VOLUME IV
FLIGHT TEST MANAGEMENT

CHAPTER 12

F. A. R. CERTIFICATION

JANUARY 1983

USAF TEST PILOT SCHOOL
EDWARDS AFB CA

FEDERAL AIR REGULATION CERTIFICATION

JAN 1983

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FEDERAL AIR REGULATION CERTIFICATION

INTRODUCTION

Most of the US aircraft flying today are evaluated against "arbitrary" performance and flying quality standards or are "certificated," which means certified to comply with US Federal Air Regulation (FAR) requirements. Table 1 emphasizes this point for flying quality evaluation.

Table 1: 1982 US Aircraft Sales
Source: Aviation Week and Space Technology (1).

	Certified to FARS ($ in billions)	Evaluated for MIL-F-8785C Compliance ($ in billions)	Evaluated for "Arbitrary" Specification Compliance ($ in billions)
Military	Ø	Ø	20
Transport	8	Ø	Ø
Business/ General Aviation	3	Ø	Ø

The Federal Aviation Administration (FAA) has held fast to certifying aircraft against FAR requirements, while the military has not recently shown any inclination to evaluate its procured aircraft against any "standard" flying qualities requirement such as MIL-F-8785C, Flying Qualities of Piloted airplanes (2).

Airworthiness Standards are requirements on the performance, flying qualities, and structural strength of US Civil aircraft which are to be FAA certificated. The airworthiness of small airplanes in the normal, utility and acrobatic categories that have a passenger seating configuration of nine seats or less is specified in FAR Part 23. The airworthiness of public transport aircraft is specified in FAR Part 25. References 3 and 4 are Engineering Flight Test Guides published by the FAA which present methods and procedures which are considered good engineering practice for determining the airworthiness and eligibility of an aircraft for a type certificate under FAR Part 23 or 25.

The reason that military test pilots and flight test engineers should be familiar with FAR regulations and test procedures is that often military aircraft are procured "off-the-shelf" after they have been found to comply with the FAR requirements. Sometimes military procurement is made without further testing. The Cessna 310 was purchased as the U-3A without a flight test program. The Beech Baron Model B55B was purchased by the U.S. Army as the T-42A and not tested until several accidents attributed to single-engine operation "made it imperative" to evaluate its flying characteristics (5). The results of this investigation included a recommendation that a warning stating that "Single-engine stalls are potentially catastrophic" be placed in the flight manual. In some cases civil certification was obtained after military evaluation and acceptance. The KC-135 was certified in this fashion. Table 2 is a partial listing of US military aircraft which have a certificated civil equivalent.

Federal aviation regulations and military flying quality specifications are attempts to ensure that all aircraft of the same class have "similiar" flying qualities and that the mission can be performed by a standard sized pilot without exceptional piloting skill. Despite this common goal, FARs and flying quality requirements have very different approaches to the problem. Flying quality testing for specification compliance involves testing throughout the operational envelope and during operational missions including "the entire spectrum of intended usage to include aircrew upgrade and training (2)". Testing for FAR compliance begins with a minimum number of test points which are added to until the requirement is considered satisfied (3). The main point to be observed is that an FAA certificated aircraft may not be suitable for a "similiar" military mission.

TABLE 2: Military Aircraft with Civil Equivalents.
Source: Jane's (8)

Military Designation	Civil Equivalent	Military Service	"Popular" Name
AU-23A	Pilatus PC-6	USAF	Peacemaker
C-45	Beech 18	USAF	Twin Beech
C-9A	DC-9	USAF	Nightingale
C-47	DC-3	USAF	Gooney Bird
C-118	DC-6A	USAF	-
C-121	Lockheed 749	USAF	Constellation
C-130	Lockheed 382B	USAF/USN	Hercules
C-140	Lockheed 1329	USAF	Jet Star
CV-2A	DHC-4A	USAF/USA	Caribou
E-4	Boeing 747	USAF	-
H-13	Bell 47	USAF/USA	Sioux
H-19	Sikorsky 55	USAF/USA	Chickasaw
HU-25A	Falcon Jet	USCG	Falcon Jet
KC-10A	DC-10	USAF	Extender
KC-135	Boeing 707	USAF	Stratoliner
L-21	PA-18	USAF/USA	Cub
L-23D	Beech F50	USA	Twin-Bonanza
L-26A	Model 560E	USAF/USA	Aero Commander
O-2A	Cessna 337B	USAF	Super Skymaster
P3V	Lockheed 188	USN	Electra
T-29	Convair 240	USAF	Convair-liner
T-39A	NA 246	USAF	Sabreliner
T-41A	Cessna 172	USAF/USA	Mescalero
T-42A	Beech B55	USA	Baron
T-43	Boeing 737	USAF	-
U-3A	Cessna 310	USAF	Twin Cessna
U-6A	DHC-2	USAF/USA	Beaver
U-10	H-295	USAF	Super Courier
U-21A	Beech B50	USA	Queen Air
UO-1	PA-23	USN	Aztec
UV-18	DHC-6	USAF	Twin Otter
VC-6A	Beech B90	USAF	King Air
VC-11A	Gulfstream II	USCG	Gulfstream II

HISTORY OF FAA CERTIFICATION

The need for Federal regulation of aviation first became apparent during the early 1920's, when large numbers of World War I aircraft were being barnstormed around the country, and the more adventuresome citizenry were being treated to their first aerial thrills. Whether or not the aircraft they rode in was "safe" was in large part determined by the safety standards which the particular pilot/owner used as his personal guide. As a result of that need, the Air Commerce Act of 1926 was enacted and the Aeronautics Branch was formed within the Department of Commerce to administer that Act. The first set of rules became effective on December 31, 1926 (6).

