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# V/STOL Certification

JAMES F. RUDOLPH*

*Federal Aviation Administration, Washington, D. C.*

**The new generation of Vertical/Short Takeoff and Landing (V/STOL) aircraft has many novel features which are not covered by the existing aircraft airworthiness standards. This has made it necessary for the Federal Aviation Administration (FAA), together with industry, to develop standards specifically oriented toward powered lift aircraft. These tentative standards have been released to the aviation community and are intended for trial application in new Short Takeoff and Landing (STOL) type certification projects. In addition to airworthiness certification standards, the FAA is also involved in the planning and development of the entire STOL system including air traffic control techniques, navigation and guidance equipment, and intercity STOL ports. Through the cooperation of the various government agencies and the aircraft industry, an important new element in our air transportation system is emerging.**

## V/STOL Certification

FOR many years there has been interest in aircraft which are capable of taking off and landing vertically or in short distances. As a result of this interest, back in 1966 a special government/industry advisory committee to the FAA Administrator recommended the formulation of tentative standards for emerging categories of aircraft. They further proposed that these tentative standards, once developed, be tried on for size, so to speak, in trial application prior to actual formal adoption. In that same year, the Vertical Lift Council of the Aerospace Industries Association (AIA) similarly recognized the need for VTOL and STOL standards and urged their development by mid-1968. The AIA volunteered to get the effort moving by formulating a working group, drawn from aircraft companies involved in the design of VTOL and STOL aircraft, for the purpose of preparing a first cut at the tentative standards. The FAA welcomed industry's offer and a program was established to ensure that all interested parties would be given an opportunity to make an input to the tentative standards.

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*Director, Flight Standards Service.

Upon receipt of the AIA draft standards, they were reviewed by the FAA offices which would ultimately be charged with their implementation. Meetings were held with the AIA working group to ensure mutual understanding, and subsequently the public was invited to participate in reviewing and commenting on the draft tentative standards at a government/industry meeting in April 1968. After consideration of all the inputs received, the FAA in July 1968 issued the document titled "Tentative Airworthiness Standards for Verticraft/Powered Lift Transport Category Aircraft"—more commonly known as the "YELLOW BOOK." It was agreed at the time of the 1968 conference that the FAA would periodically review the standards with the aviation community for updating purposes. Such a meeting was held in April of 1970. The "YELLOW BOOK" was revised and distributed to the aviation community in Oct. 1970. I might mention that there was a slight change in the title of the document—the new one being "Tentative Airworthiness Standards for Powered Lift Transport Category Aircraft." The word "verticraft" was deleted since verticraft is only one form of a powered lift aircraft.

The purpose of the "YELLOW BOOK" is to present tentative airworthiness standards for study, trial application, and comment during the design and development of VTOL and STOL transport category aircraft. The tentative standards are not regulations and are not a formal notice of proposed rule making. Pending the adoption of regulations of general applicability of these aircraft, their type certification basis will be Pt. 25 or Pt. 29 of the Federal Aviation Regulations (FAR), as supplemented by special conditions issued for the particular design under Sec. 21.16 of the FAR. Special conditions are issued when the FARs do not contain adequate or appropriate safety standards because of a novel or unusual design feature of the aircraft.

Because of the wide variety of novel features in these emerging aircraft and the lack of experience in their certification and operation, we recognize that the STOL tentative standards may not be appropriate for all designs; however, the tentative standards should provide useful guidelines for the designers and the FAA in arriving at an acceptable level of safety. Appropriate rulemaking will be undertaken when sufficient knowledge and experience have been gained to provide a sound basis for adopting regulations of general STOL applicability.

## History and Legislative Authority

In the early pioneering days of aviation, there were no standards or safety rules for aircraft. It was after World War I when civil aviation began to develop so rapidly that it became evident that governmental aid and supervision were necessary to provide for the orderly growth and prosperity of the young industry.

