

BASIC ELECTRONIC SYSTEMS CERTIFICATION

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Abstract

There is an increasing interest by aviation related companies and others, in the design, manufacture and installation of equipment on aircraft governed by the Federal Aviation Regulations (FAR's). This interest is the result of many factors in today's economy such as the recent reduction in aerospace related defense spending, the comparative vitality of commercial aviation industry in the United States, and increased entrepreneurial interest in high technology products. My paper will discuss how the fledgling avionics equipment designer/manufacturer should interact with the Federal Aviation Administration (FAA) including:

A basic primer on Federal Aviation Regulations and guidance associated with avionics and electrical systems.

FAA organizations with which an applicant will have contact.

FAA processes and procedures related to FAA design, manufacturing and installation approvals.

Pitfalls frequently encountered by new entrants into the arena of avionics and electrical system certification.

The information presented here is intended to provide a basic introduction to the certification process. Further, for those already experienced in avionics system certification, some controversial certification issues will be covered such as, the software aspects of system certification, High Intensity Radiated Fields (HIRF), Fly-by-Wire, etc.

Introduction

Any individual or company intending to develop an electronic system for use in an airborne application needs to be aware of the basic means and procedures for obtaining certification of such systems under the current Federal Aviation Regulations. The term certification used throughout this paper refers to the FAA process of approving the design of aircraft under the applicable Federal regulations. In the past, a relatively small number of companies were involved in

the development of avionics and electrical systems for aircraft. These companies, through long interaction with the FAA, had procedures to accommodate certification incorporated into their system development programs. Due to recent economic and political changes in the world, an increasing number of companies and individuals are applying for certification of airborne systems and equipment. Many of these applicants are completely new to the field of airborne systems development or were involved in development of such systems for military use and have not previously interacted with the FAA. In addition, due to employment demographics, many companies have lost the employees whose relationship with the FAA and knowledge of the regulations was instrumental in achieving certification.

This paper, while not a treatise on certification, will provide guidance on the basic approach anyone should take who intends to develop and have certified an airborne electronic system. This guidance will take the form of six basic rules each of which will be described in some depth later. These rules are:

Rule 1: Know the Regulations (and Guidance)

Rule 2: Know the FAA Organizations

Rule 3: Know the Industry Standards

Rule 4: Know the Issues

Rule 5: Plan for Certification in Advance

Rule 6: Maintain a Relationship with the FAA

Rule 1: Know the Regulations (and Guidance)

Any company or individual intending to develop a product for airborne use must manufacture it to an FAA approved design, using an FAA approved manufacturing/quality control process, and the device must be operated and maintained by the user under FAA approved procedures. The rules and regulations associated with obtaining these approvals are contained in the Code of Federal Regulations, Title 14, Chapter 1, Parts 1 through 199. Only certain Parts of these regulations will be of interest to a developer of airborne equipment since these regulations cover the gamut of aerospace activities.

Part 21 of the FAR's. Certification Procedures for Products and Parts, is organized in subparts which describe the procedural requirements for granting design, airworthiness and manufacturing approvals. The system developer should be sure to understand the kinds of approvals and certificates issued by the FAA and the eligibility requirements for each as well as the types of aircraft that are defined in Subpart B of Part 21 since these definitions form the basis for the design requirements found in later regulations. Following is a general description of the FAA certificates and approvals defined in Part 21 of particular interest to the developer of airborne systems:

- a. Type Design Certificates (TC's) and Amended Type Design Certificates (ATC's) are issued only to manufacturers of aircraft, aircraft engines and propellers subsequent to showing the FAA that the design meets the requirements for the "type" of certificate sought. For example, normal, utility, acrobatic, and commuter "types" of airplanes must be shown to meet the requirements of Part 23 while the requirements for a transport category "type" of airplane are contained in Part 25.
- b. Supplemental Type Certificates (STC) can be issued to anyone for changes to a type design where the change is not large enough to require a new type certificate. Again the applicant for STC must show that the alteration, and associated equipment, meets the airworthiness requirements for the "type" of aircraft or engine altered.
- c. An Airworthiness Certificate is issued to a registered owner of particular aircraft who shows that the aircraft conforms to a type design approved under a type certificate, and/or supplemental type certificate, and the aircraft was manufactured, altered, repaired under an approved process and is in a condition for safe operation. There are several variations of the airworthiness certificate procedure outlined in Part 21.
- d. A Production Certificate (PC) is a production approval, issued to the holder of a type certificate, or a supplemental type certificate, who is shown to have established appropriate manufacturing/quality control procedures as outlined in Subpart G of Part 21.
- e. Parts Manufacturer Approvals (PMA's), as outlined in Subpart K of Part 21, are issued to anyone producing a part for installation on a type certified product, who has an approved design and manufacturing/fabrication inspection system.
- f. Technical Standard Order (TSO) authorizations, described in Subpart O of Part 21, are issued to the manufacturer of an article which has been found to meet the design, qualification, and minimum operational requirements outlined in an FAA specification called a Technical Standard Order. The manufacturer must also have an FAA approved manufacturing/quality control process. FAA Advisory Circular (AC) 20-110X contains a list of current Technical Standard Orders. Advisory Circulars and TSO's can be obtained as described at the end of this paper.

Developers of airborne systems and equipment for sale to aircraft and engine manufacturers should understand the Part 21 procedures associated with Type Design, Amended Type Design and Production Approvals in order

to support the aircraft or engine manufacturer's application for such approvals. Others need to become very familiar with the Part 21 rules and procedures associated with STC's, PMA's and TSO's. Additionally, anyone who develops a product under the Federal Aviation Regulations should be aware of FAR paragraph (§) 21.3 which levies stringent requirements on approval holders for reporting certain airworthiness problems in approved equipment.

Parts 23 through 35 of the FAR's define specific design requirements for the "types" of aircraft defined in Part 21, engines and propellers. The developer should look for design requirements in the Part that corresponds with the intended application of the equipment. If the equipment or system is intended for use in more than one type of aircraft the developer should know the regulations related to all applications since the most stringent will apply. Each of these parts is organized according to the disciplines associated with development of the product to be certificated. Basic rules for most electronic systems will be found in the relevant systems subpart; however, some aspects of the other subparts may also apply. Most electrical equipment has mounting provisions which must be shown to comply with the rules contained in the structural subpart, and equipment for propulsion systems must comply with propulsion subpart, etc. Knowing which rules apply to the equipment under development is important since the applicant and the ACO must reach agreement on the means which will be used to show compliance with each regulation. If the equipment is to be used on a transport category airplane, it is important to note the requirements of § 25.1309. For many electrical systems, this requirement will establish the degree of rigor required in certification of the equipment.

Parts 91, and 121 through 127 of the FAR's define aircraft operational requirements. Although these Parts are not of primary interest to an equipment developer, they do contain design requirements for some systems. The developer of equipment for certain applications may also be required to supply training and maintenance information so the operator can comply with provisions of these regulations. These parts are sometimes used to require older aircraft to comply with later type certification standards retroactively.

Part 183 of the FAR's will be of peripheral interest to anyone whose development activities will require a long term relationship with the FAA. This Part defines and describes the various FAA representatives and designees which may be appointed, their associated disciplines, and the privileges and rules they must abide by when working with or for an applicant.

