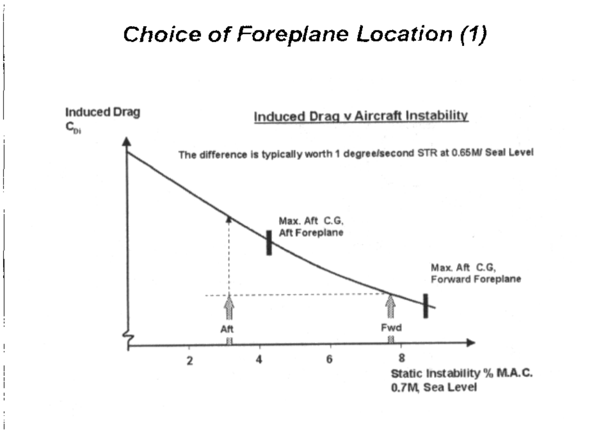
Further, having achieved a satisfactory theoretical design, the final step of the wing design activity is to take account of the wing structure to arrive at the shape that has to be manufactured in jig, in order that the shape in flight is correct. This reveals a "less traditional" interface with the manufacturing engineering organisations. Dialogue here reveals what can be built easily, and allows a further round of optimisation to ensure that the design is not so demanding that it cannot be built.

Foreplane

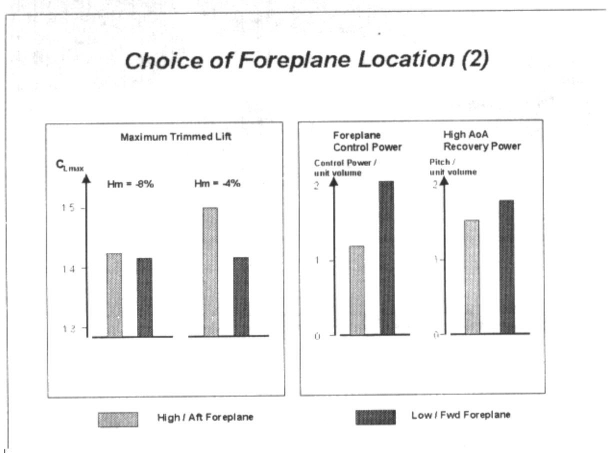
In regard to the foreplane, when factors such as aircraft layout, access, visibility from the cockpit and the aerodynamic interference with the wing are taken into account, then only two positions for the foreplane remain viable for further evaluation. These are forward and low or high and aft, using the wing plane and leading edge apex as a reference.

Extensive investigation over a period of years prior to defining Eurofighter had shown that intermediate positions were disastrous, regarding the aerodynamic interference with the wing, due to inadequate separation of the surfaces.

Consideration of aircraft performance dictates the maximum possible instability to avoid excessive induced drag penalties, which leads to the requirement for foreplane volume. The minimum induced drag occurs with a level of instability equivalent to about 16% of the mean aerodynamic chord, which is approximately twice that that the FCS can cope with. The high AoA recovery, i.e. the ability to pitch the aircraft down from high angle of attack, whilst at low speeds, dictates that the configuration should be neutrally stable with the foreplane off, which is equivalent almost to an unloaded foreplane. This dictates that the foreplane volume has to be such as to generate around 8% m.a.c. instability at low speeds. A low forward foreplane position then results in the smallest foreplane area, with a consequent benefit on supersonic drag.



Further, at the level of instability chosen for the aircraft, there was little effect on maximum lift of either position, whilst for a less unstable aircraft, a high aft foreplane does provide some benefit on lift. Further, the low forward foreplane is more effective as a control surface, with consequent benefit for nosewheel lift, trim and manoeuvre capability. This increase in effectiveness is maintained, even at high angle of attack, where the effect is to provide more pitch recovery capability for high angle of attack recovery.

