REVIEW OF TAKEOFF CONFIGURATION WARNING SYSTEMS ON LARGE JET TRANSPORTS

Aircraft Certification Division
Northwest Mountain Region
Federal Aviation Administration

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Introduction

On August 16, 1987, a McDonnell Douglas MD-82 crashed on takeoff from the Detroit airport. The results from NTSB's preliminary investigation suggested that the probable cause may have been the failure of the flight crew to set flaps/slats. This preliminary investigation also indicated that the crew did not receive a warning of the out-of-configuration condition from the airplane's takeoff configuration warning system.

In response to these preliminary findings, the FAA's Aircraft Certification Division established a special team to conduct a general review of takeoff configuration warning systems with a special emphasis on the MD-80 design. This review was to include regulatory requirements and FAA policies applied to the designs of the major manufacturers along with a review of the service difficulties, incidents, and accidents that had been experienced. Based on this review, the team was to make recommendations for changes to FAA's requirements and policies if the level of safety established by these requirements was determined to be inadequate. The team was also to make recommendations for FAA action in any areas where it found that certification, operations, or maintenance of these systems were deficient.

This report summarizes the results of that team's review.

Scope of the Review

The special review team consisted of the following individuals from the respective FAA organizations:

1. Gregory J. Holt,
   Standardization Branch, Transport Airplane Certification
   Directorate, Seattle, Wa.
2. George Meyers,
   Flight Test Branch, Seattle Aircraft Certification Office, Seattle, Wa.
3. Dick Saul,
   Systems and Equipment Branch, Long Beach Aircraft
   Certification Office, Long Beach, Ca.
4. Carroll Wright,
   Special Programs Branch, Rotorcraft Certification, Fort Worth, Tx.

The team's review of takeoff configuration warning systems included: a review of the FAA's policies and regulations; a survey of system designs by McDonnell Douglas, Boeing, Lockheed, and Airbus together with their associated operating procedures and maintenance practices; and database searches for service difficulty reports and incidents on all transport airplanes.

A meeting was held in Los Angeles with McDonnell Douglas on November 3, 1987, in which design information and service histories on the takeoff configuration warning systems of DC-8, DC-9, DC-10, the MD-80, and the MD-11 were reviewed. A similar meeting was held with the Boeing Company on January 6, 1988, in Seattle. Design information and service histories for the 727, 737, 747, 757, 767 series airplanes were reviewed. A meeting and telecon were held with Lockheed to gather information on the L1011, and a telecon was held with Airbus to obtain information on the A300 and A310 series airplanes.

The databases that were researched for service difficulties and incident and accident reports were: NASA's Aviation Safety Reporting System (ASRS), the Accident/Incident Reporting System maintained by the FAA in Oklahoma City, the Service Difficulty Reporting System maintained by the FAA in Oklahoma City, and the Boeing Company's Jet Transport Safety Event File.

The team conducted a limited survey of the pilot community to obtain first-hand knowledge of flight crew perceptions and experiences with takeoff configuration warning systems. Individual interviews were held with some pilots and a questionnaire was mailed out to airlines through the Air Line Pilots Association (ALPA).

The team also met with some of the members of the FAA's MD-82 accident investigation team and held several telecons with FAA's Accident Investigation Division ASF-100 to obtain the details of the investigative team's findings on the accident as well as their suggestions and recommendations regarding takeoff configuration warning systems.

Federal Aviation Regulations and FAA Policies for the Certification of Takeoff Warning Configurations.

FAR 25.703, "Takeoff warning system," makes it mandatory for a takeoff configuration warning system to be installed on transport airplanes with new type certificates issued after 1978. Other requirements which are applicable to the certification of takeoff configuration warning systems are FAR 25.1301, "Function and installation," and FAR 25.1309, "Equipment, systems, and installations."

FAR 25.703 was added to Part 25 by Amendment 25-42 on January 16, 1978. No additional related amendments have been made since that time. FAR 25.703 requires, in summary, that a takeoff warning system be installed and provide an aural warning to the pilots when beginning the takeoff roll, whenever the airplane is not in a safe configuration for takeoff. The preamble to Amendment 25-42 states that the amendment was being made to "update and improve the airworthiness standards." According to the preamble to the amendment, the takeoff warning system would serve as "a back-up for the checklist, particularly in unusual situations, e.g. where the checklist is interrupted or the takeoff delayed".

Prior to Amendment 25-42, there was no requirement for a takeoff configuration warning system to be installed on transport airplanes. Since this amendment was not retroactive, some transport airplane models in service today, may not have takeoff warning systems installed by virtue of their certification bases. The certification bases is determined from the date of application for the original type certification. Large transport jets with type certificate application dates prior to amendment 25-42 include: the Boeing 707, 727, 737, 747; the McDonnell Douglas DC-8, DC-9, DC-10, and MD-80; the Lockheed L1011; and the Airbus A300 and A310. For all of these airplanes, however, the manufacturers included a takeoff warning system in the basic type design at the time of initial certification. The type certification dates and certification bases of the airplanes reviewed are presented in table A1 of the appendix.

The basic FAR requirement that was applied to the certification of pre amendment 25-42 takeoff configuration warning systems installed by the manufacturers was FAR 25.1301. FAR 25.1301, among other things, requires that installed equipment must be appropriate for its use and must function properly. FAR 25.1301 was part of the recodification of CAR 4b into the FAR in 1961. It is essentially unchanged from CAR 4b.601.

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FAR 25.1309 was also part of the recodification of CAR 4b. At that time it required that systems mandated by Subchapter C perform their intended functions reliably, under all foreseeable operating conditions, and be designed to prevent hazards to the airplane caused by their malfunction or failure. Amendment 25-23 to FAR 25.1309, dated April 8, 1970, made a distinction between major and catastrophic failure conditions and provided for a mathematical analysis for the probability of failure as a means for demonstrating compliance. FAR 25.1309 was amended again on December 20, 1976, by Amendment 25-38, and on July 18, 1977, by Amendment 25-41. These later amendments, however, did not affect the certification requirements in regard to takeoff configuration warning systems.

FAR 25.1309, in its current form, requires that the consequences of both single and multiple failures be considered and be shown by analysis to have an acceptably small probability of occurrence. AC 25.1309-1, dated September 7, 1982, provides further guidance on means by which compliance with FAR 25.1309 may be demonstrated.

The basis for the certification of takeoff warning systems installed prior to Amendment 25-42 and the revision to FAR 25.1309, which provided for a quantitative probability analysis, was in general, a qualitative failure analysis, engineering judgement, and past experience with other similar systems. For systems installed after Amendment 25-42 it has been FAA policy to require a quantitative safety analysis to substantiate compliance with FAR 25.1309.

The FAA policy in applying the provisions of FAR 25.1309 has been to treat those systems designed to act as backups to the flight crew, alerting them of hazardous operating conditions, as falling into the non-essential level of criticality defined by AC 25.1309. The basis for this policy is that these systems have no visible presence to the crew and do not affect the operation of the airplane. In addition failures of these systems, in and of themselves, are not considered to: create an unsafe condition, reduce the capability of the airplane, or reduce the ability of the crew to cope with adverse operating conditions. Other systems, besides the takeoff configuration warning system, which fall into this category include: stall warning systems, overspeed warning systems, ground proximity warning systems, and windshear systems.

Generally, to demonstrate compliance with the requirements for a non-essential system, the FAA requires that it be shown by analysis that such systems have a probability of failure which is less than approximately 1.0×10^{-3} or 1.0×10^{-4}. Systems which are designed to meet these requirements are usually single string systems with limited monitoring, and maintenance checks or preflight checks are relied upon to limit the exposure to undetected failures.

