ICAS-86-3.4.3

CERTIFICATION OF ADVANCED EXPERIMENTAL AIRCRAFT

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Abstract

Advanced experimental aircraft can provide challenges for those in the field of certification of aircraft design as well as for those in the more usual areas of aeronautical engineering and science.

Building up on the core elements of certification - criteria for fitness for flight, the aircraft design, assessment of design against criteria and concurrance that the design meets the criteria - the general principles of the certification process are developed. Factors influencing certification are explored. The certification procedure for the British Aerospace Experimental Aircraft Programme is briefly discussed outlining some of the documentation developed.

Finally, it is concluded that when certificating advanced experimental aircraft the significant factor is the choice of and extent of application of codes of design and airworthiness requirements.

INTRODUCTION

The aviation experimentalist must be prepared not only to confront and explore the unknown in science and engineering, but also the (potentially) unknown in the field of certification. This paper will address this latter subject, specifically the process of certification of the design of advanced experimental aircraft.

Although it may be thought parochial to solely address design, it is the design which is the foundation of an aircraft and no matter how well an aircraft is built this cannot compensate for fundamental deficiencies in design.

Beginning with a definition for certification and what is meant by an advanced experimental aircraft, the paper will continue with a brief description of the general principles of the certification process. Following this, the factors influencing the process and the choice of procedures will be examined.

Finally, a brief description of the procedure which has been developed at B.Ae. Warton for the E.A.P. design certification.

It is not the intention here to provide a detailed "how to do it" guide, but to provide, it is hoped, some "food for thought".

DEFINITIONS

The following provide a foundation on which to proceed.

Certification

A declaration by an appropriate Authority that an aircraft design is proven as fit for flight.

Advanced Experimental Aircraft

An aircraft whose purpose is to demonstrate features which are, to a significant extent, in advance of those exhibited by in-service machines.

THE GENERAL PRINCIPLES OF THE CERTIFICATION PROCESS

The key elements of the certification process are seen to be:-

- Criteria of fitness for flight which are acceptable to the certificating Authority.
- A design.
- An assessment of that design by the certificating Authority against the criteria.
- A conclusion by the Authority that the design has (or has not) met the criteria.
- Certification (or not) of the design as fit for flight.

These basics need some expansion to orientate them to more familiar situations.

Already identified are a certificating Authority, a set of criteria, an assessment and its conclusion and certification (or not). To these must be added Organisations to procure the design from those who perform the design, a specification for the design and some feed back loops. These key elements may now be developed into general principles of the certification process (Fig. 1).

Referring to Fig. 1, a certificating Authority must ensure that there are suitable criteria against which to assess fitness for flight. Various codes of general requirements for design and fitness for flight have been published, for example, BCAR(1), DEF STAN 00-970(2), each providing a basic minimum necessary for an acceptable design.

Next a procurement Organisation, which has identified a need for an aircraft design, engages the services of a design Organisation to provide one. For this purpose an aircraft specification is proposed which consists of 2 types of requirements, those which relate to fitness for flight and others to fitness for purpose. Further, in both these categories there will be general requirements and requirements specific to the aircraft. The proposed specification is agreed between the Authority and the Organisations and design commences.

The design is subjected to the agreed assessment methods to prove it meets the requirements. These methods range from physical testing to theoretical analyses to analogous comparisons with proved existing designs. The result will either be satisfactory proof or not. If not, either the design, the assessment methods or the specification must be changed.

The satisfactory results - evidence of proof of design - are passed to the certificating Authority for approval and certification.

There emerges a proven design certificated as fit to fly within particular limits.

To complete the process, initial certification is followed by flight testing using agreed methods of analysis to eventually achieve final certification. For an experimental aircraft this final certification may be an end in itself, that is, the successful demonstration of the experimental feature.