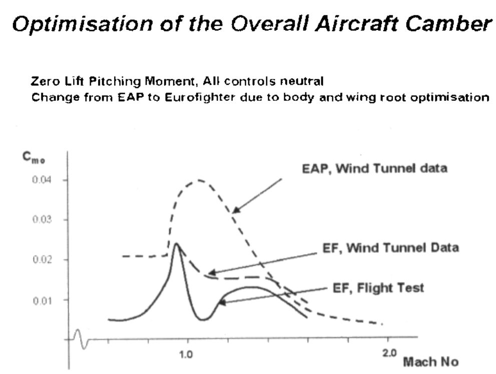


Hence, with all these considerations, the foreplane position used on Eurofighter was chosen. It is to be noted that most of this particular design optimisation was performed from an experimental data base using empirical techniques, as adequate capability to fully model all of the aerodynamic interference did not exist within the CFD modelling capability in use at the time.

Fuselage Shaping

One of the key drivers for good sustained supersonic performance derives from the combination of stability level and flap or foreplane angles to trim. Clearly, the wing itself has a significant contribution, but a major effect comes from the fuselage itself. Recognising this as a result of experience flying EAP, significant effort went into developing a capability to predict the effect of the fuselage effective camber shape on the zero lift pitching moment.

EAP had shown a significant change in this term as the Mach number increased through M=1.0, with consequent larger flap angles required to trim than had been desired. To avoid this with Eurofighter, significant effort was placed on modelling the aerodynamics using CFD methods. Design changes were restricted to the wing root camber and overall fuselage camber, within the constraints provided by the need for good vision from the cockpit and the chosen chin intake configuration and the need to minimise the basic form drag of the aircraft. These changes were then evaluated via wind tunnel test at transonic speeds, before finalising the aircraft lines for build.



Interestingly, even with this effort, this has still proven to be an area where the aircraft in flight is slightly different to prediction, although the discrepancy is a fraction of that noted on EAP.

Fin design

From the early days of the configuration development, there has been a debate about the number of fins. The early configuration studies examined both single and twin fins, but eventually the single fin was found to be the best optimum in terms of structural mass, drag, adverse flap-fin interaction for roll control transonically and effects on stability and lift.

However, this still left a decision as to whether the aircraft should adopt an all flying fin, or a more conventional fixed fin and rudder. The fin is sized by the directional stability requirement for flight at M=2.0. In the trade studies that followed, it became apparent that the fixed fin, because of its much greater structural efficiency, was smaller and lighter. Had control power been the more dominant requirement, then the all moving fin would have provided the better optimum.

In the end, the fixed fin and rudder was confirmed. The decision was again driven by the balance between reduced drag and greater control power, which would have been provided by a smaller all moving fin, against the aeroelastic stiffness problems it introduced in achieving the stability requirement, together with the size of the actuation system required.

However, the rudder is still the largest control actuator on the aircraft.

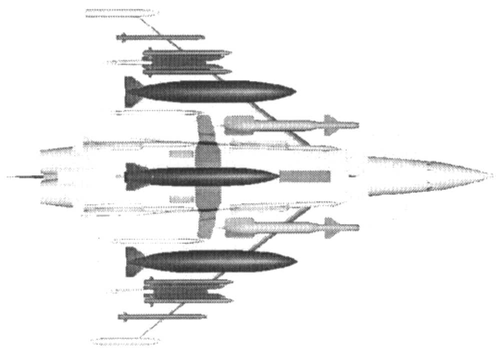
It should be said that there were some engineers, who had worked on the BAC TSR-2 project which was cancelled in 1966, who were extremely relieved at the outcome, despite the advances in technology that had taken place, due to concerns with that design over the structural coupling. Past experience suggested the likely outcome from the start, and even with the advances in materials for the aircraft structure, improved actuation systems and design techniques, the conventional fin is best, and that the all flying fin represented an unacceptable risk for the project, at least from this aspect.

Weapons Layouts

Whilst Eurofighter initially was thought of as an Air Superiority Fighter, it has always had a ground attack requirement, which is becoming stronger with time with all the partners Nations. One advantage of the configuration is that it provides a very large flying surface for the weapons engineers to hang a lot of external ordnance upon. This allows for a large number of weapon stations, and permits the aircraft to carry its Air-Air (A-A) and Air-Surface (A-S) weapons at the same time.