The FAA applies a higher level of criticality to systems whose failure would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions, or which would create an unsafe operating condition. For these systems, the FAA requires the probability of failure to be less than 1×10^{-5}. This level cannot ordinarily be achieved with existing technologies without a dual system architecture and self monitoring. The FAA considers certain navigation systems, instrument displays, etc. as falling into this category.

The highest level of criticality is applied to systems whose failure would, as a direct result, cause loss of the airplane or loss of lives. For these systems, the FAA requires the probability of failure to be less than 1×10^{-9}. The FAA considers certain CAT III autoland systems and fly-by wire flight control systems as falling into this category.

Minimum Equipment List

The Minimum Equipment List (MEL) specifies conditions under which an airplane can be dispatched in with certain equipment inoperative. The team reviewed the MEL requirements for the Boeing, McDonnell Douglas, Lockheed, and Airbus airplanes covered by this report. With the possible exception of some individual airplanes, no MEL relief for an inoperative takeoff warning system was provided. It should also be noted, however, for the majority of these airplanes, takeoff configuration warning system failures are not annunciated, and no preflight checks are required or recommended by the manufacturer.

Summary of Takeoff Warning System Designs on Airbus, Boeing, McDonnell Douglas, and Lockheed Airplanes

The takeoff warning system designs reviewed by the team ranged from the early relay logic designs in the McDonnell Douglas DC-8 airplanes, through solid state logic systems, to the microprocessor based system of the Boeing 747-400 airplane.

The team observed a definite trend towards increased sophistication of design for takeoff warning systems, corresponding to the state of technology available at the time the airplane was developed. The transition from analog to solid state circuitry resulted in more monitoring, and self-test features in the design. Microprocessors and electronic instrument systems, the latest advances in airplane system technology, have resulted in takeoff warning systems with: redundant logic/warning circuitry, extensive monitoring and self-tests, and the display of takeoff configuration warning system status messages on electronic instrument caution and alert systems (EICAS), in addition to warning lights and aural devices. The manufacturers indicated that these enhancements have been incorporated not because of poor service histories or customer experience, or because they are necessary to meet the current FAR but rather because of requirements by the airlines for extended maintenance intervals and improved dispatch capabilities from locations without spares or repair stations. The team believes, however, that the net result has been greater margins of safety.

The majority of the designs employ some dual input sensors, single string or non-redundant logic/warning circuitry and single or dual aural warning devices. All of the takeoff warning systems are armed using information that the airplane is on the ground and the throttles are advanced for takeoff, or an engine parameter such as N1 is in the takeoff range. For determining that the airplane is in the proper takeoff configuration, all of the systems use flap position. Most designs also monitor slats, speed brakes (or spoilers) and horizontal stabilizer trim. Additional inputs are supplied to the takeoff warning system on airplanes which require unique inputs for the airplane takeoff configuration e.g. body gear on the Boeing 747. In most cases, parking brakes, are not monitored by the warning system. All of the systems monitored the input parameters required by FAR 25.703 with the exception of the DC-8 which did not monitor stabilizer trim.

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Airbus Takeoff Configuration Warning Systems

The Airbus takeoff configuration warning systems that were reviewed are summarized in table A-2 of the appendix, "Airbus Takeoff Warning Configurations."

The systems on the A300-B2, -B2K, and -B4 are armed when the landing gear shock absorber is compressed and either engine reaches an N1 value greater than 97 percent. The A300-600 and A310 airplanes use takeoff throttle position to arm the system instead of N1. Once the system is armed, if any of the monitored inputs to the system indicate an improper configuration, a warning is provided. The warning devices are a horn and "CONF" warning light in the A300-B2, -B2K, and -B4. A repetitive chime and a message displayed on an electronic instrument are the takeoff warning devices used for the A300-600 and A310 airplanes. In the A300-600 and A310 airplanes, the system can be tested using a Takeoff Configuration Test pushbutton in the cockpit. This test is asserted by Airbus to detect all potential dormant failures of the system. The other airplanes listed in table A-2 do not have this capability.

Boeing Takeoff Configuration Warning Systems

The Boeing takeoff warning system configurations that were reviewed are summarized in table A-3 of the appendix, "Boeing Takeoff Warning System Configurations."

Throughout the Boeing airplane models, the design configuration remains essentially the same. Changes in design are mainly in the area of the electronic devices employed in the design. The advent of solid-state circuitry, and then microprocessors, brought with it the capability to continuously monitor the system. Up until the 757-200, 767-200, and 747-400, however, monitoring did not detect the loss of primary power to the takeoff warning system. All the designs prior to these airplanes will not provide a warning if power to the system is lost.

The logic used to arm the system is throttle position and airplane on the ground logic for all Boeing airplanes except the 757-200, 767-200, and the 747-400. ADs were issued against the 707, 727, and 737 to lower the throttle angle arm point after a 707 accident where the system failed to warn a crew of an out-of-configuration condition because of the low throttle angle required to achieve takeoff thrust in cold weather. A Boeing service bulletin was later issued for the 727-100, 727-200, 737-100, and 737-200, to add EPR information to the throttle logic to reduce nuisance takeoff warnings during all-engine taxi operations because of the lower throttle angle arm point. (Nuisance warnings as used in this report are warnings issued by a system which is functioning as designed but which are inappropriate or unnecessary.) Most operators are believed to have incorporated these bulletins, however this team believes that they are significant enough that they should be made mandatory by the FAA.

In the 757, 767, and 747-400 the engine information used to arm the system is N1 greater than 67 percent. In these airplanes a cockpit test switch has been provided which allows the logic unit and warning device to be tested. Boeing provides this test as a supplementary procedure but does not recommend it as a normal procedure.

All of the Boeing takeoff warning system designs employ some dual input sensors. The warning logic unit and aural warning devices are single string systems except for the 757, 767, and 747-400. The most sophisticated design is the 747-400. In this design, most input sensors are dual as are the logic/warning circuitry and the visual/aural warning devices. The design of the 757 and 767 takeoff warning system is essentially the same as the 747-400 system with less redundancy.

In addition to the service bulletins mentioned above, Boeing has issued other service bulletins to correct false warnings that have been known to occur on the different models of airplanes. (False warnings as used in this report refer to warnings that occur because of improper functioning of the system.) These service bulletins include one on the 747 to correct false warnings which were occurring due to selection of the midband stab/trim at the boundary conditions and one on the 757 to correct false warnings during takeoff due to momentary loss of flap/slat position data from the Flap Slat Electronic Unit (FSEU). Because of the possibility of a high speed Refused Takeoff (RTO) or that the crew will be conditioned to these false warnings and ignore a valid warning, the team believes that these two service bulletins are significant enough that they should be made mandatory.

McDonnell Douglas Takeoff Configuration Warning Systems

The McDonnell Douglas takeoff warning system configurations that were reviewed are summarized in table A-4 in the appendix "Douglas Takeoff Warning System Configurations."

As with the Boeing takeoff warning system designs, the McDonnell Douglas design configurations throughout their airplane models remain essentially the same with regard to takeoff configuration input and warning output. Changes are mainly in the area of the electronic devices used in the design. The McDonnell Douglas system designs range from the relay/switch logic of the DC-8 and DC-9 to the solid state logic of the DC-10 and MD-80, the MD-80 being an adaptation of the DC-10 design.