This first set of airworthiness rules was called "Aeronautics Bulletin 7A," which incorporated design standards based on the then-existing state-of-the-art. Many aircraft built to the standards of Bulletin 7A are still flying today-to name one, the Douglas DC-3. With today's knowledge, Bulletin 7A is a very limited yardstick against which to compare a transport type aircraft. For example, that regulation contained no requirement regarding stall characteristics (6).

As the aviation industry grew, the need for regulation, and development of the air carrier segment prompted enactment of the Civil Aeronautics Authority (later called the Civil Aeronautics Board), the Civil Aeronautics Administration, and the Air Safety Board. The duties of the Civil Aeronautics Board (CAB) included making and issuing airworthiness rules, which were administered by the Civil Aeronautics Administrator. The Air Safety Board investigated accidents and made recommendations to the CAB for the prevention of accidents (6).

From 1938 until 1958 the CAB continued as the rule-making agency for airworthiness during which time Civil Air Regulations 3, 03, 04a, 04t, and 4b were published as minimum design criteria for fixed-wing aircraft. Each of those regulations was intended to reflect the experience and knowledge of the industry at the time each rule was published, and each received the benefit of, and in final form was influenced by, the suggestions and criticisms of the aviation public.(6).

In 1958, with the enactment of the Federal Aviation Act, rule-making duties were transferred to the Federal Aviation Agency, which was created by that Act. Airworthiness standards existing at that time were continued in effect until 1962, at which time they were recodified and issued as Federal Aviation Regulations 23 and 25. The objective of the recodification program was to simplify or streamline the rules and to consolidate related material under one cover. Thus items concerning common procedural matters, for example, were extracted from each of the airworthiness regulations and placed in Federal Aviation Regulations Part 21, called "Certification Procedures for Products and Parts." Definitions were consolidated into FAR Part I, entitled simply "Definitions." (6).

CERTIFICATION CHARACTERISTICS

The regulations pertaining to the certification of any aircraft are minimums for an acceptable level of safety. They are the minimum standards specified for each category aircraft. The regulations do not specify optimums or desirable characteristics or parameters. The regulations do not infer a 50,000 mile guarantee or a 24 month warranty. The regulation in a very real sense becomes the law. The Federal Aviation Act of 1958 clearly directs (scheduled) air carriers to strive for the "highest degree of safety in the public interest" while inferring that a lower level of safety may be acceptable for other forms of air commerce. It is also true that "the level of safety" is not clearly defined. It may mean different things to different people depending on how intimately one is involved with the operation, maintenance, manufacture, or sale of these aircraft. (6).

Obviously, the FAA would not consider approving any aircraft or feature which was known to be potentially dangerous or which did not comply with the regulations. However, accident analyses continue to show that there are still many accidents attributed to design deficiencies. The FAA tries to anticipate if an aircraft will meet same reliability and safety standards airline passengers have had for the past 40 or 50 years. After an aircraft is certified the aircraft manufacturer sells it, the customer operates it, and the FAA inherits the problems which occur during the remaining life of the aircraft which is at least the next 15 or 20 years.

It may not be generally realized but one of the items in the FAA charter is to aid in the development of aviation. In 1951 the FAA appointed certain people in aircraft companies as Designated Manufacturer Certification Representatives (DMCR's) and Designated Engineering Representatives (DER's). The DMCR represented the FAA and had the authority and responsibility to sign off as an FAA representative in his assigned areas such as flight test, power plants, structures, etc. This was a big step which placed the responsibility for meeting not only the FAA regulations, but the total responsibility for the aircraft, directly on the manufacturer. Predictably, this move shortened the development and certification programs in that the FAA pilots and/or engineers no longer had to witness all tests or to re-fly the certification program.

The FAA now states at the start of a test program what tests, if any, they want to witness and what flight tests, if any, they will want to repeat. The system has been modified so that instead of having DMCR's companies now have Delegation Option Authorization representatives (DOA's). Basically, the only difference is that instead of the DMCR being directly responsible to the FAA, the DOA represents the company and the company is responsible to the FAA. Quite often, the engineering flight test pilot and his group are the first, last, and only persons to see the finished product prior to certification and delivery (7).

This process sometimes leads more outspoken FAA representatives to ask the following questions:

1. Are questionable aircraft characteristics identified during an aircraft's life cycle (often thru accident investigation) foreseen during the development testing of the aircraft?

2. If questionable design details are foreseen, why are they not corrected?

3. Are the manufacturer and engineering test pilot passing on to the customer the dubious privileges of being the "real test pilot" in actual operation?

4. Is marketing ahead of the flight test state-of-the-art?

CERTIFICATION FLIGHT TEST PHILOSOPHY

Because of the recent increase in litigations involving product liability, aircraft manufacturers are very reluctant to publicly discuss not only flight test philosophy, but even test procedures and methods. As mentioned in the Introduction, testing for FAR compliance involves a minimum number of test points. Many people would argue that an aircraft manufacturer has test responsibilities over and above testing for certification.

All aircraft companies are in business to make money; that is, maximize return on investment. One aircraft company states its number one rule as this: "To engineer, develop, manufacture, sell, and support a good, reliable, competitive, safe product in the most economical manner possible (7)". The schedule, overall costs, and management desires influence test pilot decisions. The pressure of time and economics prevents the test group from achieving all of its objectives and forces compromise. This is one of the realities of the aircraft business.