Improvements were being made in the ability to model weapons trajectories in the early phase of the release from the aircraft. It was possible to consider packing the

Eurofighter
Illustration of the Weapon Packing Density



weapons together more densely and to reduce the amount of basic wind tunnel testing that was to be planned into the programme from the outset. Further, the aerodynamic modelling processes, as proven on current previous projects, had shown that the need for such test techniques as twin sting rigs, or for wind tunnel measurement of external flow fields, were no longer essential. As a direct consequence, all flow field data is generated via CFD calculation. The only test evidence that is now used are the installed loads data, or, in the case of missiles, loads measured at the end of stroke or end of rail positions.

Eurofighter
Configured with Air-Ground & Air Weapons

The Changing World

As the project moved through its Development Phase into the Flight Test Phase, and activity started to build up towards Production, a number of significant changes have come about to the world in which the aircraft was to operate. The Berlin Wall came down; there were numerous conflicts and a change in role for the Air Forces of the Nations within NATO. The role of the aircraft was reconfirmed, with an increased emphasis being placed on the A-S capability, with the requirement moving to a very much more flexible aircraft, capable of operating autonomously for extended periods.

These changes do not affect the aerodynamics of the vehicle itself, but do have a very significant impact on the aerodynamicists involved in the project, and indeed upon every other engineer involved within the Eurofighter project and across all partner companies. The changes affect the way in which the engineers work, which in turn, impacts back onto what they have to do.

No longer could any area work in isolation from the other areas of the team. Affordability became a key driver for all the engineering and manufacturing areas, changing the working processes employed. This change is the move from the old cost plus environment, where everyone was paid for the work they did, to a fixed price contract structure, with both penalties and incentives. This has forced the adoption of parallel working in Integrated Product Teams, changing both the technical processes that are used and the management and leadership skills that are required to deliver the results.

Achievement of the recently placed Production Investment and Production contracts by the four Nations is totally dependent on the success of implementing the changed working practices, tool-sets and behaviours of the people involved in the project, wherever they work within the Customer – Supply chain.

This chain of events is set to continue throughout the life of the project, with every Customer and with every Supplier

The Changing Role of the Aerodynamic Technologies

As the project has developed with time, the role of the Aerodynamics specialists has changed, to meet the demands that have been placed upon the project by both the Customer and Industry. This situation is continually developing and is likely to increase the pace of change as the Customer base for the project increases.

The project is moving to a vision of being able to respond to changes in Customer needs on a regular basis, particularly as the need to integrate new weapons increases. This drives a range of Airframe related activities and the associated changes in Avionics or Flight Control System.

The aerodynamic technologies, which relate to optimising the design or installation, completing the design data and then generating the appropriate flight clearances have required significant modernisation and adaptation in order to be able to contribute to the overall integrated product.

Two main areas can be considered where the change can best be described, namely in the Processes involved in the technical work and in the management of the integrated product teams.

Process Changes

To maximise support for the project activity, dedicated project teams have been established. These teams are broken down into product based teams, populated with members drawn from those areas that have to work together to achieve a final, deliverable product. All the team members are focussed on delivery of their individual products to the project stream. This has resulted in significant changes to both the tool sets that are employed and to the development of concurrent engineering management practices, supported by excellent modelling environments.

Technical Processes

A key change that has occurred with the production activities is the change from a drawing based environment to an electronic product definition, with the concurrent activities requiring major attention to configuration control and release of data. This has enabled a change to the total process of design and manufacture, with the ability for the design teams to interact directly with the product being manufactured. To meet the challenges that this environment has posed, new working environments have been developed. This new environment is known as the Integrated Product Development (IPD) Process.