The oldest and simplest McDonnell Douglas takeoff warning system design was the one installed on the DC-8. The system is comprised of switches and relays for takeoff configuration inputs (spoiler retraction, flap position, throttle position and airplane on the ground logic), a motor driven interrupter timer and a warning horn driven by the timer.

In the DC-10 and MD-80 designs the takeoff configuration warning system is part of the Central Aural Warning System (CAWS) and solid state logic is employed. Built-in-test enables the system to be continuously monitored. This monitoring is estimated by McDonnell Douglas to detect approximately 80% of the latent failures in the warning and logic unit. The monitoring does not detect the loss of primary power to the takeoff warning system. Prior to the MD-80 accident in August 1987, the Failure Mode and Effects Analysis for the MD-80 takeoff warning system incorrectly showed that a power loss would be annunciated. It was subsequently revised to reflect the actual configuration.

A microprocessor based takeoff warning system is planned for the MD-11. The design of this system had not progressed sufficiently at the time of the team meeting with McDonnell Douglas to afford an in-depth review. It was noted by McDonnell Douglas, however, that the MD-11 design would detect the loss of primary power to the takeoff warning system.

The McDonnell Douglas takeoff warning systems are all armed using airplane on the ground and throttle position logic. In all McDonnell Douglas airplanes, except the DC-9 series, either of two throttles in the takeoff position arm the system. In the DC-9 series airplanes, both throttles must be positioned to their takeoff position to arm the system. The DC-9 design eliminates susceptibly to nuisance warnings during single engine taxi.

The warning device in all the McDonnell Douglas designs is a horn or loudspeaker. The horn in the DC-8 and DC-9 series is operated by an interrupter timer. A tone, generated by an oscillator, is sent to cockpit loudspeakers in the DC-10 and MD-80 series. On the MD-80 airplanes, McDonnell Douglas offers an option to operators which adds a voice warning to the takeoff warning system. This voice warning advises which part of the airplane is not properly configured for takeoff.

All of the McDonnell Douglas takeoff warning system designs are non-redundant, except for some dual configuration inputs and for dual loudspeakers in the DC-10 and MD-80 series airplanes. Duality in the DC-8 design is found in the spoiler and throttle position inputs, while slat position information is the only dual element in the DC-9 design. In the DC-10 and MD-80 airplanes, duality is present in the throttle position, slat position and in the loudspeakers.

Lockheed Takeoff Configuration Warning System

The Lockheed takeoff configuration warning system is shown in table A-5 in the appendix "Lockheed Takeoff Warning System Configurations." The L1011 system is armed when the airplane is on the ground and any two (2) of the three (3) throttles are advanced beyond 50% of their idle thrust position. Once the system is armed, if the flaps, slats, speed brake lever, or horizontal stabilizer is not in the proper configuration for takeoff, a tone warning will be provided to two (2) cockpit loudspeakers. An aural warning test panel is available in the cockpit to test the takeoff warning system. The test from the panel detects, along with various other faults, the loss of primary power to the takeoff warning system. Except for the two loudspeakers installed in the cockpit, the L1011 takeoff warning system is a single string system.

Takeoff Warning System Tests

Table A-6 of the appendix, "Takeoff Warning System Test Periods," depicts the frequency of testing on the takeoff warning system which is recommended at the present time by the manufacturer of each of the airplanes listed. The frequencies vary because of differences in takeoff warning system configurations, designs, and reliability. Test frequencies may also vary because of differences in airplane operation and maintenance philosophies. The actual test frequencies and the actual tests employed by operators of the listed airplanes were not reviewed by the team.

Just as the test frequencies vary, the types of tests also vary as a function of configuration, design, and reliability. Some cockpit tests check for proper operation of the warning device without having to place the airplane in an out-of-takeoff configuration. Others require the airplane be in an out-of-takeoff configuration. Some cockpit tests move the throttle levers to check the system, while others simulate the engine's high power settings. Finally, some cockpit tests check the logic/warning circuitry and/or output of the takeoff warning system using a switch located in the cockpit.

If a system uses throttle position as part of the takeoff warning logic, and not an actual thrust value, it may be possible to test the takeoff warning system at the gate without an airplane configuration change. This type of test has been recommended by McDonnell Douglas on the DC-10 since July 1979 and on all of its other airplane models since the MD-80 accident.

If the takeoff warning system uses an actual thrust level as part of the warning logic, a check of the system may not be possible prior to takeoff. In some systems using actual thrust values, a switch is provided which simulates the thrust input. The Boeing 757 and 767 both have this capability and Boeing provides supplemental procedures for the 757 and 767 airplanes but does not recommend the test as part of their normal procedures.

Functional tests of the takeoff warning system which require airplane configuration changes and/or high thrust values may not be possible between the gate and takeoff without endangering personnel or equipment outside the airplane.

None of the tests completely check the takeoff warning system, with the possible exception of maintenance tests performed during the A and C checks of the airplane. Functional tests performed prior to takeoff which move the throttle levers generally check only one configuration logic input, the logic/warning circuitry for that input and the warning device installed in the cockpit. Cockpit tests initiated by test panels or switches in the cockpit check the warning device only (the Lockheed design) or simulate the takeoff thrust level to check the throttle input logic, logic/warning circuitry and the warning device (the Boeing design). None of the cockpit tests check the takeoff warning system completely. Because of this, latent failures can exist in the takeoff warning system. Cockpit tests which are deemed successful when no warning is received after the test is initiated may be especially prone to latent failures.

Latent failures can also exist in takeoff warning systems employing solid-state circuitry or microprocessors. Although these systems do enable extensive monitoring and test capabilities for the logic/warning circuitry and the cockpit warning devices, they do not completely test the system unless the devices used for the configuration logic inputs are also exercised. Only a test which actuates each takeoff configuration input device, all the logic/warning circuitry, and each warning device (light, horn, loudspeaker, etc.) would prevent a latent failure and assure takeoff warning system integrity.

Airframe manufacturers generally recommend complete takeoff warning system tests during the A and C checks of the airplane. The intervals for the tests are based on engineering judgement and the reliability of the system and take into account the potential for latent failures. The manufacturers use the in-service history of each takeoff warning system to determine that the check period is adequate.

The test frequencies shown on the chart for Boeing have been recommended by Boeing since FAA certification of the listed airplanes. The cockpit set-up column indicates a recommended takeoff warning system functional test for the 707-320B and the 747-100/-200/-300. Although Boeing does not require or recommend a takeoff warning system test for the 747-400, 757, and 767 airplanes, they do provide a supplemental test procedure for operators who wish to incorporate a test in their cockpit set-up checklist. Boeing indicated they do recommend a circuit breaker check in the cockpit set-up checklist for all the airplanes listed. The test recommended by Boeing for the 737-100/-200/-300 at 375 hours during the A check is a functional test of the takeoff warning. In addition, Boeing recommends a check of the aural warning system at 125 hours.

At the time of initial FAA certification of the McDonnell Douglas airplanes listed in the test frequency chart, no pre-flight test of the takeoff warning system was required or recommended by McDonnell Douglas. A functional test of the takeoff warning system incorporated in the DC-10 airplanes was added to the cockpit set-up checklist as a result of AD 79-15-05 dated July 13, 1979. This test uses slats as the configuration input to check the system. The functional tests indicated for the other McDonnell Douglas airplanes in the pre-start checklist column of table A-6 in the Appendix were recommended by McDonnell Douglas through the following All Operators Letters (AOL): for the DC-8, AOL C1-E60-HHK-L643, dated November 30, 1987; for the DC-9, AOL C1-E60-HHK-L644, dated November 30, 1987, revised December 3, 1987; for the MD-80 by an all operators telex, C1-E60-HHK-T484, dated September 1, 1987.