The general aviation (which includes business aircraft) flight test community has an additional unique problem. Even though most of the famous test pilots of yesterday are graduates of general aviation, they had moved on to the bigger and faster aircraft by World War II. Consequently, flight test personnel in general aviation do not have the heritage of great or famous test pilots to draw on as those who work for the larger companies do. General aviation test groups grew without the aid of this heritage or the aura of glamor that is associated with larger and faster aircraft and without the aid and push of the Military (7). The FAA contends that very few general aviation test pilots have the reputation, skill, and professional stature to command the respect that their findings should instill in management (6). Regardless of that fact, no matter how much confidence management has in the test pilot, many suggested changes are deferred for economical reasons until a major model change. Or, as stated by the Chief of Flight Test Operations for a major general aviation company, "We accept and live with these (deferred changes) because we realize that changes requested by (test) pilots can be rather expensive, and believe it or not, we are interested in the company we work for making money (7)." The only reason that this situation is at all tenable is that, in reality, there are relatively few new aircraft developed by general aviation companies, and a test pilot's input in most areas is more a process of evolution than rapid change. When a general aviation company does develop an entirely new aircraft, more often than not, a competent test pilot from outside the general aviation community is hired for the duration of the flight test certification program.

What is the obligation of the company test pilot to the customer? The answer depends on who you ask. For example:

(1) Many corporate test pilots say, "The test pilot has no obligation to the customer, his obligation is to his management (10)",

(2) An FAA representative says, " The answer to the question is very, very simple. It's to thoroughly investigate and resolve every unknown and uncertainty in an aircraft and to present it to the user pilot completely tamed and with new full assurance that airplane will meet its intended function. That means that not only the number one prototype or airplane number seventeen, but also airplane number 1163 off the production line will be just as good. Perhaps my viewpoint is too idealistic but I have gone on record with my friends in the flight test profession many, many, many times in the last decade in expressing my professional disappointment with the airplanes that are being handed to the public. I'm not referring so much as to whether or not the airplane meets the minimum certification requirements. I'm talking about whether or not that airplane has been fully explored in a professional manner by professional airmen with an obligation to do it. My concern goes beyond the minimums. I think I can sum it all up by directing one question to the general aviation development test pilot and that is this 'Have you fully explored that airplane, or are you turning it over to the general aviation user pilots to do it for you?' And, if you are, then SETP better get ready to accept about 100,000 additional applications. (10)."

(3) A business aviation customer says, "(The corporate test pilot) talks of building bridges, of the responsibility of the test pilots to build bridges from the design engineer to the customer. I'll be doggoned if I can see how he can build bridges when he stays always on the same side of the river. I'm going to suggest that he get out and come and see the customer one day and find out where that bridge should finally lead...(Business aviation) is quite sophisticated and yet, as far as the test pilot is concerned, quite ignorant. Ignorant in the sense that we really don't know the specifications, we have to take what is offered and hope it is right. We depend, to a major degree, on the test pilot

telling us what training is required, what techniques are required. The manufacturer for this type product builds what he thinks he can sell. The customer buys the best available to serve his recognized needs at that time. The two never match. It's a compromise all the way. We have to ask what the aircraft will do and then find out how much of our job can be performed efficiently. We fully understand and appreciate that any aircraft can be flown safely. We know full well also that any aircraft can be flown unsafely. I think the difference entirely, of course, is the degree of training of the pilot. But I do feel also that some aircraft unfortunately require a great deal more training in the pilot than some others. This is the sort of information that we hope the test pilot will tell us. After we get this aircraft and learn as much about it as possible in order to operate safely on the airways, we find, unfortunately, we are doing operational testing for the manufacturer - that which he did not have time for within the budget allotted-to keep the price where he can sell the product. Now, we need a great deal of communications from the operator back to the manufacturer that he may understand what did not work the way he said it would. Very frequently we find that we're not getting through to him...And we're vitally interested in the test pilot's consideration of reliability. We like to know, for example, that he knows the reason for failure is improper design, or manufacturing, packaging or handling, installation, operation, servicing or repair and modification-and that there are no other causes for lack of reliability. Now, if he'll only identify them and take the necessary steps we would hope that we might arrive at a safe, comfortable and convenient future. (9)."

Obviously, the test pilot's obligation to the customer is a subject of debate. The corporate test pilot opinion cited above could be characterized as "crass and shortsighted," the FAA representative opinion as "idealistic or unrealistic," and the business aviation customer opinion as "understanding the problem, but asking for more than the manufacturer will ever provide." Let the buyer beware.

INFORMATION TO THE CUSTOMER

A good first question would be, "What information must the manufacturer provide to the customer?" Answer: "Not much". The FAA requires no formal handbooks on aircraft weighing under 6,000 pounds. If the aircraft manufacturer so desires he can put all of the necessary information on placards in the airplane.

These placards are check lists, emergency procedures, limitations, etc. All companies, of course, comply with this; in addition some companies publish pilot manuals with system descriptions, performance, check lists, emergency procedures, etc.

For aircraft over 6,000 pounds, the FAA requires a flight manual that includes what they consider is the necessary information to safely fly the aircraft. Again some manufacturers expand on this and include more detailed descriptions and performance.

This is not too much of a problem in the transport field, since users (by necessity) expand on the flight manual furnished by the manufacturer by publishing their own operating procedures for every aircraft model they fly.

It is different in general aviation. There are varied types of pilots to write one flight manual for. About flight manuals, manufacturers say:

(1) If it is too thick or complicated it will not be read.

(2) If it is written for novice pilots it preempts the rights of instructor pilots.

(3) If it gets too basic the average pilot will believe he is being "talked down to" and ignore what the manual has to say.

(4) Information must be given in a positive manner, accurate and truthful; however, care must be taken not to make statements that can frighten a beginner or give competitors a sales advantage (7).