FACTORS INFLUENCING CERTIFICATION

Now that the principles of the certification process have been established I shall look at factors which influence certification. Some of the following factors are inter-related however, applying some broad divisions:-

Purpose of the Aircraft

This may be:-

- Singular - for example, the NASA/Ames Oblique Wing Aircraft AD 1.(3)
- Multiple Consecutive - the Sikorsky S72 Rotor Systems Research Aircraft.(4)
- Multiple simultaneous - the British Aerospace EAP.(5)

In the first and last cases, the bulk of the process of certification will probably be concentrated before first flight, whereas multiple consecutive programmes may result in a series of certification steps, each requiring effort equal to that expended prior to first flight.

A potential complication arising from a multiple-consecutive purpose is that the initial requirements for the design and design proving of the relatively unchanging base aircraft must anticipate, are as far as possible, the interface with items whose function and fitness for flight requirements might change from one experiment to the next.

A further variation is a change of purpose during the design process - for example from a prototype to an experimental aircraft. Such a transition can lead to inappropriate assumptions and requirements - parts of the design acquiring additional functions not envisaged by the original purpose.

Procurement of the Aircraft

The traditional UK duality of role - procurement and certification - both being performed by military Authorities may be invalid if a military type aircraft, (experimental or not) is to be certificated under military rules but procured by a civilian body, for example the manufacturer. Care should be taken to ensure that the degree of involvement by the certificating authority is commensurate with certification alone.

The Level and Extent of the Proposed Technology

Both the use and level of technology used will depend upon the feature(s) the aircraft is to demonstrate. There is little, if anything, to be gained from using advanced technology for its own sake. For example, for experiments with radars, enhanced optical systems and engines "hack" aircraft provide already certificated vehicles. At the other extreme the Sikorsky S75 Advanced Composite Airframe Programme (ACAP)(6) has a fuselage made entirely of composite materials, but has the transmission and rotors of an S76.

Extent to which the Aircraft is New

The aircraft under this heading are in a category different from the "hack" variety considered above. Here the experimental features have considerable impact. An initial assessment may be that the existing parts will require very limited consideration when compared with the new items introduced for the purpose of the experiment. There are however, potential traps for the unwary.

It might be that the new experimental items are to meet a different code of general requirements from that used for the base aircraft. It is also highly probable that the base aircraft, and in particular its systems, will have been designed for a role far different from the use to which they are now to be put.

Both of these situations arose during the Fly By Wire (FBW)(7) Jaguar programme. The Jaguar, a tactical support aircraft, is designed to Air Reglement (AIR)(8) while the full authority Digital Flight Control System (FCS) is generally based on MIL SPEC (9) requirements. It is true to say that Jaguar electrical, hydraulic and air conditioning systems were not originally intended to have the integrity necessary to support the demonstrator FCS. Indeed modifications to these supporting systems produced a ripple effect throughout the aircraft by which changes to these affected yet other systems, all resulting in an unexpected and undesirable amount of interaction.

Choice of General Requirements for Design and Airworthiness

There exist a number of codes of general requirements, civil - BCAR, FAR,(10) JAR (11) and military - DEF STAN 00-970, MIL SPEC, AIR, some of which have already been mentioned.

These codes have been formulated and developed over many years, for example, the UK military code has its origins in the joint military and civil requirements of AP 970, (12) first published in 1924. By their very nature, parts of such collections of mature received wisdom, will not be appropriate to advanced experimental aircraft. The main reason is that they are intended for state-of-the-art production aircraft. It is not suggested that they should be dismissed out of hand, only that a careful assessment is made of those which are available and thought relevant.

The following should be considered when assessing such codes:-

1) The features the aircraft is to demonstrate.

2) Whether there is a choice of the general requirements which may be used or will a code be imposed by the Authority?

3) With which codes is the design Organisation most familiar and similarly the proposed certificating Authority?

4) Examine the code(s) available and determine what is and is not relevant mindful that some of the requirements, particularly in the case of military ones, will relate to fitness for purpose.

Having identified the useful parts of an existing code, further requirements will probably be necessary to provide a set sufficient to obtain certification.

There are two options:-

1) Use from another code those requirements which are suitable.

2) Draw up new requirements specifically for the project.

A series of requirements should be coherent and so transferring requirements from one series to another should be treated with caution. For example, transferred items might depend for their effectiveness, either directly or indirectly, on other requirements in their parent series.