A cursory reading of the FAR's will reveal that they do not describe the means by which an applicant shows that airborne equipment is compliant with the regulations. The FAA bridges this gap with a body of documents called Advisory Circulars. AC's describe one means, but not the only means, for showing compliance to regulations. Some AC's describe means of compliance for specific regulations while other AC's cover overall means of compliance for particular systems. If an applicant wishes to use a means or method other than that described in an AC or if an AC does not exist which describes the means of compliance for a particular system, another compliance means may be established through discussion and negotiation with the

responsible ACO. In general however the AC's delineate the basic method by which the ACO's will expect to find compliance for most airborne systems and equipment. Consequently, a system developer should be aware of the relevant AC's when discussing compliance issues with the ACO. The place to start researching applicable Advisory Circulars is to obtain the latest FAA AC directory, AC 00-2.X, Advisory Circular Checklist, which contains a listing of all published advisory circulars.

Among the specific AC's that developers of systems and equipment for transport category airplanes should be familiar with are AC 25-10 and AC 25.1309-1A. AC 25-10 which is titled, Guidance for Installation of Miscellaneous Nonrequired Electrical Equipment, establishes the minimum compliance requirements for all electrical equipment used in transport airplanes. Additional requirements and associated means of compliance may apply depending on the application of a particular system but these means will be over and above those specified in AC 25-10. AC 25.1309-1A, describes a method of determining hazards associated with a particular airborne system and the resultant methods of showing compliance to the safety requirements of § 25.1309.

Rule 2: Know the FAA Organizations:

The new entrant into the FAA approval processes may find the task of determining how to interface with such a large and seemingly mysterious agency daunting. Fortunately the FAA is structured to facilitate public access. In order to promote access and assure compliance with the Federal Airworthiness Regulations, the FAA has established collaborative field offices across the country to provide regulatory approvals. One of the many responsibilities of these offices is accessibility to the public and the aircraft industry.

Aircraft Certification Offices (ACO's) are field engineering organizations chartered to certify certain aircraft, engines and propellers. For most airborne equipment developers, the ACO is the first and primary contact with the FAA. The ACO is the organization which will, under the type certification and supplemental type certification process previously described, approve the design of an airborne system under the applicable regulations. The ACO also, as provided in Part 21, issues TSO authorizations and participates in the issuance of PMA's. The ACO will also aid applicants in other aspects of the FAA approval process including coordinating contact with the FAA organizations responsible for manufacturing and operational approval when required. Further, the ACO will be aware of industry trends that could affect the development of the product and an applicant's ability to gain FAA approval of a particular airborne system.

The FAA has also established Manufacturing Inspection District Offices (MIDO's) which are field organizations responsible for ongoing approval of aircraft and aircraft equipment manufacturing/quality control procedures as outlined in Part 21 of the FAR's. Among other duties, the MIDO issues production certificates and parts manufacturer approvals. Additionally, when required, as part of the production approval or certification process, the MIDO will assure that manufactured articles and altered type certificated

products conform to an FAA approved design. Flight Standards District Offices (FSDO's) are responsible for the approval of the operational and maintenance procedures for aircraft operated within their jurisdiction.

It is very important that any company developing equipment for airborne applications be aware of the FAA offices, and the individuals in those offices, responsible for coordinating the three types of approvals previously described. A dialogue should be established with these offices very early in the development program. The first step in establishing this dialogue is to contact the appropriate ACO. The ACO to contact is the one which will receive the application for certification of the product; TC, ATC or STC. When unsure of who the applicant will be, the system or equipment developer should contact the closest ACO for advice. At the end of this paper is an ACO list which includes a general description of the area served and, the name and phone number of the ACO manager.

Rule 3: Know the Industry Standards

The Federal Aviation Regulations contain the requirements for airborne systems and equipment, Advisory Circulars, where they exist, outline means of compliance to the regulations, and TSO's outline a means of obtaining manufacturing authorization for specific equipment. AC's and TSO's will often reference industry specifications, standards or guidelines. In fact, the FAA accepts and supports the development of industry documents for use in many areas associated with FAA design manufacturing and operational approvals. Several industry/FAA teams are in the process of developing or revising such documents at any given time. The standards are developed by a wide cross section of representatives from industry and government and, as such, represent a consensus on the direction that technology will follow in certain areas of airborne system development. The standards are also the media wherein industry and the FAA reach agreement on the safety issues related to new technology systems and equipment. For the stated reasons and more, the developer of airborne systems should be aware of existing applicable industry standards and, if possible, should participate on the committees developing future standards.

