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An SAE International Group

AEROSPACE STANDARD

AS 8044

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TAKEOFF PERFORMANCE MONITOR (TOPM) SYSTEM, AIRPLANE, MINIMUM PERFORMANCE STANDARD FOR

RATIONALE

This document has been reaffirmed to comply with the SAE 5-Year Review policy.

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1. SCOPE:

1.1 Scope: This Aerospace Standard (AS), establishes minimum performance standards for those sensors, computers, transponders, and airplane flight deck controls/displays which together comprise a Takeoff Performance Monitor (TOPM) System. This standard also defines functional capabilities, design requirements, and test procedures. A TOPM system is intended to monitor the progress of the takeoff and to provide advisory information which the crew may use in conjunction with other available cues to decide to continue or abort the takeoff. See Appendix A for supplementary information relating to NTSB, CAA, and ad hoc committee concerns and background information.

1.2 Product Classification: Takeoff Performance Monitors covered by this standard shall be identified by type and class as defined in paragraphs 1.2.1 and 1.2.2. Each type and class of monitor may also incorporate additional features such as predicting and monitoring landing stopping distance, accounting for windshear conditions during takeoff and landing, or other innovative features contributing to further improvements in airplane safety. Such additional features are, however, not addressed in this standard.

1.2.1 Types:

Type I: Takeoff monitors which compare the achieved airplane performance to the airplane reference performance and indicate to the crew any deviation from the airplane reference performance. Type I monitors have no predictive capability and indicate only the deviation noted.

Type II: Takeoff monitors, which in addition to making the performance comparisons and providing the deviation indications of Type I, are capable of predicting the continued takeoff situation (e.g., the location where the takeoff will be complete; the effect of a critical engine suddenly becoming inoperative, etc.). Type II monitors do not, however, predict stopping performance.

Type III: Takeoff monitors, which, in addition to making the performance comparison and providing the deviation indications of Type I and II monitors, continuously predict from the existing speed and position on the runway, on the basis of reported or estimated runway conditions, the ability to continue or abort the takeoff including the condition when a critical engine suddenly becomes inoperative.

1.2.2 Classes: One of the following sub-classifications is applicable to each of the preceding types.

Class A - TOPM equipment that interfaces with airplane installed equipment in order to determine the runway position of the airplane.

Class B - TOPM equipment that interfaces with ground based equipment in order to determine the runway position of the airplane.

Class C - TOPM equipment that has no provisions or capability to determine runway position of the airplane.

1.3 Field of Application:

1.3.1 Applicable Airplanes: The TOPM system is applicable to any commercial and general aviation civil airplanes. The applicable documents herein compiled were written primarily for civil airplane applications.

The TOPM system may also be applied to military airplanes; however, this standard has made no attempt to compile the applicable military specifications.

1.3.2 Applicable Airports: The TOPM system is intended for use at all airports available to the applicable airplanes and where the necessary information about the airport and its runways is available; however, equipment requiring ground installations (Class B) may be utilized only on those runways where appropriate facilities are available and the airport management makes available the information necessary for its use.

1.3.3 Applicable Operations: The TOPM System is intended for use during all takeoff operations whether the airplane is at its maximum operating weight for the existing conditions or operating at a lesser weight. It is not intended that the presence of a TOPM should affect the operating weight limitations established by the FAA Airworthiness Standards.

2. REFERENCES:

2.1 Applicable Documents: The following documents and their subsequent revisions shall form a part of this standard unless otherwise limited herein. In the event of conflict between these documents and this standard, the contents of this standard shall govern.

2.1.1 SAE Publications: Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

AS 425C - Nomenclature and Abbreviations for Use on the Flight Deck (to be superseded by ARP 4103)

ARP 450D- Flight Deck Visual, Audible, and Tactile Signals (to be superseded by ARP 4104/4, Flight Deck Alerting System [FAS])

ARP 461B - Synchros

ARP 582A - Lighting, Integral, for Aircraft Instruments: Criteria for Design of Red Lighted Instruments

ARP 798 - Design Criteria for White Incandescent Lighted Aerospace Instruments

2.1.1 (Cont'd.)

ARP 1068B - Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft (to be superseded by ARP 4102, Flight Deck Panels, Controls and Displays; ARP 4102/7, Electronic Displays; and ARP 4102/8, Flight Deck, Head Up Displays

ARP 1570 - Flight Management Computer System (to be superseded by ARP 4102/9, Flight Management Computer System)

AS 264D - Instrument and Cockpit Lighting for Commercial Transport Aircraft (to be superseded by ARP 4101/3, Instrument and Flight Deck Lighting)

AS 8034 - Minimum Performance Standard for Airborne Multipurpose Electronic Displays

2.1.2 Industry Specifications:

ARINC documents available from: Aeronautical Radio, Inc., 2551 Riva Road, Annapolis, Maryland 21401.