McDonnell Douglas presently has no requirements or recommendations for A or C checks for the DC-8 or DC-10 airplanes, as shown in the columns of table A-6. McDonnell Douglas indicated that operators of these airplanes were checking the takeoff warning system during the C check (3000 hours). McDonnell Douglas also indicated it plans to recommend 3000 hours for a check of this system in both the DC-8 and DC-10 airplanes. The test period for the takeoff warning system in the DC-9 series airplanes is presently listed as every 10,000 hours in the C check column. McDonnell Douglas indicated they planned to reduce this time period recommendation to every 5000 hours.

The Lockheed test frequencies shown in table A-6 for L1011 airplanes indicate three (3) tests of the system prior to takeoff. These three (3) tests, however, only determine that the warning horn will work. Functional tests of the system are accomplished only during the A and C checks on the airplane.

The team believes that all of the systems reviewed would meet the current requirements in terms of reliability, provided the manufacturers' recommendations for the system checks were followed in service. For several of these systems, however, the manufacturers had no recommended maintenance check intervals, or the maintenance check interval appeared to this team to be excessive given the single string elements of those designs and the degree of monitoring.

Takeoff Warning System Reliability

For most of the systems reviewed a reliability analysis was not required as part of the original type certification. In order to make some comparisons between the various systems and get a rough idea of the failure rates of these systems, the team obtained the mean time between unscheduled removals (MTBUR) for the line replaceable unit containing the logic and warning circuitry of the takeoff warning system from the airframe manufacturers. The manufactures maintain a record of this information, as supplied by the operators, for the purposes of customer support, warranty claims, maintenance trends, etc. Typically the rates from this type of data vary widely depending on the equipment, operators maintenance procedures, frequency of system checks, and accuracy of reporting.

The reporting period for Boeing airplanes covers the period from 1982 through 1986, with the exception of the 757 which covers the period from 1983 through 1986. For

McDonnell Douglas airplanes the period covered for the DC-10 is 1971 through July 1987 and for the MD-80, 1983 through September 1987. The MTBUR figures are listed below in flight hours:

Table 1: MTBUR for Takeoff Warning Systems

Manufacturer	Airplane Model	MTBUR
Airbus		not available
Boeing	727-100/-200	4700
	737-200/-300	11000
	747-100/-200/-300	20000
	757	7200
	767	14000
McDonnell Douglas	DC-10	8000
	MD-80	7500

The mean time between failures (MTBF) of electronic units is, in general, always larger than the MTBUR and can approach more than twice the MTBUR depending on the unit. Since the above figures are MTBUR, it appears that the MTBF for the logic and warning circuitry in all of these airplanes are in line with the current regulatory requirements for these systems.

Historical Data On Service Difficulties and Accident/Incident Reports

The question of whether the requirements and FAA policies for takeoff warning systems are providing an acceptable level of safety requires an examination of the service records associated with takeoff warning systems and airplane accident/incident records.

The available databases were researched to determine if there were trends which would indicate any generic in-service problems with takeoff warning systems, or if certain systems were experiencing a disproportionately large number of service difficulties. System reliability cannot be inferred from this data since, for many of the takeoff warning systems, no preflight check is performed and maintenance action which occurs during regularly scheduled maintenance is not normally reported.

The special review team requested a search of the NASA Aviation Safety Reporting System (ASRS) database search for Takeoff Warning Systems Problems. A broad search strategy was employed. All transport airplanes weighing more than 60,000 lbs were considered and no distinction was made as to which warning system was involved. Any reference to an alarm or warning accompanied by the airplane being in the takeoff or initial climb phase was deemed acceptable.

At the time of this search, the ASRS database contained 32,801 total incident records of all types received since January 1, 1981. The search resulted in 119 reports of incidents where an airplane warning system was involved during the takeoff or initial climb phase. Of these 119 reports, 11 were on the takeoff warning system. Six of the takeoff warning reports were identified as being due to incorrect trim of the airplane, where the systems functioned properly. Three reports were identified as false warnings of an out-of-takeoff configuration condition. One of these three false warning reports stated that recycling the flaps cleared the problem. Two takeoff warning reports contained insufficient information to categorize.

The FAA's Accident/Incident Reporting Database was searched for any incidents reported during the takeoff phase of operations for specific models of airplanes. The airplane models requested were the 727,737,747,757, and 767. A second search was requested for airplane models DC-8, DC-9, DC-10, and the L1011. There were 470 incident reports with 10 incidents involving the takeoff warning system. One of these was due to incorrect trim of the airplane. Three were due to faulty switches, three were listed as false warnings and in three reports the reason for the warning was unclear.

The FAA's Service Difficulty Reporting System was queried for reported problems with warning systems on takeoff for all airplane models. Forty reports were obtained. Four of these reports were due to takeoff configuration warnings. Two of these reports were listed as false warnings in that no problems were found and there was no warning on the subsequent takeoff. One reported warning was identified as being caused by a burned resistor in the takeoff warning box and one was a report of an intermittent warning due to the speed brake warning switch.

The review team also requested Boeing to perform a search of their Product Safety Jet Transport Database for takeoff warnings. This is a database maintained by Boeing which covers safety events world wide, for all jet transports, regardless of the manufacturer. It includes: NTSB reports, international accident investigative reports, international insurance safety reports, and reports by Boeing representatives and the airlines. Although this data is not all-inclusive it is a large sample of data, much of which is not included in the NASA of FAA databases. Approximately 15% of the reports had descriptive text that provided more details such as what corrective actions were taken for the problem.

The Boeing data indicated there were five incidents recorded between 1959 and 1976 involving the takeoff warning systems. All five incidents involved a rejected takeoff due to a warning horn. There was no information to indicate whether the warning was legitimate or false. There were 180 incidents reported for the 1977 through 1987 time period. Of these incidents, 164 were reported as rejected takeoffs due to configuration warnings with 13 of these reported as false warnings. Of the remaining 16 incidents, 8 resulted in the airplane returning to the airport. The other 8 reports did not specify what action was taken.

A review was also conducted on data from one major airline's "Captains Reports," some of which were not contained in any of the above databases. This particular carrier's procedures required the crew to stop and clear the runway for any warnings received after lining up for takeoff. During a one year period there were 195 reported incidents. Thirty-five of these were associated with takeoff configuration warnings. The information available on these incidents was insufficient to determine what percent of these were valid warnings and what percent of these were invalid warnings. However, because of the strict procedural and reporting requirements of this airline, this data is believed to be somewhat representative of the frequency with which takeoff configuration warnings occur.

In general it appeared that there was no correlation between the different reporting systems databases. For example, an incident that may have been reported in the NASA ASRS was not necessarily found in the FAA's Accident/Incident Reporting system nor in the Boeing Product Safety Jet Transport Database. There did not appear to be any clear cut trends in the reports and no particular system appeared to have an unusual number of service difficulties associated with it other than as noted. The data does indicate, however, that takeoffs are being aborted as a result of takeoff configuration warnings. The data from the one major airline's "Captains Reports" suggests that there are a greater number of these than what is implied by the other databases.