The legislative authority of the present Federal Aviation Administration is contained in Public Law 85-726, known as the Federal Aviation Act of 1958. The Act empowers and requires the Administrator to promote safety of flight of civil aircraft by prescribing and revising from time to time such minimum standards governing the design, materials, workmanship, construction, and performance of aircraft, aircraft engines, propellers, and appliances including such reasonable rules and regulations or minimum standards governing practices, methods, and procedures as he finds necessary in the interest of safety.

## Development of Standards

The minimum standards are issued in the Federal Aviation Regulations. The rules for certification of aircraft contained in these regulations are known as "airworthiness standards." Before discussing STOL standards, it would be appropriate to give you an idea of the format in which the present rules are codified. All of the FARs are codified in Title 14 of the Code of Federal Regulations. Aircraft rules are set forth in Subchapter C, and run from Pts. 21–59. As provided under the Act, there are Federal Aviation Regulations governing the certification of aircraft, aircraft engines, and propellers. The aircraft regulations are further separated into standards governing the certification of airplanes, rotorcraft, gliders, and manned free balloons. A further division is made with respect to airplanes and rotorcraft. In this connection, small airplanes are certificated in the normal, utility, and acrobatic categories under one set of airworthiness standards, while large airplanes are certificated in the transport category under a generally more comprehensive set of standards. Rotorcraft standards are segregated into normal and transport category with a weight demarcation of 6000 lb.

The airworthiness standards in the Federal Aviation Regulations are both objective and subjective. They apply well to the conventional, so-called "proven" designs. The existing airworthiness standards were developed originally on the basis of operating experience with generally conventional aircraft. However, when a radical advance occurs, such as now is the case with supersonic airplanes and STOL aircraft, new standards must be developed without the benefit of extensive operating experience. Such advances require anticipating the new environmental factors, airplane characteristics, and resulting airworthiness problems. They also pose problems of timing as airplane projects progress through design, testing, and certification. The designer needs to know at an early stage what standards will have to be met. On the other hand, it may not be possible to make a final determination as to whether certain standards are adequate or realistic until a prototype airplane is built and considerable flight experience is obtained.

## Problem Areas

There are many novel or unusual design features anticipated in the coming generation of STOL aircraft which will present formidable problems in developing airworthiness standards. Among the more significant problem items are: 1) noise certification; 2) definition of STOL aircraft; 3) control system duality; 4) STOL all-weather operation; 5) cluster of engines; 6) fire protection of lift engines; 7) endurance test for lift engines; 8) handling qualities; and 9) performance.

## Noise Certification

FAR 36, which was issued in December 1969, covers subsonic transport category airplanes and subsonic turbojet airplanes regardless of category. This regulation establishes specific noise levels and measurement distances for certification of new aircraft. In addition, FAR 36 prohibits escalation of aircraft noise on existing airplanes and follow-on models by requiring that noise levels of the derivative aircraft either meet FAR 36 specific levels or be quieter than the parent airplane. FAR 36 is not orientated towards the performance capabilities of STOL aircraft.

The FAA has in the final stages of development an advance notice of proposed rule making for STOL aircraft. At the present time, it is envisaged the noise requirement will define a perimeter around STOL ports with specified maximum noise levels along the perimeter. Criteria to be proposed for rulemaking will be developed following review of the comments submitted in response to the advance notice of proposed rule making. In any event, the present mood of ecological awareness dictates the concept that STOL aircraft be compatible with the community they serve.

A number of studies have been undertaken by the FAA to evaluate the subjective aspects of STOL noise and further studies are underway regarding economic and other implications of STOL noise regulation. These include consideration of factors which differentiate the STOL/VTOL operations from the conventional airplane operations. Some of the factors are: a) high thrust/weight ratios; b) high approach power setting; c) complexity of operations; d) low-altitude operations; e) reverse thrust noise (not necessarily confined to airport areas); f) three-dimensional noise sensitivity of metropolitan area; and g) competitive economics.