Some industry standards are uniformly applied to airborne systems for certain aspects of certification. For example, RTCA/DO-160C is the industry standard used most often to specify the environmental qualification aspects of certification and RTCA/DO-178A is used to address the software aspects of certification. These and other RTCA documents can be obtained by contacting:

The Radio Technical Commission for Aeronautics
One McPherson Square
1425 K Street N.W., Suite 500
Washington D.C., 20005

Other industry standards define the minimum operational requirements for specific equipment applications. The ACO will be able to help a developer identify and obtain the industry standards applicable to the certification aspects of a specific system.

Rule 4: Know the Issues

The developer of airborne systems and equipment will find applicable regulations and associated guidance in place which covers the certification aspects of most airborne systems; however the guidance does not always reflect every aspect of certification for certain systems. The pace of technological progress in some areas has outstripped the ability of the FAA to keep all guidance current. Aircraft systems are now being developed which did not exist when the rules governing their use were written. Further, many analytical and testing means used in the past to show compliance to the regulations have been displaced by better methods, or are inappropriate when applied in the certification of newer systems and equipment. For these reasons, an applicant for FAA approval must be aware of both the general and specific certification issues which may apply to the particular systems or equipment involved. In some cases methods of compliance must be incorporated in the early stages of development of airborne equipment to avoid difficulties during equipment certification.

Here again, early communication with the responsible ACO is essential. If queried, the ACO will be able to identify certification issues which apply for certification. In the event such issues arise, the ACO will identify and coordinate means of compliance not covered completely by existing guidance. Some systems may be such that the ACO must prepare and issue special conditions. A special condition defines a rule or additional rules to cover requirements for features that are novel or unique with respect to existing regulations.

Described below are some issues and general categories of issues which should be considered in the development of new airborne systems. This is not a complete list of such issues nor do the issues listed apply to all categories of equipment. The issues described represent examples of the more common and controversial issues which may arise during certification of systems for transport category airplanes.

Software - There are three main issues related to software aspects of certification: the method of demonstrating compliance for the software aspects of certification; determination of the rigor required for assuring software integrity; and incorporation of the software contribution to system hazards into a system safety analysis.

The FAA has determined that software developed in compliance with the guidance of RTCA/DO-178A is one means of showing compliance for the software aspects of certification. This special standard was developed by an FAA/Industry team to specifically cover the software aspects of certification because most software is too complex to test for errors in the manner in which hardware has traditionally been tested. The standard is based on the knowledge gained from experience that software errors are reduced in proportion to the level of structure used in the software development process. Hence, as the hazards associated with potential errors in a software based system increase, so does the rigor of structured development required by RTCA/DO-178A and the subsequent artifacts of the development process that the FAA will want to see for assurance of compliance with the development guideline. The important point here is that the developer of software

for an airborne system must be compliant with the guideline from the very beginning of the development process and have representative artifacts which demonstrate the appropriate rigor of development.

For systems in transport category, Part 25 airplanes, the level of RTCA/DO-178A development required for software in a particular system should be determined in coordination with the appropriate ACO. The software level required is determined from the functional hazard analysis process outlined in AC 25.1309-1A. This analysis will identify system hazard categories which have corresponding software development levels defined in RTCA/DO-178A. The system developer should get ACO concurrence with the assumptions used in the analysis, the hazard category identified, and the resultant software level selected.

A question that often arises during certification of systems containing software is how the software aspects of certification are combined with numerical failure analysis for the rest of the system as outlined in AC 25.1309-1A. The truth is that software can't be incorporated into such analyses since the probability of a hazardous error in software cannot be quantified. Consequently, the rigor of software development required to account for a particular system hazard cannot be lowered as a result of redundancy alone. System architectural means have been used to lower the level software development but such means should be approved by the appropriate ACO in advance.