In summary, too much should not be expected of a manufacturer's flight manual (if one exists). For example, the following is the complete flight characteristics section of a currently certificated production business jet aircraft:

Flight Characteristics: The flight characteristics of this aircraft are similiar to those of other aircraft in its class.

The following is an evaluation of general aviation aircraft owner's manuals by an FAA representative: "If you will review at random a few modern aircraft owner's manuals, you will find many of them contain detailed information on how to keep the upholstery clean and the paint shining while some of these same manuals have no information whatsoever regarding procedures to cope with an abnormal or unusual situation such as in-flight engine restarts-when certain controls must be selected and set properly, in-flight fire, or what to do in case of an accidental icing encounter. Most aircraft have pecularities and there's normally nothing included in the manual speaking to these peculiarities. (13)."

To illustrate this point, the following "note" and "caution" are taken from Reference 14, which is one of the "better" general aviation owner's manuals, even though it does not have an emergency procedures section.

NOTE

Tube type wheels cannot be used with tubeless tires.

CAUTION

Never clean the exterior with detergent or harsh alkalines.

The statement below, which appears in the introduction to the normal procedures section of Reference 14 is as close to a "warning" as can be found in the manual.

"...final responsibility for safe flight falls squarely on the shoulders of the pilot. Operation of an airplane in excess of its marked limits, constitutes a violation of CAA regulations and, therefore, is illegal as well as dangerous."

FAR REQUIREMENTS FOR CERTIFICATION

Some FAR requirements are interesting and/or controversial. Selected requirements will be discussed and some compared to military requirements.

The first interesting fact about FAR certification is that once an aircraft receives a type certificate; that is, "certificated", an almost limitless number of major design changes can be made to the aircraft which do not require recertification. For example all three aircraft whose design and construction differences are shown in Table 3 are manufactured under the same type certificate.

Table 3 shows a growth in gross weight of 35 percent and an increase of over 58 percent in horsepower between models. This situation is not unique to Beechcraft, but exists at other manufacturers or well. Most currently selling general aviation aircraft began life 15 or 20 years ago and have been updated by the process of model changes. Some companies change models yearly (like Detroit does), others when sales begin to lag, and some companies a combination of the two. Whatever method is used the goal is to keep the cost of changes to a minimum to keep the price competitive. Changes are only those necessary for safety or to meet competition in terms of performance, looks, load carrying capability, or price. Note that improved flying qualities is not among the reasons for change, and even general aviation test pilots will admit that they have been unable to get this point across to their management. As models are changed by power increases, stretching the center of gravity ranges, etc., management does not believe that improving flying qualities, cockpit arrangement, or systems is worth the effort (7).

In general, FAA regulations for Part 23 aircraft are more strict in the area of flight characteristics (flying qualities) than regulations for Part 25 aircraft. The reasoning behind this is that Part 25 aircraft will be flown by highly trained and well qualified pilots while Part 23 aircraft for the most part are flown by relatively unqualified pilots, Stall characteristics are a case in point (7).

Stalls. Requirements on stall speeds and characteristics are probably the most discussed and controversial of all the FAR specifications. Part 23 states that stalls are performed by pulling back on the elevator so that the rate of speed reduction will not exceed one knot per second until a stall is produced, as shown by an uncontrollable downward pitching motion

TABLE 3: Major Differences in Beech Baron Aircraft.
Source: C. A. Rembleske, Beech Aircraft Corporation.

	Model 95	Model 55	Model 58
Gross Weight (lb)	4,000	4,800	5,400
Engine Power (HP)	180	260	285
Prop Diameter (in)	72	78	78
Forward CG Extreme at Gross Weight (in)	79.4	79.4	78
Rear CG Extreme at Gross Weight (in)	83	86	86
Vertical Tail Area (Sq-ft)	19.08	24.42	24.42
Vertical Tail Leading Edge Sweep (deg)	5	40	40
Vertical Tail Arm (ft)	14.2	15.2	15.2
Horizontal Stablilizer Incidence (deg LEU)	2	2	4
Horizontal Tail Area (sq ft)	47	49	55
Fuselage Length (ft)	25.3	25.3	27.2
Engine Nacelles	Round cross-section contour	Rectangular cross-section contour	Rectangular cross-section contour

of the aircraft, or until the elevator reaches the stop. Other indications of the stall, such as those allowed by Part 25 or MIL-F-8785C, cannot be used. The nose must pitch down uncontrollably, or the elevator must be full up. In most instances, since most general aviation aircraft have enough elevator power to allow a wide center of gravity range, the stall as defined by Part 23 occurs at full up elevator. Usually this means that the aircraft is in heavy buffet and has been for quite a few knots. In this condition it must be able to produce and correct roll by unreversed use of the rolling control and to produce and correct yaw by unreversed use of the directional control. This is one area the manufacturer has trouble meeting and is an area that calls for judgement since the average pilot should be able to stall the aircraft and control it throughout the maneuver. In this discussion an average pilot is one weighing 170 pounds (7, 10).