The overall FAA effort has been under the direction of a task force, chaired by the FAA and comprised of industry, airlines, airport operations, the National Aeronautics and Space Administration (NASA), and local government representatives.

## Definition of STOL Aircraft

The term STOL has been widely used without having a definition beyond short takeoff and landing. The agency endeavored to come up with a definition for STOL predicated on its performance capabilities and/or special design features but was unsuccessful in light of the fact that a STOL can be any one of a combination of several types of aircraft ranging from VTOL to conventional fixed wing design.

We now believe a better approach to this problem is to develop a definition to cover the transportation system rather than just the aircraft utilized. If this concept is accepted, a

STOL aircraft can then be defined as an aircraft which is capable of operating from a STOL runway in compliance with the STOL operational and airworthiness requirements.

Although the agency has not issued a definition of terms related to the STOL system, we believe standards for the STOL system will be comprised of: 1) new standards for STOL runways, navigation facilities, and air traffic procedures; 2) supplementary aircraft characteristics; and 3) airworthiness and operational standards applicable for operation on STOL runways. In our current thinking, we envisage that the criteria utilized in establishing the STOL system will be: 1) runway length of approximately 1800 ft; 2) approach glide slope 6-7.5°; 3) precision approach capability; i.e., microwave ILS or VOR/DME RNAV; 4) approach obstacle clearance plane to meet those specialized operational criteria; 5) landing threshold height of approximately 35 ft; and 6) if the STOL port is elevated, an emergency arresting system.

Guidance for the planning and design of metropolitan STOL ports has been published in an FAA advisory circular. This publication provides the physical, technical, and public interest factors which will be considered in the establishment of a STOL port. It is available without charge from the FAA.

As a point of interest, the Airworthiness Committee of the International Civil Aviation Organization (ICAO) included in its agenda for the Ninth Meeting held in Montreal, Canada, during November 16 through December 1970 the subject of defining STOL and VTOL aircraft. The Committee considered that, while no difficulty would be experienced in stating precisely what is meant by vertical takeoff and landing, no satisfactory definition could be developed to define the term STOL. The Committee was of the opinion that aircraft with STOL capabilities should be considered in relation to the environmental system in which they are likely to operate. For example, consideration would have to be given not only to the performance capabilities of these aircraft but also to their operational requirements, approach guidance and navigational system requirements, obstacle clearance surface requirements in the approach and departure areas, emergency containment system requirements, and to their noise constraints. From the results of this meeting, it appears that the FAA viewpoint on the definition of STOL is in agreement with ICAO.

## V/STOL Control System Duality

The present fixed wing transport category regulations require continued safe flight and landing after a failure in the control system. To meet this requirement, the aircraft designer has provided at least two completely independent systems for use by the pilot to maintain sufficient control of the aircraft if such a failure should occur. However, for some promising V/STOL configurations such as tilting rotors, stopped rotors, folding prop rotors, monocyclic tilt wing, lift fan, etc., dual control systems may be very difficult to achieve. For example, the swash plate is a traditional interface area. A practical means of dualizing the mixing functions of the swash plate would present a very difficult design problem.

It may, therefore, be necessary to depart from the traditional dualization of control systems and establish some other requirements for V/STOL aircraft which would meet the objective of the failsafe concept provided for in present fixed wing transport airplanes.

Some usable considerations in providing an equivalent safety level would involve, if possible, the increased reliability with regard to failures due to: a) exceedance of design loads; b) fatigue; c) human error, including quality control; maintenance problems, including omission of vital parts, such as fasteners, etc.; d) environmental conditions such as corrosion, sand, dust, etc.; e) jamming; f) hydraulic or electric power source failures and runaway of control; and g) combinations of probable failures.

## STOL All-Weather Operations

At the start, STOL operation will not be an all-weather operation; eventually, to be reliable, STOL commercial operation may want to be operable during all weather conditions. The problems of all-weather operations include: a) the handling qualities; b) the automatic landing system; and c) the landing guidance. As with conventional aircraft, "blind" landings probably will be automatically controlled by a sophisticated autopilot, or integrated flight control system.