High Intensity Radiated Fields (HIRF) and Lightning - Airborne systems associated with certain categories of hazards (see AC 25.1309-1A) must be shown to be safe when subjected to the effects of HIRF and Lightning. Concern over the effects of such hazards has increased in proportion to increased use of digital electronic equipment in today's aircraft. For most systems, the tests called out in RTCA/DO-160C will be sufficient for certification; however, some systems will have additional requirements related to either HIRF or Lightning. The applicant for certification of an electronic system should become aware through coordination with the appropriate ACO of the requirements related to HIRF and lightning. Some foreign regulatory agencies have different requirements with respect to these phenomena and the developer of a system which may require certification abroad should become aware of the differences in requirements. Here again the ACO can help.

Complexity - As mentioned previously, some airborne systems contain software which is too complex to adequately test in the traditional manner. The same is now true for certain hardware components within modern electronic systems such as large gate arrays and application specific integrated circuits. Some electronics systems themselves have attained a complexity level such that traditional lab and flight testing methods cannot realistically be extensive enough to show compliance to existing requirements. Because of the rapid evolution of the industry in this area, the FAA does not have specific guidance on appropriate means of compliance for such systems and components. There are industry/FAA groups chartered to resolve this issue in certain areas; however, for the near term, certification requirements will need to be determined individually for each such complex system or component.

Rule 5: Plan for Certification in Advance

Very early in the planning process of new system development the appropriate ACO should be contacted. Both the system or equipment developer and the applicant for certification, if different should be involved. Ask to meet with the supervisors and engineers who will be responsible for certification of the system. Also ask that the appropriate representatives of the MIDO and FSDO be in attendance. This meeting serves two main purposes; it alerts the responsible FAA office to the upcoming program so appropriate FAA resources can be scheduled; and provides the system developer a forum to acquire the information needed to gain the approvals required.

At the meeting, be prepared with a general technical description of the device or system, a description of how it will be operated and the specific application in which the system will be installed. If the system is intended for general usage, information on the scope of application will be needed, i.e., commercial airplanes, general aviation aircraft, rotorcraft, etc. If the system or appliance contains software, a general overview of the planned software development process should be discussed.

The applicant should obtain certain information during the meeting. This information correlates directly to the rules which are the basis of this paper including: FAA contacts for the system in the areas of certification, manufacturing and operational approval; Federal Aviation Regulations and associated guidance under which the system will be certified, manufactured, and approved operationally; industry standards applicable to the system which relate to certification, manufacturing and operational approval; general description of any issues or special conditions for certification which will be applicable to the system; procedures for application, coordination of certification; and preferred format and content of the system certification plan. If all this information cannot be obtained during the meeting, provision should be made for obtaining it at a specified later date. Once again, to emphasize the point, the meeting should occur very early in the development process since some areas of regulatory approval must be addressed early to avoid major problems later.

Rule 6: Maintain a Relationship with the FAA

The best method for an airborne equipment developer to nurture a relationship with the FAA is for certain members of its organization to become FAA designees. Based on qualifications, extent of familiarity with the FAA, and need, the FAA may appoint persons outside the FAA to perform certain FAA responsibilities. Each of the FAA organizations described previously appoints such designees. ACO's appoint Designated Engineering Representatives (DER's), who can approve certain design data and testing on the FAA's behalf. Ask the ACO for a copy of FAA Order 8110.37, Designated Engineering Representative Guidance Handbook, which explains and defines the responsibilities of a DER. The regulations also have provision for Designated Manufacturing Inspection Representatives (DMIR's) and Designated Airworthiness Representatives (DAR's). The MIDO and FSDO respectively should be contacted for information regarding these designations. Such designees can provide the ongoing FAA/applicant relationship essential to a successful aircraft system development

program.