In all of the databases, many of the warnings were reportedly cleared by recycling flaps or speed brake handles and subsequent takeoffs were then made without further warnings. This type of report can be read as an intermittent malfunction (false warning) or an actual out of configuration attempt at takeoff. There is no incentive for the flight crew to report that a takeoff warning was caused by an out of configuration condition. This makes it difficult to evaluate how many of these reports are actual out of configuration takeoff attempts and how many of them are due to false warnings. Regardless of how small a percentage it is assumed are due to an actual out-of-takeoff configuration condition, it appears some accidents/incidents may have been avoided because a takeoff configuration warning system was installed.

Out of Configuration Takeoff Accidents on Airplanes Equipped with Takeoff Warning Systems

In addition to the recent MD-82 accident, the team is aware of 12 accidents in the worldwide jet fleet involving the takeoff configuration of airplanes equipped with a takeoff configuration warning system. These 12 accidents occurred between 1958 and 1987. The accidents are listed in Table A-7 of the Appendix "Takeoff Configuration Accidents on Jet Transports with a Warning System."

In 7 of the 12 accidents the pilots received no warning because the out of configuration condition was not covered by the airplane's takeoff configuration warning system. One of the 12 accidents occurred because the warning was ignored. One accident was the result of an RTO due to a warning which occurred because trim was inadvertently changed near Vr (There were no injuries and damage was minor; a serious accident may have occurred had the crew tried to takeoff). One was the result of an RTO due to a false ground spoiler position light. In 2 of the 12 accidents the status of the takeoff warning system was unknown.

Several of these accidents resulted in the issuance of Airworthiness Directives (AD) which required the takeoff configuration warning system on certain model airplanes to be modified to include elements of the takeoff configuration not covered prior to the accident. Following the Boeing 707 accident on December 26, 1968, AD 69-12-02 was issued after the landing at Detroit, indicating that the DFDR was operating properly prior to the crash. In addition, the flap handle was found in the up/retract position in the wreckage and the NTSB's examination of flap and slat pieces, actuators and indicators, further substantiated the flap/slat up configuration shown by the DFDR (Docket No. SA 495, Exhibit No. 9A, p4).

The airplane's Central Aural Warning System (CAWS), part of which is designed to alert the crew to an improper takeoff configuration, was recovered undamaged from the crash. The NTSB tested the CAWS and found that it was functioning properly in all modes (Docket No. SA495, Exhibit No. 12B, p2). The NTSB's examination of the wiring between the CAWS unit and the circuit breaker showed no evidence of a problem that would have prevented the proper operation of CAWS (Docket No. SA 495, Exhibit No. 9A, p5). In addition, one witness who was in the cockpit jump seat on an earlier leg has stated that he heard the aural takeoff warning annunciation during taxi in, indicating that the system was operative earlier that day.

The NTSB's examination of the cockpit voice recorder (CVR) data shows that the crew missed the taxi check list which calls for a check of the flap setting. The data also shows that the aural stall warning operated prior to impact. The MD-80 CAWS generates two aural stall warnings under normal conditions. A sound spectrum study indicated that only the primary system operated. The signature of the redundant system, which is powered through the same circuit breaker as the takeoff configuration warning, was not present (Docket No. SA495, Exhibit No. 12B, p 4).

Airplane performance studies were conducted for the investigation. These show that a zero flap and no slat setting at flight 255's takeoff weight would result in takeoff performance similar to that experienced by flight 255.

Although the NTSB has not at this time determined the cause of the accident, the information presented at the public hearing in November indicates that the probable cause of the accident was improper flaps and slats on takeoff. It also appears that the crew failed to receive a warning of an improper takeoff configuration because there was no power to the warning system from the circuit breaker. The possibility that power could be interrupted through contact contamination in the circuit breaker while the breaker appeared set is still under investigation. However, the likelihood that this circuit breaker failed, when it was working earlier that day, appears very remote to this team.

which required the throttle arm point for the warning system to be lowered to account for the throttle angle that occurred in cold weather takeoffs.. This AD applied to all model 707, 720, and 727 series airplanes and Following the Boeing 747 accident on November 20, 1974, AD 75-05-11 was issued which required a modification to the takeoff configuration warning system which would cause the warning horn to sound when ever the leading edge flaps were not fully extended for takeoff. This AD applied to all model 747 series airplanes. Following the Boeing 737 accident on December 12, 1978, AD 80-22-12 was issued which required a modification to the takeoff configuration warning system which would cause the warning horn to sound when ever the leading edge devices were not extended for takeoff. This AD applied to all model 707, 720, 727, and 737 series airplanes.

It should be noted that none of the 12 accidents listed in Table A-7 can be attributed to latent failures of the system installed on the airplane. However, nearly three quarters of the accidents occurred because the takeoff configuration warning system did not cover a key element in the takeoff configuration. The DC-8 alone has had three accidents due to horizontal stabilizer trim, which is not part of its takeoff configuration warning system. One of these was as recent as 1984.

The Detroit MD-82 Accident

Northwest Airlines flight 255 crashed on takeoff at 2046 EDT on August 16, 1987, at the Detroit Metropolitan Airport. Of the planes 156 occupants, 155 were killed in the accident. The airplane was a McDonnell Douglas MD-82. The NTSB investigators have concluded that the airplane was properly loaded within weight and balance limitations and that the flight crew was properly qualified in the airplane.

Weather is not considered to have been a factor and the NTSB's investigation of the airplane revealed no malfunctions in either of the engines nor any failures of the airplane's systems that could have been a contributing factor in the crash. The maintenance records showed that all maintenance requirements had been met.

The Digital Flight Data recorder (DFDR) was recovered from the wreckage with some impact and fire damage. For the takeoff from Detroit, the DFDR indicated that no flaps or slats were set. The NTSB review of the DFDR information showed normal positions for the flaps and slats in the MD-82's previous takeoffs and the retraction of these surfaces

A possible alternative scenario is that the circuit breaker was pulled by the crew to eliminate nuisance warnings from the takeoff configuration warning system while taxing single engine on a leg prior to Detroit and that the circuit breaker remained forgotten in that position until the accident occurred.

The MD-80 series airplane uses throttle angle position to trigger the warning if the takeoff configuration is not correct. When the airplane is taxied with a single engine, the warning will routinely activate when sufficient thrust is applied to begin to roll. One way this warning can be eliminated by the flight crew for single engine taxi is to deactivate the system. While it's also true that during all engine taxi operations on a hot day with a heavy airplane, aggressive use of the throttles may cause the warning system to activate, the warning under these circumstances can easily be avoid by using less aggressive throttle actions.

Operational Experience

Obtaining meaningful data with regard to takeoff configuration warning systems is difficult. When the system does its job it is not normally reported. Flight crews do report malfunctions but many are not duplicated during maintenance trouble shooting. Except for accident reporting, there is no data collection system that will report crew omissions or inattention that cause warnings in the cockpit.

To obtain more direct information about flight crew experiences with takeoff configuration warning systems, a number of pilots were interviewed. The intent of the interviews was to identify possible problems with takeoff configuration warning systems and reasons which might cause a crew to intentionally deactivate the system via the circuit breaker. The pilots interviewed were active MD-82 airline pilots, FAA certification pilots, airline training pilots, and FAA flight standards pilots.

It became apparent from these interviews that most pilots feel that audio warnings, although necessary, are becoming a distraction because of their frequency of occurrence and the number of different warnings. History shows that when nuisance warnings occur, pilots have deactivated the warning system to prevent the distraction. (Nuisance warning is defined here to mean a warning that is given within its tolerance of operation but is unnecessary).

Other observations drawn from the pilot interviews are as follows:

1. The active airline pilots felt that pilots did pull circuit breakers to silence nuisance aural warnings, but they also stated that they would not personally do so.