Present day cockpit displays, flight directors, and instrument landing systems (ILS) are not adequate for guiding conventional aircraft to a Category III landing, and they cannot meet the requirements of STOL aircraft. A recommended configuration for a microwave instrument landing system to ultimately replace existing ILS is emerging from two years of study.

## Cluster of Engines

Our new requirements are orientated toward engine independence; that is, requiring that a failure of one engine should not affect the safety of another or the safety of the aircraft. When lift engines are used in clusters, the extent to which one engine affects another suggests a re-evaluation of our independence rules. For example, it might be possible for two or more failures in a cluster of engines to occur which still might not adversely affect the overall safety of the machine. It has been suggested that the engine fire protection requirements need major rework since application of the present rules to lift engines and clusters of engines might prove too great a weight penalty for the aircraft.

## Endurance Test for Lift Engines

The endurance test requirements of FAR 33 appear inappropriate to lift engines. FAR 33 requires a 150 hr test program for approval of an engine. A different test time might be more suitable for lift engines intended to be operated for short takeoff and landing periods only. In addition, the test schedule in FAR 33 may not be applicable for such engines; to be more specific, more time at high power levels is believed to be more fitting for these engines.

## Handling Qualities

A difficult problem we have encountered in developing airworthiness standards for handling qualities is that associated with the uniqueness of STOL aircraft; i.e., the capability of making steep approaches at low speeds for landings. Our experience in this area is with aircraft which were generally flown at descent angles of about 3° using an approach speed of approximately 130 knots. These aircraft had adequate aerodynamic control including the capability of operating in crosswinds up to 30–35 knots. For STOL aircraft, we envisage the aircraft will be operated at descent angles of about $7\frac{1}{2}$° using approach speeds of 60–80 knots. In addition, STOL aircraft will be required to make precision approaches to touchdown because of the lack of long runways. Whereas in the past controllability was important, it was not a serious problem in terms of limiting the aircraft from operating in most crosswind, turbulence, and wind shear conditions. This is not true in the case of STOL aircraft since these conditions become increasingly critical as the approach speed of the aircraft is reduced. STOL aircraft will probably utilize some form of thrust augmentation to supplement controllability obtained from aerodynamic means. Due to this new importance of slow speed controllability and associated design complexity, we need to define our handling quality requirements in more precise terms.

Research leading to STOL lateral control maneuverability criteria for use in civil certification was undertaken by FAA in 1968. The program was a flight simulator effort using the NASA S-16 moving-base simulator facility. This was the first of a several-phase program designed to cover the whole range of flight characteristics. In 1970, second-phase work was begun on directional control criteria. We are expanding this to provide for research on adverse ground effect. The final phase of the STOL program is directed to collecting data on longitudinal dynamics and flight-path control with lift augmentation systems. Flight validation of STOL flight characteristics criteria in a suitable vehicle is our next objective.

The very successful use of variable-stability aircraft or in-flight simulator by the military and NASA to develop quantitative flying and handling qualities specifications for military aircraft has suggested their use by the FAA. All of our work is being conducted in close cooperation with NASA and the military services. In fact, some of our projects have been jointly sponsored, or have been mutually complementary in nature with those of NASA and the military, to avoid duplication of effort and to help achieve the best technical and administrative supervision.

## Performance

Since STOL operation will be based on keeping runway lengths to a minimum consistent with safety, the determination of a reasonable landing distance becomes a prime area of interest. Landing distances for current conventional transport operations are based upon increasing the landing distance determined from flight test by a factor of $\frac{5}{3}$ to account for operational variables. A detailed study of these variables and their individual effect on landing performance is being made to determine what is applicable for STOL operational use.

A flight program using a Twin Otter aircraft has resulted in a data base for development of ground level approach, landing, and takeoff operational criteria. The investigation involves: 1) location of the microwave guidance system in relation to the target touchdown point. 2) Determination of maximum and optimum glide slope angle. 3) Determination of obstacle clearance plane for the various angles including approach, takeoff, and missed approach. 4) Flyability and approach minima for the various microwave guidance systems.