The importance of early contact with the FAA and attention to the above rules cannot be overemphasized. Following these rules will greatly increase the chances of a problem free airborne system certification and will subsequently benefit to the developer in terms of cost, schedule, efficiency and general good will. The FAA also benefits by the reduction of overall resources needed to administer a structured, early coordinated certification program.

FAA AIRCRAFT CERTIFICATION OFFICES

BOSTON AIRCRAFT CERTIFICATION OFFICE - ANE-150

Ronald L. Vavruska, Manager
(617)273-7118
12 New England Executive Park Fax:
(617)270-2412
Burlington, MA 01803

NEW YORK AIRCRAFT CERTIFICATION OFFICE - ANE-170

Irwin Brumer, Manager
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181 South Franklin Avenue, Room 202 FAX:
(516)791-9024
Valley Stream, NY 11581

ATLANTA AIRCRAFT CERTIFICATION OFFICE - ACE-1158

Paul Sconyers, Acting Manager
(404)991-6121
Suite 210C FAX:
(404)991-3606
1669 Phoenix Parkway
Atlanta, GA 30349

CHICAGO AIRCRAFT CERTIFICATION OFFICE - ACE-115C

Donald P. Michal, Manager
(312)694-7357
2300 East Devon Avenue, Room 232 FAX: (312)694-7834
Des Plaines, IL 60018

WICHITA AIRCRAFT CERTIFICATION OFFICE - ACE-115W

Lawrence A. Herron, Manager
(316)946-4100
1801 Airport Road, Room 100 FAX:
(316)946-4407
Mid-Continent Airport
Wichita, KS 67209

SEATTLE AIRCRAFT CERTIFICATION OFFICE - ANM-100S

Donald L. Riggin, Manager
(206)227-2180
1601 Lind Avenue, SW FAX:
(206)392-1181
Renton, WA 98055-4056

ANCHORAGE AIRCRAFT CERTIFICATION FIELD OFFICE - ACE-115N

Jim Chudy, Aerospace Engineer
(907)271-2668
605 W. 4th Avenue, Room 214 FAX:
(907)279-2527
Anchorage, AK 99501

DENVER AIRCRAFT CERTIFICATION FIELD OFFICE - ANM-191D

Richard Jennings, Manager
(303)398-0840
2390 Syracuse Street FAX:
(303)398-0826
Denver, CO 80207

LOS ANGELES AIRCRAFT CERTIFICATION OFFICE - ANM-100L

Frederick Lee, Manager
(310)988-5200
3229 E. Spring Street FAX:
(310)988-5210
Long Beach, CA 90806-2425

DALLAS/FORT WORTH AIRPLANE CERTIFICATION OFFICE - ASW-150

Michele Owsley, Manager
(817)624-5150
4400 Blue Mound Road FAX:
(817)740-3394
Fort Worth, TX 76193-0150

DALLAS/FORT WORTH ROTORCRAFT CERTIFICATION OFFICE - ASW-170

Larry M. Kelly, Manager
(817)624-5170
4400 Blue Mound Road FAX:
(817)740-3394
Fort Worth, TX 76193-0170

DALLAS/FORT WORTH ROTORCRAFT SPECIAL CERTIFICATION OFFICE - ASW-190

Mark Schilling
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4400 Blue Mound Road FAX:
(817)740-3394
Fort Worth, TX 76193-0170

ADVISORY CIRCULARS AND TECHNICAL STANDARD ORDERS

Ordering and purchase information for Federal Aviation Regulations, Advisory Circulars, Technical Standard Orders and other relevant government publications can be obtained at the nearest United States government book store, or from:

Superintendent of Documents
U.S. Government Printing Office
Washington D.C. 20402

Additionally, Technical Standard Orders can be obtained from:

Federal Aviation Administration
Office of Airworthiness
Aircraft Engineering Division (AIR-100)
800 Independence Avenue, SW.,
Washington D.C. 20591