It follows that any new requirements developed must be checked for integration with those already chosen. Additionally, the establishing of new requirements should be as early as possible in the project life span, ideally the definition phase. Whatever the source of requirements for fitness for flight and proof of design, it is essential that they are identified early and are brought to the notice of both engineering and project management within the design organisation and within the certificating Authority. In this way, the risk that tasks necessary to provide evidence of proof of design not being identified or not completed will be reduced.

The Certificating Authority's Experience with the Design Requirements

As proposed earlier, a design Organisation may be permitted considerable discretion in the choice of requirements. The choice should be made giving due consideration to the amount of experience that potential certificating Authorities have of the various codes.

The greater the experience, the more time will be available for discussion of unfamiliar requirements, particularly those which the design Organisation has developed for the advanced features of the aircraft.

Munitions - Carriage and Release

Any proposed experimentation with munitions should be carefully considered, as this is likely to force certification down the military route.

Levels of International Involvement

The trend for collaborative projects for the design, manufacture and development of production aircraft continues. It is not unreasonable to believe that in future collaborative programmes involving experimental aircraft will occur; I think it unlikely that problems concerning certification would influence the need for collaboration. What then might be the factors which an international certification procedure must take account?

To begin with, if there is more than one aircraft, are they all to be certificated by one authority?

Is the Authority to be a joint one or will authorities in individual countries accept reciprocal certification? For example:- An aircraft certificated in one country, may not be permitted by rules to fly outside that country's airspace.

Do lowest common denominators win in so far as certification requirements are concerned - would it be practical or necessary to develop new requirements and procedures?

Will aircraft have to be designed in one country and constructed in another, yet certificated and flown elsewhere?

THE CERTIFICATION PROCEDURE FOR EAP

Having reviewed the general principles of certification and factors influencing the certification of advanced experimental aircraft I shall look briefly at an application. But before discussing the procedure developed and used for the EAP, a brief consideration of existing UK procedures is necessary.

For UK registered aircraft there are, under the provision of the UK Air Navigation Order, only two possible types of certification - civil or military.

For civil aircraft the Authority is the Civil Aviation Authority while for military aircraft it is the Ministry of Defence Procurement Executive (MoD(PE)).

Although an aircraft designed to meet the requirements of military codes is not precluded from certification as a civil aircraft nor vice versa, for initial certification the tradition is military design then military certification and similarly for civil design - civil certification.

The EAP has its root in a private venture aeroplane, the Agile Combat Aircraft (ACA) funded by UK, Germany and Italy. It was the intention that two prototypes would be built, the first flights of which were to be one in UK and one in Germany. This presented a unique opportunity to develop certification procedures.

Previous exploration of possible certification routes for another B.Ae. project ruled out, on economic grounds, the initial certification by the civil Authority an aircraft designed to military codes. The only practical alternative for the UK prototype was military certification by MoD(PE); proposals to this effect were drawn up by B.Ae.

Almost coincident with this was the announcement, at the Farnborough Airshow in 1982, that the UK Government would contribute to a technology demonstration for an Experimental Aircraft Programme based on ACA.

This participation of MoD facilitated an agree ment that EAP would be certificated by MoD acting as a Military Airworthiness Authority. The aircraft design would be multi-national but it would be offered for certification by B.Ae. to MoD.

As already described, the certification process begins at the time of initial specification The basic general requirements chosen were an aggregate of DEF STAN 00-970 and MIL SPECS. Technologies incorporated in the aircraft meant that special requirements had to be developed and in particular in the areas of structures, flight resident software, systems integration and flying handling qualities. For these new requirements there existed a large base of experience from programmes such as the Jaguar Carbon Fibre Composite (CFC) wing,(13) the Tornado CFC Taileron (14) and the FBW Jaguar.

Experience over recent years during previous experimental programmes lead to the conclusion that there had developed, in terms of specification, a significant gap between Air Vehicle Specification (AVS) and Equipment Specification. To fill the gap for EAP, Systems Specifications were developed (Fig. 2). These provide an easier transition during the specification process and a more logical top-down decomposition of requirements. Although this group of documents were assigned the generic title of System Specifications there were equivalent documents in the provinces of Structures, Aerodynamics and Electro-Magnetic Compatibility (EMC). Systems Specifications can, if used effectively, foster an holistic approach to design countering any natural tendency toward designing systems in isolation and the interface problems which might result from this.