Preliminary findings indicate that the microwave guidance system should be located approximately 150 ft to 200 ft ahead of the target touchdown point and a maximum glide slope angle of $7\frac{1}{2}°$ with an optimum angle of 6°. This program will be continued including verifying instrument approach configurations using other STOL aircraft. For an elevated runway, a flight program will commence using a representative type elevated runway pending construction of an elevated runway structure.

Implementation of other factors such as use of reverse thrust on landing to allow operations onto shorter runways also requires serious consideration. The reliability of such systems and the attendant problems of a failure in these systems must be carefully studied to preserve the level of safety enjoyed in current operations.

With STOL ports planned for construction in the proximity of metropolitan centers, obstacle clearance following engine failure becomes an increasingly important consideration. The one-engine-out takeoff performance capability of current twin engine airplanes may not be economically feasible for STOL operation. To overcome this, the first generation STOL aircraft may well be aircraft with more than two engines or otherwise provided with auxiliary means of propulsion.

## Research Programs

The FAA has initiated or is participating in many other research programs. Research attention is also being directed at other areas not necessarily confined to airworthiness. Some of these programs are now in process and others are planned for the immediate future. Some of the more significant programs are discussed below.

### 1. Canadian DOT/STOL Program for Evaluation of Operation and Airworthiness Requirements

The U.S.-Canada joint effort to develop and fly the augmentor-wing Buffalo will contribute in many ways to STOL development. In addition to flight performance and characteristics of this STOL concept, we look upon this vehicle as an advanced STOL vehicle with which to conduct STOL navigation and approach and landing research.

### 2. Joint NASA/FAA Programs

NASA and DOT are conducting comprehensive simulation and flight tests to: a) determine by dynamic Air Traffic Control (ATC) simulation the capability of STOL aircraft to operate effectively at major hub airports and intercity STOL ports. b) Investigate aircraft response to representative STOL flight paths and ATC commands in the terminal area to optimize STOL/ATC techniques. c) Determine the application of various contending area navigation techniques; i.e., LORAN C/D, DECCA, OMEGA, VOR/DME, to STOL terminal navigation and guidance. d) Investigate straight and curved path STOL approaches in manual, semiautomatic, and automatic modes using a microwave scanning beam ILS (MODILS) and VOR/DME system elements. e) Employ two-way data link for position reporting and ATC data.

### 3. Elevated STOL Ports

Planning for multiple use of land near a metropolitan area by having air access to the top level of a building and office, hotel, and ground transportation on the lower levels appears necessary for the future. To determine the effect on aircraft design and operation, navigation siting, approach and runway lighting, and airport safety, research must be conducted at an elevated facility. Although it would be easier to do this at the National Aviation Facilities Experimental Center (NAFEC), the FAA recognizes that the investment in such a structure might better be spent in cooperation with a local community such that the elevated STOL port would be an operational facility after the research was completed. We are conferring with various communities throughout the U.S. to see where this might be most useful for all concerned.

We also are considering the alternative of using a floating STOL port instead of an elevated structure on land. A study was completed last fall of the technical feasibility and engineering and economic analysis of the design, fabrication, and installation of the floating STOL port concept. The choice of a site on the Hudson River for this study, between W 26th and W 34th Streets, was not intended as a final site location but rather represented a real environment with all the complex problems that would be associated with a floating STOL port located near any city center.

## Conclusion

It is clear that we all have our work cut out for us, from the standpoint of prescribing design and operation standards which are both technologically practical and economically reasonable and which will insure a level of safety commensurate with our air transportation system. I emphasize the words "practical" and "reasonable." We recognize, as you do too, that we can make an airplane so safe that it can't get off the ground. Our task is to legislate sensibly and support what promises to be an important element in our air transportation system—the STOL.