The stall speed requirement is also controversial. Part 23 states that stall speed for a single engine aircraft, or a multiengine aircraft of 6,000 pounds or less which cannot meet the minimum rate of climb specification may not exceed 61 knots (70 mph). The history behind the current regulation dates back to the U S Department of Commerce Aeronautic's Branch Bulletin 7A, Jan 1, 1932. The requirement was based on operational constraints (field lengths and surfaces, for example) as well as crash survivability. Designers often argue that designing an aircraft to the low wing loadings dictated by low stall speeds is too severe a penalty on cruise performance (up to 12 percent at higher altitudes). However, the safety discussion tends toward a debate of risk and benefits. It is argued that technology has radically changed operational and crashworthiness aspects of aircraft design since 1932. This doubtful. How badly designers misunderstand the certification and regulatory problem is illustrated by the following quote, "... only pilots with high skill levels would be flying high-performance singles (high wing loaded aircraft) and a 'class rating' or other such pilot certification would seem to be a logical prerequisite for the operation of such an airplane (11)". In any case, the 61 knot maximum stall speed is intended by the FAA to be a crash-worthiness safety of flight item for all aircraft which do not have the ability to continue safe flight with one engine inoperative. This approach seems reasonable. Stall speed is also very important because it is used to determine minimum climb performance standards, trim criteria, approach speeds, takeoff speeds, and some flying quality requirements.

The conditions for determining this maximum stall speed are engines idle, propeller in takeoff position, gear down, flaps land, most unfavorable center of gravity (usually the forward limit) and maximum weight.

In addition, wing level stalls must be shown engines idle, power on, and flaps and gear in any position. During all of these stalls it must be possible to produce and correct roll and yaw by unreversed use of the controls, up to the time the airplane pitches nose down, or the elevator reaches the stop.

Takeoff. FAR Part 25 requirements on takeoff performance for airline type aircraft for the all engines operating and engine-out cases are similiar to those which should be found in any military performance specification for a new aircraft. There are no takeoff performance requirements for general aviation aircraft weighing less than 6,000 pounds except that the takeoff must not require exceptional piloting skill. For aircraft over 6,000 pounds the distance required to takeoff and climb over a fifty foot obstacle must be determined.

Climb. The Part 23 climb requirements are interesting. Aircraft weighing more than 6,000 pounds must have an all engines operating sea level rate of climb of at least 300 feet per minute. For aircraft weighing less than 6,000 pounds the minimum all engines operating sea level rate of climb is 300 feet per minute, or 11.5 times stall speed in knots, whichever is higher.

There are no engine-out climb performance requirements on aircraft weighing less than 6,000 pounds which stall at less than 61 knots. In this case, rate of climb at 5,000 feet must be determined, but it can be negative. Aircraft which stall at speeds greater than 61 knots or weigh more than 6,000 pounds must have an engine-out steady rate of climb of at least 0.027 times stall speed in knots squared at 5,000 feet. These are essentially under the most ideal conditions (gears up, propeller at minimum drag). Many light and medium twins barely meet this requirement and their safety and accident records are correspondingly poor. Accident statistics from the National Transportation Safety Board have shown that an engine failure related accident in a twin engine aircraft is significantly more likely to cause serious or fatal injuries than an engine failure related accident in a single engine aircraft.

Landing The Part 23 landing requirement is that landings can be made safely without exceptional piloting skill and without excessive vertical acceleration or tendency to bounce, nose over, ground loop, or porpoise. For aircraft weighing more than 6,000 pounds, the total distance to land and stop from 50 feet above the ground must be determined.

Controllability and Maneuverability. Interestingly enough, the FAA Engineering Flight Test Guide makes a point of trying to discredit the current state-of-the-art in flying qualities flight test. It states, "It is, therefore, impossible to measure a flight characteristic. It has been found possible, by rather elaborate instrumentation, to measure certain displacements or velocities or accelerations involved in the motion of the airplane. Except, however, for the purpose of comparing the behavior of one airplane with another or of attempting to rationalize the impressions of pilots, such measurements have not served any useful purpose because ultimately the decision as to whether or not any one or all of the flight characteristics of an airplane are 'satisfactory' must be taken upon the basis of the opinion of those who have flown the airplane (3)." So much for military flying quality specifications and standards.

Static Longitudinal Stability. The cruise and power approach longitudinal static stability requirements of the FARs are very similar to those of MIL-F-8785C; that is, positive speed stablility about trim is required. Acceptable control friction is determined by a "free return" test. When disturbed (held) forty knots (or forty pounds) from trim and controls slowly released, the airspeed must return to within plus or minus ten percent of the original trim speed. This test is thought to, "effectively limit the amount of control friction which will be acceptable since excessive friction would have a masking effect on stability (3)."

FAR Part 23 places requirements on longitudinal static stability during climb. The stick force curve must have a stable slope, at speeds between 85 and 115 percent of the (climb) trim speed in climb configuration with maximum climb power applied. Often, for some reason, the FAA assumes this to be the most critical conditions at which to test speed stability. In fact, the climb test is the one specified in detail in Reference 3.

Lateral-Directional Static Stability. Positive directional stability is required during steady state sideslips from trim conditions essentially throughout the airspeed range up to ten degrees of bank or 150 pounds of rudder force, whichever comes first. In contrast with MIL-F-8785C (which allows force reversals, but not reduction to zero), the FARS do not allow rudder force reversals during sideslips.

FAR Part 23 allows "simplified" two-control aircraft, and some have been built and certificated. The Ercoupe designed by Fred Weick is an example. For these aircraft, the directional stability of the airplane must be shown by rapidly rolling from a 45 degree bank in one direction to a 45 degree bank in the opposite direction, without developing dangerous skid characteristics. The lateral stability is demonstrated by showing that the aircraft will not assume a dangerous attitude or speed when the controls are abandoned in flight for two minutes.