Visibility and traceability are corner stones of efficient certification. To improve both of these qualities two types of document were developed - referring to figure 2 the Route to Certification and the Statement of Design.

A Route to Certification provides, for each system and province, a plan setting out the tasks to be completed to produce evidence of proof of design. It contains:-

- Lists of the applicable specification and requirement documents.

- Brief descriptions of the methods of tests and analyses to be used.

- References to the documents which describe in detail the various tests, analytical methods and importantly where a new method of proof is proposed, the justifying philosophy for this.

Also included are references and titles of reports to be produced for the various tasks. The plans served as a basis for discussion between engineers and scientists, from B.Ae. on one side and those advising the Military Airworthiness Authority on the other, of the design proving methods to be used. Additionally, they form a check list used during preparation of documentation for the design certification.

The objective of the Statement of Design document is to provide an executive summary of design evidence in a manner permitting requirements and evidence to be linked and establishing the degree to which proof of design has been achieved. The Statements, one for each system and province offer a further opportunity to verify compliance with the previously identified routes and requirements.

Briefly, Statements of Design comprise:-

- A summary of requirements including appropriate references to the AVS and the System Specification.

- Certification philosophy and procedures - Route to Certification.

- Summaries of the results of important tests and analyses.

- Supporting evidence in the form of Certificate of Design for the equipments in the system and any significant deviations from the Equipment Specifications resulting in limitations.

- A statement of compliance with these original requirements and the justification for acceptance of the design where the requirements are not met.

These Statements of Design are collected together to form an Aircraft Statement of Design and the result is a concise record of the design data and evidence of proof of design in support of the certification of the aircraft.

Consistent with MoD's role, the authorisation of the expansion of the flight envelope has, within mutually agreed limits, been delegated to B.Ae.

The uniqueness of the documentation used during the certification of EAP arises not from the technologies but from the aircraft's private venture origins and the particular role of the MoD. Nevertheless, it is considered that System Specifications, Routes to Certification and Statements of Design offer means of visibility and traceability for any project, experimental or not.

CONCLUSION

Advanced Experimental Aircraft provide a challenge not only in the fields of science and engineering but also that of certification.

Although the principles at the core of the certification process are simple enough it is likely that for an advanced experimental aircraft, the means for establishing a safe design might not be readily available within existing codes and procedures.

To facilitate and achieve successful certification of a design a number of factors, including the purpose of the aircraft, the level and extent of technology to be used, the applicability of existing codes of requirements and the Certificating Authorities experience with intended Codes of Requirements, must be assessed. Of these factors, the most significant is the choice of, and extent of application of, existing codes.

The EAP has provided British Aerospace with a unique opportunity, not only for advances in science and engineering, but also design certification. To this end, new documents have been devised which are considered to have aided the visibility and traceability of evidence of proof of design.

REFERENCES

(1) British Civil Airworthiness Requirements. Issued by Civil Aviation Authority (U.K.).

(2) Design and Airworthiness Requirements for Service Aircraft - Defence Standard 00-970. Issued by Ministry of Defence (U.K.).

(3) Jane's All the World's Aircraft 1981-82. Jane's Publishing Co. Ltd., London, p.417.

(4) Jane's All the World's Aircraft 1979-80. Jane's Publishing Co. Ltd., London, p.437.

(5) Flight International, Transport Press, Sutton. 19th April 1986, pp. 25-30. Air International, Pilot Press Ltd., London. Vol. 30, No. 6, June 1986, pp. 304-307.

(6) Jane's All the World's Aircraft 1985-86. Jane's Publishing Co. Ltd., London, p.513.

(7) C.J. Yeo, Fly-By-Wire Jaguar, Aerospace, Royal Aeronautical Society Journal, March 1984.

(8) Reglements AIR. Issued by Ministiere de la Defense (France).

(9) Military Specifications and Standards. Issued by Department of Defense (U.S.A.).