2. It was generally believed that the takeoff warning circuit breaker was sometimes pulled by pilots for reduced engine taxi because the power required to taxi puts the thrust levers in the takeoff warning range causing a nuisance warning. (Reduced engine taxi is a procedure sometimes used as a fuel conservation measure for a long taxi)

3. One active airline pilot reported two situations where other warnings are routinely cancelled or deactivated because of nuisance warnings i.e. landing gear and GPWS.

4. A pilot of an MD-80 demonstrated unusual familiarity with the location of the takeoff warning circuit breaker when he reached back and pulled it during the interview without looking for its location.

5. An operations supervisor of a large FSDO reported that there was high usage indicated on the takeoff warning circuit breaker on one operator's DC-9/MD-80 airplane observed.

The Airline Pilots Association (ALPA) was contacted to enlist their support in surveying the pilot community on takeoff warning systems. A questionnaire was developed with questions that would indicate if there were operations routinely performed by the airlines that would cause nuisance takeoff configuration warnings.

Five different airlines responded to the survey. All of the responses were made by a single representative of the airline rather than the hoped for response by individual pilots.

The responses indicated that there were a significant number of routine operations that would produce nuisance takeoff configuration warnings. Specifically single engine taxi, or in the case of 3 and 4 engine airplanes, taxi with something less than all engines operating was identified as a routine operating condition. The responses also indicated that the airline crews regarded the reliability of the takeoff warning systems as high. There were also some reports of warnings being caused by trim range adjustments and speed brake handle adjustments.

Accident Statistics Associated With Warning Systems

To place the accidents associated with takeoff configurations in perspective with other types of accidents, various accident statistics were reviewed by the team. These statistics are based on the data contained in the Boeing Product Safety Jet Transportation Database. According to information contained in this database, 12.2% of all accidents have occurred during the takeoff phase of airplane operations from various causes. Of these accidents, airplanes equipped with takeoff configuration warning systems have had thirteen accidents (including the MD-82 at Detroit). This amounts to 1.7% of all accidents.

Airplane stall, and controlled flight into terrain, are other operating hazards for which warning systems have been required. In the case of stall, a warning system is required when the airplanes natural buffet characteristics provide inadequate cues to the pilot. As a result of accidents associated with flight into controlled terrain, Part 121 was amended in 1975 to require a Ground Proximity Warning System.

In recent years, windshear has also been recognized as a factor in accidents. Currently, there is no rule requiring airplanes be equipped with windshear detection devices. However, an Advisory Circular (AC) for windshear systems has been issued and Part 121 rulemaking is being considered to require that a windshear system be installed.

In all cases, the FAA requirements for the warning systems which have been installed to deal with these operational hazards have been those associated with the lowest level of criticality defined in AC 25.1309-1. The accident rates associated with these various operational hazards are given in Table 2 below.

Table 2: Accident Rates For Selected Operational Hazards

Probable Cause	1958-1976	1977-1987	Total
Total Accidents (All causes & types)	485	263	748
Improper T-O Config. (Includes MD-82)	9 (1.9%)	4 (1.5%)	13 (1.7%)
Stall	14 (2.9%)	8 (3.0%)	22 (2.9%)
Controlled flight into terrain (includes some windshear accidents)	108 (22.3%)	38 (14.5%)	146(19.5%)
Windshear			30 (4.0%)

Note that the statistics for the above operational hazards cannot be compared directly because each one is made up of a variety of different factors. For instance, the statistics for takeoff configuration accidents include only those airplanes equipped with takeoff configuration warning systems, while the accident statistics for controlled flight into terrain include all airplanes, few airplanes were equipped with GPWS prior to 1975 and many, but not all, airplanes (foreign operators) were equipped with GPWS after 1976.

The above statistics do suggest, however, that extreme measures to improve the reliability of takeoff configuration warning systems in the fleet are not warranted at this time.

Possible Solutions to Prevent Further Takeoff Configuration Accidents

There are several different approaches which could be taken in attempting to prevent the reoccurrence of an accident similar to the MD-82 accident. Some of these are considered below.

1. Make a check of the takeoff configuration warning system before each flight by placing the throttles in the takeoff position before the airplane is configured for takeoff to verify that the warning horn sounds. As noted earlier, this has been recommended by McDonnell Douglas for its DC-8, DC-9, MD-80, and DC-10 airplanes via All Operator Letters. This procedure reduces the possibility that the takeoff configuration warning system will be unpowered at the time of takeoff.

This procedure, however, has several short falls. The simple check does not ensure that the takeoff configuration warning system will perform its intended function since it does not check all of the configuration inputs that trigger a takeoff warning. However, a complete check prior to takeoff is impractical. The check can also be forgotten or omitted like any other preflight checklist item. The procedure is feasible only on airplanes that use throttle angle to arm the takeoff warning system. It is not feasible on systems that use EPR or N1. Lastly, it does not protect against system failure or deactivation after the check.

2. Install a warning light that would annunciate the absence of power to the takeoff configuration warning system. This solution can be easily implemented on some airplanes and was recommended in an FAA memo from the Minneapolis Air Carrier District Office dated September 16, 1987, to the Accident Investigation Division (ASF-100). This solution may have prevented the Detroit accident because loss of power or deactivation of the system would be annunciated. It should be noted, however, that the reasons for power loss or deactivation of the takeoff configuration warning system by the flight crew are not unique to the MD-80. Most other airplanes that have been reviewed by this team are equally susceptible. EICAS equipped airplanes do not fall into this category because power loss or deactivation of the takeoff configuration warning system is usually displayed on the EICAS.

The shortfall of this approach is that it treats a symptom and not the problem, which this team believes is nuisance warnings. Furthermore, this approach carries with it the implication that all warning systems of any type should have warning lights for the absence of power. Service experience with warning systems and accident/incident histories regarding warning systems do not provide justification for this approach.

3. Improve the reliability of the takeoff configuration warning system by requiring the systems be designed to meet the requirements of FAR 25.1309 for equipment in the essential category as defined by AC 25.1309. This could be achieved by redundancy,

increased monitoring, more frequent maintenance checks, or some combination thereof. This approach would probably not have prevented the Detroit accident since the equipment was known to have been working the same day the accident occurred. The data that has been reviewed by this team does not support the contention that takeoff warning systems are not sufficiently reliable relative to their intended function and in comparison with other warning systems on the airplane.

4. Eliminate nuisance takeoff configuration warnings that occur during reduced engine taxi. The team believes this approach has the most merit. The information that has been gathered by this team points to nuisance warnings as a potential problem on most of the airplanes reviewed.

When many of the airplanes in transport service today were designed, flight tested, and certified, taxiing with less than all engines operating was not a practice used in normal operations. When fuel prices began to rise, operators began shutting down engines during ground operations when it was shown to operations inspectors that it could be done safely. As a result, airplanes are being operated under conditions that are incompatible with the design of most takeoff configuration warning systems.

Since each type of airplane has a different means of arming the takeoff configuration warning system, the magnitude of the nuisance warning problem varies with airplane type. For example, some airplanes use only a single throttle position, some use position from either a single or multiple throttles, some use EPR, some use N1 and some use a combination of these. What was clear to this team in its review is that none of the systems had been designed considering the use of less than all engines during taxi. When reduced engine taxi is used on the 747, for example, the outboard engines are usually the ones shut down. The takeoff warning system, however, is tied to the number 3 engine.