Dynamics. The dynamics requirements of FAR Part 23 are straightforward. Any short period longitudinal, or "short period" lateral-directional oscillations must be heavily damped, stick free and fixed. Heavily damped, is defined by the FAA: "The term heavily damped as it applies to directional and lateral stability, which is a qualitative evaluation,means the oscillations should damp to one-tenth amplitude in seven cycles (this corresponds to a damping ratio of 0.05). The (longitudinal) short period oscillation is a qualitative evaluation, and is the first oscillation the pilot sees after disturbing the aircraft from its trim condition. Heavily damped is interpreted to mean that the aircraft (longitudinal oscillation are) damped within two cycles after the initial input. This is associated with 0.30 damping ratio (3)." These minimums can be compared to MIL-F-8785C requirements of 0.08 lateral-directional, and 0.35 longitudinal(2).

Engine-Out Characteristics. Engine-out requirements on airline type aircraft specified in FAR Part 25 are generally considered adequate and are covered in the Engine-Out course here at the School. Multiengine aircraft certified under FAR Part 23 are generally twin engine aircraft and have special problems. Minimum control speed on the ground is not discussed in FAR Part 23 because few (if any) light twin reciprocating aircraft can continue takeoff after engine loss on takeoff roll.

Minimum control speed in the air is the minimum speed at which when any engine is suddenly failed, it is possible to recover the aircraft with that engine still inoperative and maintain straight flight at either zero yaw or up to five degrees of bank angle. This speed may not be more than 1.2 times stall speed and the specified configuration is maximum available power on remaining engines, aft center of gravity, flaps in takeoff position, gear up, and propeller windmilling unless the aircraft has automatic feathering. Reference 3 suggests performing these tests up to full rudder deflection or 150 pounds rudder force at various altitudes and extrapolating to obtain a sea level value. Note that this is the only configuration at which minimum control speed need be defined. Most general aviation flight manuals present only this one value of minimum control speed, and usually do not state where it occurs. Obviously, minimum control speed determination should be made in other configurations, notably takeoff and landing, since this information is of great importance to the operational pilot.

Since engine power decreases with altitude, above some altitude (about 7,000 feet for several light twins), single engine stall will be encountered prior to minimum control speed during a minimum control speed investigation. Although it seems basic that single engine stall characteristics should have some degree of acceptability, the FAR Part 23 requirement states only that a multiengine airplane must not display any undue spinning tendency and must be safely recoverable without applying power to the inoperative engine with the critical engine inoperative, flaps and gear up, and the remaining engines operating up to 75 percent maximum continuous power except that the power need not be greater than that at which the use of maximum control travel just holds the wings laterally level approaching the stall. There are several problems with this requirement. First, no altitude is specified. Second, when single engine stall is encountered operationally (or in flight test) it will probably be at some bank angle, up to five degrees (or angle where beta is zero). Single engine stall characteristics tend to be more abrupt, violent, and the departure more rapid when banked into the operating engine. Also, a very large problem exists in interpretation of the term "undue spinning tendency" in the requirement. Guidance in Reference 3 states, "An 'undue tendency to spin' would be considered to exist when other than normal use of the controls or exceptional skill strength or alertness were required to prevent spinning." A problem with the guidance is in interpreting what "exceptional skill or alertness" means. Several recent litigations have had the interpretation of this requirement as their central theme.

Documentation for compliance with the FAR requirement on single engine stalls is often a one-line entry where the test pilot checks a "yes" or "no" block to answer the question: Does the aircraft exhibit an undue spinning tendency? Test techniques or conditions are not presented. No description of stall characteristics is made. Contrast this approach with the following description extracted from an airplane safety communique written by the manufacturer to aircraft owners and operators:

"At the first sign of either (minimum control speed) or stall warning (which may be evidenced by inability to maintain longitudinal, lateral or directional control, aerodynamic stall buffet, or stall warning horn sound) the pilot must initiate immediate recovery...If this procedure is not followed and the airplane is allowed to become fully stalled while one engine is providing lift-producing thrust, a rapid rolling and yawing motion may develop even against full aileron and rudder, resulting in the airplane becoming inverted during the onset of a spinning motion. Once the airplane is allowed to reach the rapid rolling and yawing condition, the pilot must immediately initiate the generally accepted spin recovery procedure for these light twin engine airplanes. ...(12)."

This airplane communique goes on to state, "Always remember that extra alertness and pilot techniques are required for slow flight maneuvers including the practice or demonstration of stalls or (minimum control speed)...(12)." The question is: Should the "yes" block on the certification documentation be checked when the manufacturer himself describes the single engine stall characteristics as quoted?

Spins. In about 1948, industry petitioned the Civil Aeronautics Authority (FAA predecessor) to delete spins from pilot certification requirements on the promise that they would improve stall characteristics and develop spin resistant aircraft. This progress has not been made. One of the principal causes of fatal accidents is still stall/spin characteristics and much effort by FAA test pilots is toward improving stall characteristics of new or modified aircraft (6).

There are no FAR spin recovery requirements for multiengine aircraft. A normal category single engine aircraft must be able to recover from a one-turn spin flaps up or down in not more than one additional turn with recovery controls used as recommended. An acrobatic category airplane must recover from any point in a spin, in not more than one and one-half additional turns after normal recovery application of the controls. Prior to the recovery application of the controls, the spin must proceed for six turns with flaps up, and one-turn flaps down. The result is that if an aircraft operator performs over a one-turn spin flaps down in either a normal or acrobatic category aircraft, he is performing flight tests. If an aircraft operator performs over a six turn spin in an acrobatic aircraft flaps up, he also becomes a test pilot. The fastest way to begin a flight test program is to put any number of turns on a multiengine aircraft.