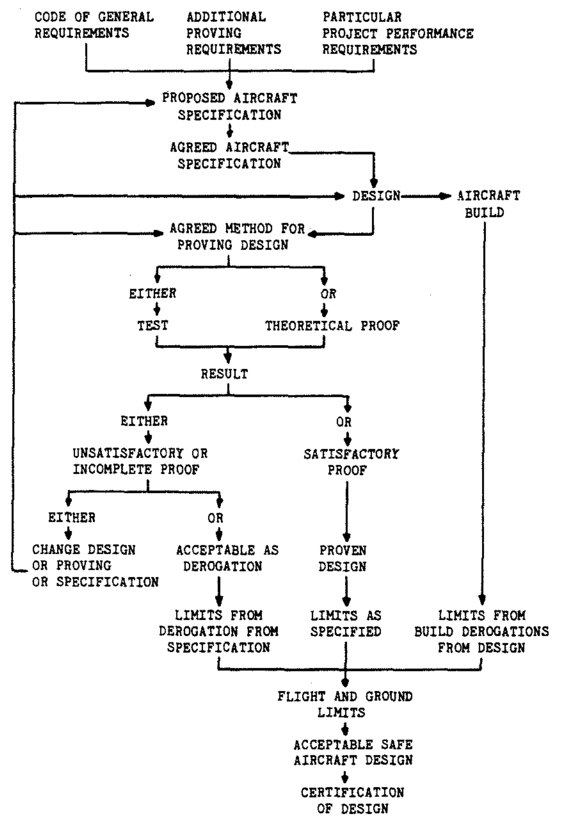
(10) Federal Aviation Requirements. Issued by Federal Aviation Administration (U.S.A.).

(11) Joint Airworthiness Requirements. Issued by Airworthiness Authorities Steering Committee (European).

(12) K.J. Meekcoms, The Origins of Evolution of Design Requirements for British Military Aircraft, HMSO.

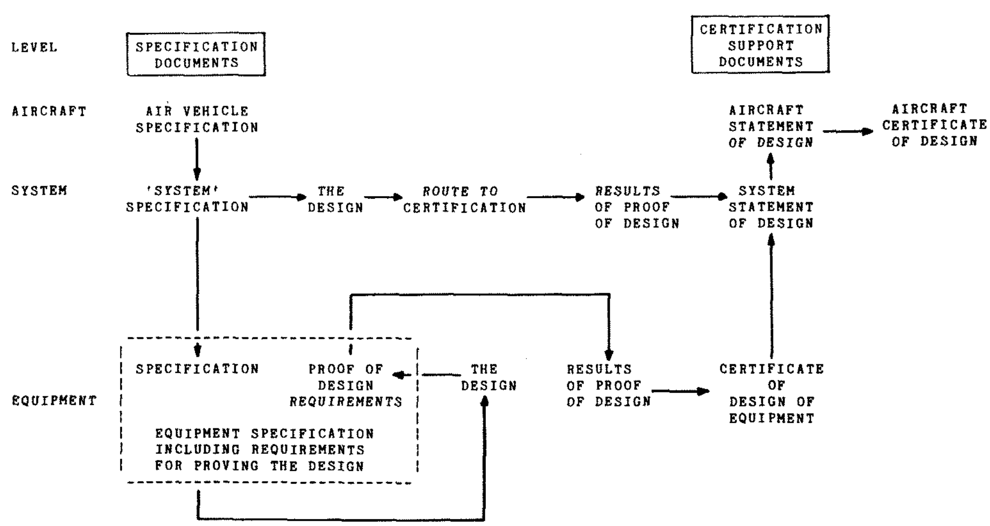
(13) Interavia, Interavia SA, Geneva, Vol. XXXVI, 5/1981, May 1981. (English Edition), P.466.

(14) Flight International, Transport Press, Sutton. 28th November 1982, p.1565.



GENERAL PRINCIPLES OF THE CERTIFICATION PROCESS

FIGURE 1.



E.A.P. - OUTLINE OF THE PROOF OF DESIGN PROCEDURE AND DOCUMENTATION

FIGURE 2.