Two approaches can be taken to eliminate the problem of nuisance warnings. The FAA could issue an Airworthiness Directive requiring that takeoff configuration warning systems be modified to eliminate nuisance warnings during reduced engine taxi. Alternatively, the FAA could restrict normal taxi operations with less than all engines operating unless it can be shown that either nuisance warnings are not possible or that the airplanes are equipped with a system that annunciates deactivation of the takeoff configuration warning system. Many of the EICAS equipped airplanes, for example, annunciate warning system deactivation on the status page and require any such message be cleared prior to takeoff.

Conclusions

The review team believes that in general the existing requirements and policies provide a suitable and rational approach to the certification of takeoff warning systems which is consistent with the intended function, the requirements imposed on other systems, and their role on the airplane.

The design of the takeoff configuration warning systems reviewed all appeared to be acceptable from the stand point of reliability. For many of these system, however, the manufacturers had no recommended maintenance check interval, or the maintenance check interval appeared to be excessive given the system design.

The accident/incidents statistics show a high accident rate for the DC-8 resulting from out of trim conditions. This suggests that the design of the existing takeoff configuration warning system on this airplane is inadequate and should be modified to include trim. No other trends were observed based on service experience or accident/incident rates, for the takeoff warning systems of the other airplanes reviewed, that pointed to an existing design inadequacy or reliability problems.

As with any airplane system, service difficulties have arisen over time with the takeoff warning system of various airplanes. These have been corrected through service bulletins issued by the airplane manufacturers. Of the takeoff warning system service bulletins this team is aware of, certain of these correct nuisance or false warning problems. In light of the fact that nuisance and false warnings can adversely affect flight crews and airplane safety, the team believes these are significant enough to be made mandatory by the FAA and have been identified in the recommendations section of this report.

Lastly, reduced engine taxi appears incompatible with many of the takeoff configuration warning system designs. Takeoff configuration nuisance warnings are occurring in normal airline operations because takeoff configuration warning systems have not been designed to function without nuisance warnings for less than all engine taxi operations. Anytime there are nuisance warnings generated, there is a possibility that the crew will be tempted to eliminate them through system deactivation. One way this can be accomplished is by pulling the takeoff configuration warning circuit breaker. With no indication of this circuit breaker being out, there is a good chance this system will remain deactivated until the airplane changes crew or undergoes maintenance. This situation exists for most transport airplanes, with the exception of EICAS equipped airplanes which indicate when warning systems are not functional due to loss of power to the system.

Although the NTSB has not completed their investigation, it appears at this time as though the probable cause of the Detroit MD-82 accident was the failure of the crew to properly configure the airplane for takeoff. The takeoff configuration warning system did not warn the crew of this incorrect configuration. This team believes that one possible scenario that could lead to such an accident, and one that should be addressed on all transport airplanes, is the disabling of the takeoff configuration warning system by the crew to avoid nuisance warnings during single engine taxi.

Recommendations

This review has concentrated on large jet transport airplanes. The takeoff configuration warning systems of various Airbus, Boeing, McDonnell Douglas, and Lockheed airplanes, were reviewed. These systems are considered to be representative of the systems on Part 25 airplanes. The takeoff configuration warning systems of other transport airplanes were not reviewed and some may not have a takeoff warning system installed since FAR 25.703 is applicable only to new type certificates applied for after 1978. However, since the scope of the accident/incident data reviewed was sufficiently broad the team believes any significant problems with these other aircraft would have surfaced during this review.

Based on this review, this team believes that the following actions should be taken by the FAA with regard to takeoff configuration warning systems in general:

1. Prohibit reduced engine taxi unless the takeoff warning system has been designed such that nuisance warnings will not occur or unless there is an annunciation to the crew of deactivation of the takeoff configuration warning system, such as on EICAS equipped airplanes .

2. Issue a Transport Directorate letter requiring all future takeoff configuration warning systems presented for certification to be designed such that nuisance warnings do not occur for reduced engine taxi. Since all engine taxi and less than all engine taxi can both be considered normal operating conditions, nuisance warnings of the takeoff warning system should not occur in either case in order to comply with FAR 25.1301 and 25.1309.

Based on the in-service experience of the designs reviewed and accident/incident histories, the following FAA actions are recommended for certain airplane models:

1. Require, through mandatory action , that the DC-8 takeoff warning system be modified to provide a warning for incorrect stabilizer trim in accordance with the provisions of FAR 25.703. A disproportionate number of accidents that have occurred on this airplane as a result of an out of trim condition.

2. Require manufacturers to re-examine and justify their currently recommended maintenance intervals or recommend new ones for the Airbus A300, A310, the Boeing 707, 727-100, and the McDonnell Douglas DC-8, -9, and -10.

3. Make mandatory, the installation of the Boeing service bulletins for the 727 and 737, which add EPR information to throttle logic to reduce nuisance takeoff warnings during all-engine taxi.

4. Make mandatory, the installation of the Boeing service bulletin for the 757 which eliminates false warnings that may occur during takeoff due to momentary loss of flap/slat position.

5. Make mandatory, the installation of the Boeing service bulletin for the 747 which eliminates false warnings that may occur during takeoff due to the selection of a stabilizer midband at boundary trim conditions.

Appendix

AIRCRAFT CERTIFICATION BASES

AIRCRAFT MODEL	DATA SHEET	CERTIFICATION BASES		CERTIFICATION DATE
		REGULATION	AMENDMENTS	
AIRBUS				
A300-B2	A35EU	FAR 25	1-20	MAY 30 1974
-B2K	A35EU	FAR 25	1-20	JUN 30,1976
-B4	A35EU	FAR 25	1-20	OCT 4,1979
-600	A35EU	FAR 25	1-44	NOT CERTIFIED
A310	A35EU	FAR 25	1-45	FEB 21,1985
BOEING				
707-320B	4A26	CAR 4b	1-3	MAY 31,1962
727-100	A3WE	CAR 4b	1-11	DEC 24,1963
-200	A3WE	CAR 4b	1-11	NOV 29,1967
737-100	A16WE	FAR 25	1-3,7,15	DEC 15,1967
-200	A16WE	FAR 25	1-3,7,15	DEC 21,1967
-300	A16WE	FAR 25	1-3,7,15	NOV 14,1984
-400	A16WE	FAR 25	1-3,7,15	NOT CERTIFIED
747-100	A20WE	FAR 25	1-8,15,17, 18,20,39	DEC 30,1969
-200	A20WE	FAR 25	1-8,15,17, 18,20,39	DEC 23,1970
-300	A20WE	FAR 25	1-8,15,17, 18,20,39	MAR 1,1983
-400	A20WE	FAR 25	1-59	NOT CERTIFIED
757-200	A2NM	FAR 25	1-45	DEC 21.1982
767-200	A1NM	FAR 25	1-37	JUL 30,1982
DOUGLAS				
DC8-50	4A25	CAR 4b	1-9	APR 28,1961
-60	4A25	CAR 4b	1-9,14	SEP 1,1966
DC9-10	A6WE	CAR 4b	1-16	NOV 23,1965
-20	A6WE	CAR 4b	1-16	NOV 25,1968
-30	A6WE	CAR 4b	1-16	DEC 19,1966
-40	A6WE	CAR 4b	1-16	FEB 21,1968
-50	A6WE	CAR 4b	1-16	AUG 11,1975
MD 80	A6WE	FAR 25	1-40	AUG 25,1980
DC10-10	A22WE	FAR 25	1-22	JUL 29,1971
-30	A22WE	FAR 25	1-22	NOV 21,1972
LOCKHEED				
L1011	A23WE	FAR 25	1-18,20	APR 14,1972

NOTE: Only certification basis items which may be pertinent to the take-off warning system are noted on the above chart. Other FAR'S, exemptions, amendments, special conditions, etc., are listed in the certification data sheets and specifications but may not be relevant and were not included. Those interested will have to look at the specific type certification data sheet to obtain the complete aircraft certification basis.