This process, supported by a software based configuration management tool, Product Manager, is becoming the established means of controlling the output of all engineering tasks on the project. Initial work with the process focussed upon the creation of the replacement for the traditional drawing sets, with all designers and the manufacturers having access to the data concurrently, but only able to use it for its defined purpose once formally released electronically. This is now being extended to cover the functional aspects of the design, such that the data pertaining to all the aircraft systems, which include all the aerodynamic "discipline" based systems, are all included. Hence all the design calculations, clearance calculations and performance verification data are to be included within this tool, either directly or with a controlled reference, with consequent immediate access for all to properly configured data.

Currently, this is being extended to cover, not just the form and fit of the individual systems, but also the function of each of the systems. This tool will form the environment for management and control all of the data used for qualification, certification and verification of performance against the contracted levels. Any changes that occur in any of the data within the system has to be approved by the relevant stake holders before the data can go live, but it then goes live immediately to all potential users.

The use of desk-top processing, as opposed to the mainframe environment that existed on previous projects, has enabled the development of a new generation of engineering tools. The key drivers have been towards the development of interactive tools capable of producing their answers quickly, such that the engineers can develop the next step in the design quickly, as required by the parallel working practice now in use. In many cases, this has simply meant the porting of existing software tools into the new desk-top environment, but for some areas, completely new tool sets have been required.

As an example, further advances have been required in the analysis tools for extraction of the flight data. Experience with EAP had shown that the traditional Parameter Identification tools in use at BAe could no longer cope with an aircraft with a high level of basic instability combined with aerodynamic non-linearity, as experienced on Eurofighter and as predicted from wind tunnel testing. As identification of the aircraft remains a key to the final verification of many of the defined requirements, particularly relating to handling and performance, a capable tool was an essential requirement. This has lead to the development of regression techniques within Bae. These are now being applied successfully to a number of issues, with an example being described in a recent RTO Systems Integration Conference in Madrid[3].

Such techniques apply throughout the vehicle design and clearance cycle, and even into the flight test data analysis, where Eurofighter has brought its own specific challenges relating to the ability to derive data from flight measured parameters.

Management Processes

The changes that have been required of the processes and the team members have also required significant development of the management processes, in order to provide adequate support for the activities and their implications for individual team members.

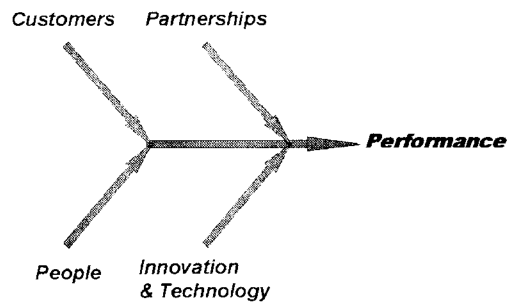
Whilst team performance has been the required end result of the changes, to ensure that this is achieved requires a number of supporting actions to be put in place. This has resulted in significant re-thinking of exactly how such teams are led and managed, how they interact with their Customers and Suppliers, and the need to generate the involvement of the team in implementation of the changes that result.

The basis for the changes derives from the consideration of the five BAe Company values, as outlined in the BenchmarkBAe corporate cultural change programme and as recently described by the company chairman in his recent book[(4)], viz:

- Customers – our highest priority.
- People – our greatest strength.
- Performance – the key to winning.
- Partnerships – our future.
- Innovation – our competitive edge.

The BenchmarkBAe Values at Work

(The concept of Team Based Value Planning)



Benchmark drives thinking about behaviours related to each of the values, especially how any individual behaviour impacts upon those around that individual. Using an approach to planning tasks which addresses all of these values, the teams develop the overall plan of the work to be undertaken. Consideration of each of these values, for each major task, asks a series of questions that should be answered in the total plan being developed. Further, the process adds an ability to put the required events in the right order. Some of the issues that the approach would raise are obvious, but all too often in the past, it is the least obvious, softer, people management issues that are not considered and that cause a change-process to fail. The process is referred to as Team Based Value Planning, and it is a major enabler to the achievement of a rigorous Earned Value Management System that is now being deployed across the project.