Motherhood. Nobody is immune from writing "motherhood" statements. The FAA is no exception. Part 23 states that, "It must be possible to make a smooth transition from one flight condition to another (including turns and slips) without exceptional piloting skill, alertness, or strength, and without danger of exceeding the limit load factor, under any probable operating condition (including, for multengine airplanes, those conditions normally encountered in the sudden failure of any engine)." Company test pilots have no trouble certifying that their aircraft meet this requirement since, the FAA states, "no special test is required to satisfy (this requirement) since in the course of testing to other flight characteristics the conditions specified in this (requirement) are encountered...(3)."

CASE STUDIES

The following paragraph from Aviation Week and Space Technology will be discussed in class. Details from the discussion will not be published at this time since they involve competition sensitive information.

Out of the Running

Gulfstream American has been informed by the U.S. Air Force that it was "non-responsive" in its approach to the service's rules and specifications for more than 600 primary jet trainers. Gulfstream proposed that, with engine manufacturer Williams International, it **absorb the research and development costs, certificate the trainer to Federal Aviation Administration Part 25 standards, conform to military specifications where different from commercial and then offer the service an off-the-shelf trainer.** USAF's elimination of Gulfstream because it did not follow the traditional military specification practices now leaves Cessna Aircraft, Rockwell International, Fairchild and Ensign Aircraft Co. still competing for the trainer program. A decision on the single contractor winner is expected within the next three months.

—Washington Staff

Aviation Week & Space Technology, April 5, 1982

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The following item from Aviation Week and Space Technology shows that the FAA certification process is becoming a public dispute.

KC-10 Certification Process Disputed

Los Angeles—Factions within the U. S. Air Force differ on the relative merits of the Federal Aviation Administration certification of its McDonnell Douglas KC-10 advanced tanker/cargo transport.

As part of its contract with McDonnell Douglas, the Air Force required FAA certification of the KC-10 in order to take advantage of previous testing, which had been done on the DC-10 Series 30CF.

The Air Force KC-10 program office said the FAA made a strong contribution to the program. "What the FAA certified, we don't have to test. If the Air Force had done all of the testing it would have taken a lot longer," according to a program officer.

But the Air Force combined test force at Edwards AFB, Calif., which tested the KC-10, disagrees.

"It costs us about 70 extra hours of testing," an Air Force test pilot said. "The mission of the FAA is contrary to the mission of the Air Force. We want a tanker in order to fight wars. That doesn't really fit with the safety rules of the FAA. It was entirely inappropriate."

"We spent a lot of time on the smoke detection system, hours of pumping smoke through the back of the airplane during flight," he said. "Military requirements are far less stringent. We give the guys smoke goggles and oxygen masks and tell them to press on. What the FAA considers safety and what the Air Force considers safety are two different things."

The test force was also bothered by the amount of time given to environment testing that according to the pilot pertained more to commercial passengers than to military personnel. Tests were conducted for air flow and for temperature. "We could have tested the temperature to meet a military utility so personnel wouldn't freeze to death or roast to death, but could have been a little uncomfortable. We aren't taking women and children to Boston," the pilot said.

But the KC-10 program officer pointed out that "all the FAA does is certify airworthiness. In terms of the total scheme, it's very difficult to sort out what is a performance requirement and what is a demonstration of safety. The test force at Edwards isn't looking at the total effect."

Another Air Force officer, involved with the KC-10 but not with the program office or the test force, said he could see the justification for wanting FAA certification. "The DC-10CF has undergone a lot of testing, and the KC-10 was just a derivative of it. The way I understand it, the test force is unhappy because some of the testing dealt with how quickly you can detect smoke in the cargo department, but we're going to be carrying cargo too."

McDonnell Douglas said the FAA certification program had helped the Air Force reduce the size of the flight test program and had reduced the amount of data submitted in a typical military program. "Taking advantage of the FAA certification program really saved the Air Force a lot of money. I think it was in the government's best interest to take advantage of the agency that knows the most about the aircraft," according to a McDonnell Douglas KC-10 program official.

Aviation Week & Space Technology, June 15, 1981

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The above news item and the three "Lessons Learned" examples from the KC-10 test program which follows will be discussed in class.

TOPIC: Development Risks and "Off the Shelf" Hardware

LESSON LEARNED: Assumptions concerning performance of "Off the Shelf" Hardware systems may cost time and money not anticipated.

PROBLEM: The KC-10 is a modification of the DC-10. Assumptions concerning systems performance were made using the DC-10 operating in the commercial environment rather than the military environment. This led to a program that was considered to have no technical risk after the development of the Advanced Air Refueling Boom (AARB). The modifications to the DC-10 such as changing the pressurized area and air refueling manifold have caused problems and delays and further testing may surface other problems than can cause costly engineering changes. Even though the airplane has considerable commercial experience, there is risk when transferring this experience to a military environment.

DISCUSSION: High risk programs usually have no hardware to use to minimize the risk, therefore the risk must be accepted. In "off the shelf" hardware, there is a tendency to assume performance and use analysis of existing data to evaluate the system even though there is hardware available. Usually cost savings are cited as the reason for not actually evaluating the "off the shelf" equipment prior to a production decision. However, configuration changes, however minor, become very expensive once the system is procured and negate the savings of not conducting an early "hands on" evaluation that may have identified the problem.

APPROPRIATE ACTION: Early "hands on" evaluation of "off the shelf" hardware in a military/mission environment is a must and should be accomplished before source selection and certainly before major acquisition begins. Early evaluation may adequately define problem areas and solutions to those problems and save time and money by minimizing risk.

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TOPIC: FAA Certification of KC-10 Aircraft

LESSONS LEARNED: FAA certification in conjunction with development testing should be critically reviewed in developing future weapons systems. The FAA is only interested in vehicle airworthiness, not mission accomplishment. FAA certification can result in redundant testing that is wasteful of resources. The FAA certification of aircraft requires additional flight test time compared to military testing.