TABLE A-2

AIRBUS TAKE-OFF WARNING SYSTEM CONFIGURATIONS

AIRCRAFT MODEL	WARNING LOGIC: ANY THROTTLE BELOW ------> 1	2	------> AND ANY ITEM BELOW: FLAPS	SLATS	SPEED BRAKE	HORIZONTAL STABILIZER	PARKING BRAKE	FLAP/SLAT ASYMETRY	LO SPEED AILERON	WARNING DEVICE	NOTES
A300-B2	N1>97%	N1>97%	X	X	X	X		X	X	HORN CONFIG WARNING	
A300-B2K -B4	N1>97% N1>97%	N1>97% N1>97%	X X	X X	X X	X X		X X	X X	HORN CONFIG WARNING	ADDITIONAL LOGIC IS KRUGER FLAP/ SLAT LEVER DISAGREEMENT
A300-600	X	X	X	X	X	X	X	NA	NA	CHIME ECAM MESSAGE	
A310	X	X	X	X	X	X	X	NA	NA	CHIME ECAM MESSAGE	

TABLE A-3

BOEING TAKE-OFF WARNING SYSTEM CONFIGURATIONS

AIRCRAFT MODEL	WARNING LOGIC: ANY THROTTLE BELOW ——> 1	2	3	4	AND ——> AND ANY ITEM BELOW: EPR	FLAPS	SLATS	SPEED BRAKE	HORIZONTAL STABILIZER	PARKING BRAKE	BODY GEAR	WARNING DEVICE	NOTES
707-320B			X			X	X	X	X		NA	HORN	
727-100 -200			X X			X X	X X	X X	X X		NA NA	HORN	
727-100 -200	X X		X X		>1.4 >1.4	X X	X X	X X	X X		NA NA	HORN	>1.4 EPR ADDED BY SERVICE BULLETIN
737-100 -200		X X				X X	X X	X X	X X		NA NA	HORN	
737-100 -200	X X	X X			>1.4 >1.4	X X	X X	X X	X X		NA NA	HORN	>1.4 EPR ADDED BY SERVICE BULLETIN
737-300 -400	X X	X X				X X	X X	X X	X X		NA NA	HORN	
747-100 -200 -300			X X X			X X X	X X X	X X X	X X X	OPTION OPTION OPTION	X X X	HORN	
747-400		N1>67%	N1>67%			X	X	X	X	X	X	SIREN EICAS MESSAGE MASTER WARNING	
757-200	N1>67%	N1>67%				X	X	X	X	X	NA	SIREN EICAS MESSAGE MASTER WARNING CONFIG WARNING	
767-200	N1>67%	N1>67%				X	X	X	X	X	NA	SIREN EICAS MESSAGE MASTER WARNING CONFIG WARNING	ADDITIONAL LOGIC IS FLAP HANDLE/FLAP POSITION DISAGREE

DOUGLAS TAKE-OFF WARNING SYSTEM CONFIGURATIONS

AIRCRAFT MODEL	WARNING LOGIC: ANY THROTTLE BELOW --->				---> AND ANY ITEM BELOW					WARNING DEVICE	NOTES
	1	2	3	4	FLAPS	SLATS	SPEED BRAKE	HORIZONTAL STABILIZER	PARKING BRAKE		
DC8-50	X		X		X	NA	X			HORN	
-60	X		X		X	NA	X				
DC9-10	B	B			X	NA		X		HORN	B=ARMED WHEN BOTH THROTTLES ADVANCE
-20	B	B			X	X		X	X	HORN	
-30	B	B			X	X	X	X	X	HORN	
-40	B	B			X	X	X	X	X	HORN	
-50	B	B			X	X	X	X	X	HORN	
MD 80	X	X			X	X	X	X	X	HORN VOICE IS OPTION	
DC10-10	X	X			X	X	X	X	X	HORN	
-30	X	X			X	X	X	X	X		

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TABLE A-5

LOCKHEED TAKE-OFF WARNING SYSTEM CONFIGURATIONS

AIRCRAFT MODEL	WARNING LOGIC								WARNING DEVICE	NOTES
	TWO OR MORE THROTTLES BELOW ---->			------> AND ANY ITEM BELOW						
	1	2	3	FLAPS	SLATS	SPEED BRAKE	HORIZONTAL STABILIZER	PARKING BRAKE		
L-1011	X	X	X	X	X	X	X		HORN	

TABLE A-6

TAKE-OFF WARNING SYSTEM TEST PERIODS

AIRCRAFT MODEL	COCKPIT SET-UP	PRE-START CHECKLIST	BEFORE TAXI CHECKLIST	TAXI CHECKLIST	PRE-TAKEOFF CHECKLIST	A CHECK	C CHECK	SYSTEM POWER-UP	CONTINUOUS MONITORING	BUILT IN TEST
AIRBUS										
A300-B2				X						
-B2K				X						
-B4				X						
-600				X		300	3000			X
A310				X		250	3000			X
BOEING										
707-320B	X									
727-100										
-200						400	3200			
737-100						375	3000			
-200						375	3000			
-300						375	3000			
-400							TBD			
747-100	X									
-200	X						3600			
-300	X						3600			
-400	SUP						TBD	X	X	X
757-200	SUP					1200	3000	X	X	X
767-200	SUP					300	3000	X	X	X
DOUGLAS								2500	2500	
DC8-50		X								
-60		X								
DC9-10		X					10000	4000 →	2000	
-20		X					10000	"	"	
-30		X					10000	"	"	
-40		X					10000		"	
-50		X					10000	"	"	
MD 80		X					2500		X	X
DC10-10	X							2000	X	X
-30	X							3000	X	X
LOCKHEED										
L1011	X	X	X			300	2000			X

Per Dick [illegible]

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Table A-7: Takeoff Configuration Accidents on Jet Transports with a Warning System

Date	A/C	Conf. Discrepancy	T-O Warning Status	On Board/Fatal	A/C Damage
6-03-62	707	Incorrect flaps	Cond. not covered	132/130	Hull loss
8-20-62	DC8	Trim changed	Cond. not covered	105/15	Hull loss
3-21-68	727	Incorrect flaps	Warning ignored	3/0	Hull loss
1-30-66	707	Trim was changed near Vr to improper setting	Warning operated properly	22/0	Minor (fuselage skin wrinkled aft of NLG)
12-26-68	707	Flaps not extended	Cond. not covered Throttle not in op range(Cold weather)	3/3	Hull loss
10-16-69	DC8	False spoiler warning	Spoiler light malf.	5/0	Hull loss
11-20-74	747	Leading edge flaps not extended	Cond. not covered	157/59	Hull loss
11-9-75	F28	Flaps not extended	Warning sys config unknown	27/0	Substaintial
12-16-76	880	Trim not set	Warning sys config unknown	3/0	Hull loss
12-17-78	737	LE flaps not extended	Cond. not covered	132/1	Hull loss
1-11-83	DC8	Incorrect stab trim	Cond. not covered	3/0	Hull loss
9-18-84	DC8	Incorrect stab trim	Cond. not covered	4/0	Hull loss