Role out of these techniques is taking place within all the teams operating on the Eurofighter project within BAe, and the key to success is the embedding of this approach without the team requiring conscious effort to achieve it. This will come with practice, but even thinking consciously through the questions that the values pose can lead to significant improvements in the overall team management and ability to meet the demands being placed upon them by Customers.

***BenchmarkBAe** - Achieving Customer Excellence*

- ***The ACE Tool** - A simple self-assessment tool for use within all Project and Product Teams*
- *Identify the Customer - do we really know who this is and what he wants?*
  - *Where are we in terms of the service provided?*
  - *Where do we need to be?*
- *Develop a Customer Strategy and Customer Care Plan*
  - *Establish the contact maps*
  - *Establish metrics agreed with the Customer and measure the teams own performance against these*
  - *How do we handle complaints?*

Further Capability Development to support an Integrated Product Team Environment

A number of lessons have been learned from the design processes of the Eurofighter. In particular, the work stressed the need for a balanced and combined application of experimental methods, prediction techniques, whether based upon empirical data analysis or upon more sophisticated aerodynamic CFD modelling, as well as experience. The drive for faster turn around of change leads to the requirements for easy-to-use tools that enable the engineers to think about the job and not become experts in dealing with the quirks of an unfriendly piece of software.

Traditionally, many of the tools in use were developed for dedicated tasks. What is now occurring, is a move to more generic tools that cope with a multitude of different, but related tasks. The applications are then driven by the requirements of the user, with the possibility of customising the user interface for a specific application. This leads to the development of user friendly front ends appropriate to the application. The days of taking months to set up geometry definitions for use in CFD calculations, as part of the normal working environment, are over in such a team.

There are areas where significant technique development is required.

One of the major concerns that remains is the ability to adequately predict the effects of unsteady aerodynamics, particularly due to aerodynamic separation and the large extent of the vortex flows that develop at high angles of attack. The areas of concern relate to being adequately model buffet loading, on the aircraft and the weapons it carries, to improving the modelling of the aero-servo-elastic characteristics to minimise the loss of phase that the current generations of filters can introduce into the flight control system.

The aerodynamic non-linearity that was seen in the wind tunnel has necessitated the development of very sophisticated flight analysis techniques, in order to enable a satisfactory resolution of the flight data, essential for verification of the aircraft models upon which flight clearance development and verification of performance are based.

One of the major, pleasant surprises has continued to be just how good a representation of the aircraft has been achieved in the wind tunnel modelling of the aircraft, especially regarding the non-linear behaviour.

It is also clear, that there is much more than the development of the required tools required for the success of a multi-disciplinary team. A major aspect remains the personal development of the teams and the personnel to take part in the teams. A key issue hinges around the encouragement of individuals to realise that they can do far more than their specialist knowledge might indicate, and that the best people to support them are the other team members, as well as their functional departments or home disciplines.

Concluding Remarks

Eurofighter required a significant involvement of the aerodynamic engineers from the very outset of the project design, across all of the partner companies involved in the project. Examples have been shown of the nature of some of the design decisions in which the role of the aerodynamicist has been a key.

As time has progressed, the Eurofighter Project has seen a significant change in the integration of the aerodynamics disciplines into a modern project and product focussed mode of operation.

This has impacted primarily in the areas of:

- Technical processes and tools
- Management processes
- Leadership styles and personal behaviour.

There is a definite move away from the tools which are not user friendly and which require detail knowledge and experience of the tool itself for successful application. There is a move towards tools that are easy to use and understand and quick to apply, wherever this is possible. Often this involves capturing of experience and building this into the user interface, such that the system leads the user through the right questions and decision points. There remains much to do in this respect.

Within British Aerospace, these changes are being focussed around the setting up of a product based work structure, in line with the requirements of modern Earned Value Management practices. However, to ensure that this is implemented successfully, the other major effort that is required is the recognition and acceptance of all the team members of their involvement in developing the plans by which the products are delivered. The key enabler being used for this is the Team Based Value Planning and the disciplines that this brings with it regarding the softer, non task focussed issues that are more readily overlooked in more traditional approaches.

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