DISCUSSION:

1. It is my experience on the KC-10 that FAA certification is absorbing valuable USAF dollars to accomplish items that are being or should be accomplished by USAF test crewmembers. For example, both the FAA and USAF accomplished an evaluation of the adequacy and suitability of lighting in the boom operator's pod. The FAA was concerned only that the lights allowed the boom operator to escape safely from the area. Obviously, the USAF boom operators were concerned about their safety, but more important, were concerned about the ability of the KC-10 to accomplish night air refueling operations. I could give numerous other examples, but the point is that the FAA is only interested in the airworthiness of the vehicle. A military tester is concerned not only with airworthiness but with the ability of the vehicle to accomplish the mission. The FAA has very little experience in the conduct of the mission of the aircraft. For example, the FAA requires an aircraft experiencing cabin depressurization to descend to 10,000 feet MSL or 2,000 AGL. The oxygen systems in FAA certified aircraft are designed to meet this requirement. The USAF, on the other hand, may continue the mission in a depressurized aircraft at 25,000 feet. Oxygen equipment designed for FAA requirements may not meet USAF requirements. The fact that an aircraft is FAA certified in no way insures that the aircraft will be capable of completing its assigned military mission. The KC-10 has a standard military IFF with modes 1, 2, 3 and 4. The military tested all the modes, including mode 4, and found them satisfactory. The FAA required FAA tests to certify the IFF that were essentially a duplication of the AF effort. The USAF is wasting valuable resources to certify an IFF that is known to function acceptably already. FAA certification can result in redundant testing that is wasteful of resources. The FAA flight test crewmembers only participate on demonstration flights. The contractor normally flies the mission first to insure there are no problems. The USAF flight test crewmembers participate in all flights and do not require a separate demonstration flight. The FAA certification of aircraft requires additional flight test time compared to military testing.

2. The mission of the KC-10 involves the receiver aircraft, the aerial refueling boom and the KC-10. All these systems must be considered during testing. For example, the FAA conducted a simulated icing evaluation on the KC-10 boom. The objective of the test was to determine if simulated ice on the boom was a hazard to the flying qualities of the KC-10, or if the simulated ice prevented the boom from being stowed. While these objectives are important, they are only one part of the evaluation. The program office is not testing the entire system, i.e., receiver, boom and tanker in simulated or actual icing conditions. The fact that the FAA is certifying the KC-10 for operations in icing conditions in no way means the KC-10 is capable of performing its mission in icing conditions. Likewise, several mission

deficiencies have been identified to the FAA and they refuse to correct them. For example, crewmembers can become locked in the KC-10 latrine and can get out only when the door is unlocked from outside. It seems the FAA should be concerned about the ability of crewmembers to egress from all compartments of the KC-10 in the event of a fire or emergency, let alone during normal flight conditions. Test control also suffers under FAA certification testing. The FAA is not bound to abide by USAF safety procedures. For example, the Air Force Flight Test Center accomplished a safety review board which identified and specified certain minimizing procedures to be followed while testing the KC-10, whether flown by the FAA, USAF or contractor pilots. The safety review board procedures specified a buildup technique for engine out takeoff tests and for using a four-second rotation rate. The FAA pilot used a much faster rotation rate and caused a boom strike during rotation for takeoff. The USAF in no way could control the FAA pilot's actions during the test program. Fortunately, the boom strike did minimal damage but the USAF had to spend time and dollars to inspect the boom and KC-10. The USAF must be able to control the test conduct to insure testing is done safely and efficiently. The FAA is not bound to adhere to USAF test procedures.

APPROPRIATE ACTION: Determine on a case by case basis the value of FAA certification in the development of future weapons systems.

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TOPIC: Contractor Test Facilities

LESSON LEARNED: Contractor test facilities/equipment are not always adequate to satisfy Air Force requirements.

PROBLEM: The KC-10 program is using the contractor facility at Yuma, AZ during the predelivery tests. There was inadequate firefighting equipment at the facility necessitating movement of equipment and crews from AFFTC to Yuma.

DISCUSSION: Although this example is fire trucks and crews, it can be expanded to instrumentation systems and chase airplanes. The AF program offices have used contractor facilities justified by cost and schedule consideration only to find they must provide considerable resources to the contractor facilities. The tangible costs are usually not as significant as the intangible span of control and efficient utilization of resources.

APPROPRIATE ACTION: Early surveys of contractor facilities to insure proper resources are available. Consider not only the tangible cost of these resources but also the intangibles of operating away from an Air Force test facility.

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CONCLUSIONS

An FAA certificated aircraft may, or may not meet FAR Part 23 or Part 25 requirements. Nobody except the contractor knows. FAR requirements are sometimes (1) too restrictive (Part 25 engine out), (2) very similar to military requirements (Part 23 and Part 25 dynamics), or (3) not restrictive enough (Part 23 engine out), for determining military suitability. There are no mission (operational) considerations involved in testing for FAR compliance. According to the FARs, all aircraft certified to Part 25 (or Part 23) are the the same; that is, the Learjet, DC-9, Boeing 747, and DC-10 are alike. Published performance and flying qualities data on certificated aircraft are inadequate by military standards. There is high risk associated with assuming that an "off-the-shelf" aircraft with considerable commercial experience will be suitable for a military mission.

RECOMMENDATION

Beware of (1) the claimed cost savings which result from "off-the-shelf" procurement, (2) the accuracy and adequacy of contractor FAR certification and published data, and (3) assuming that an FAA certificated aircraft will be suitable for a military mission.

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