ARINC-403 - Guidance for Designers of Airborne Electronics Equipment
ARINC-408A - Air Transport Indicator Cases and Mounting
ARINC-409A - Selection and Application of Semiconductor Devices
ARINC-413 - Aircraft Electrical Power Utilization and Transient Protection
ARINC-415 - Operational and Technical Guide Lines on Failure Warning and Functional Test
ARINC-429-9 - Mark 33 Digital Information Transfer Systems (DITS)
ARINC-600 - Equipment Cases and Racking-Air Transport
ARINC-602-1 - Test Equipment Guidance
ARINC-604 - Guidance for Design and Use of Built-in Test Equipment (BITE)

RTCA documents available from: Radio Technical Commission for Aeronautics, One McPherson Square, 1425 K Street N.W., Suite 500, Washington, D.C. 20005.

RTCA Document DO-160B - Environmental Conditions and Test Procedures for Airborne Equipment
RTCA Document DO-178A - Software Considerations in Airborne Systems and Equipment Certification

ATA Documents are available from: Air Transport Association of America, 1709 New York Avenue N.W., Washington, D.C. 20006.

ATA No. 100 - Specifications for Manufacturers Technical Data
ATA No. 300 - Specifications for Packaging of Airline Supplies

International Civil Aviation Organization (ICAO) publications are available from: International Civil Aviation Organization, ATTN: Distribution Officer, 1000 Sherbrooke Street West, Suite 400, Montreal, Quebec, Canada H3A 2R2.

2.1.2 (Cont'd.)

ICAO ANNEX 14 - Aerodromes
ICAO ANNEX 15 - Aeronautical Information Services

2.1.3 Federal Aviation Regulations: Available from Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402.

The applicable parts of the following documents should be adhered to:

FAR PART 23 - Airworthiness Standards: Normal, Utility, and Acrobatic Category Airplanes
FAR PART 25 - Airworthiness Standards: Transport Category Airplanes
FAR PART 91 - General Operating and Flight Rules
FAR PART 121 - Certification and Operations: Domestic Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft
FAR Part 135 - Air Taxi Operators and Commercial Operators

2.1.4 Military Specifications: No military specifications are referenced. This standard primarily addresses civil airplane applications but does not preclude applications to military airplanes.

2.1.5 Special Documents: It can be expected that other special documents may be made applicable to the manufacturer of the TOPM system by a particular airplane manufacturer for the type of airplane for which the system is intended to be installed. It is not within the scope of this standard to define these special documents.

2.2 Definitions:

The following definitions and glossary terms are applicable to this aerospace standard. Terms for which standard dictionary definitions apply are not included herein.

a. achieved airplane performance: The performance which an airplane is actually attaining in the particular combination of circumstances and environment present during the time period the operation is being conducted.

b. airplane reference performance: The takeoff performance which the particular airplane can be expected to demonstrate under the expected airfield, and environmental conditions, in the absence of failures, and when operated using normal procedures.

c. control: Control herein is defined as a means of measuring and displaying, during takeoff, the performance deviation from what was planned (airplane reference performance) and what has been attained (achieved airplane performance) so that the crew may, if necessary, make those input changes necessary to assure success. Control shall also imply, when the deviation is significant, the visibility and capability to completely alter the pilot planned action and do it safely on that runway when executed in a timely manner.

d. equipment: Any item of hardware specifically designed to meet system requirements, excluding interfaces and associated use of available aircraft sensors not specifically designed to meet the requirements of this aerospace standard.

e. instrument: An item of equipment installed in the airplane flight deck to provide the desired flight crew indications. An instrument can be either an item of equipment designed specifically to meet system requirements or otherwise already available in the airplane.

f. minimum performance standard: A standard that establishes the minimum values for the performance characteristics of the equipment or software.

g. shall function: The system shall not exceed the given tolerance.

h. shall not be adversely affected: The system and equipment shall not exhibit characteristics or sustain damage which precludes proper functioning and/or use.

i. system: The total function of all equipment and interfaces associated with required operation.

2.3 Symbols and Abbreviations:

a. AFM Airplane Flight Manual
b. ARINC Aeronautical Radio Incorporated
c. ARP SAE Aerospace Recommended Practice
d. AS SAE Aerospace Standard
e. ATC Air Traffic Control
f. BITE Built-In Test Equipment
g. FAA Federal Aviation Administration
h. FMS Flight Management System
i. PMCS Performance Management Computer System
j. RTCA Radio Technical Commission for Aeronautics
k. SAE Society of Automotive Engineers
l. TOPM Takeoff Performance Monitor
m. TSO FAA Technical Standard Order

3. TECHNICAL REQUIREMENTS:

3.1 General:

3.1.1 Material and Workmanship:

3.1.1.1 Materials: Materials shall be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in airplane equipment.

3.1.1.2 Workmanship: Workmanship shall be consistent with high grade aerospace equipment manufacturing practice.

3.1.2 Identification: The following information shall be legibly and permanently marked on each of the major items of equipment:

a. Equipment title, type, and class
b. SAE AS 8044
c. Manufacturer's part number
d. Manufacturer's serial number or date of manufacture
e. Manufacturer's name and/or trade mark
f. TSO number (if applicable)
g. Modification status number or code (including software revision number)
h. Airplane type (if applicable)
i. Lamp type/Fuse type (as applicable)
j. Electrical interface diagram (as applicable)
k. Weight to the nearest tenth of a pound

3.1.3 Interchangeability: Equipment with the same part number shall be directly and completely interchangeable without requiring recalibration.

3.1.4 Accessibility of Information: The TOPM flight deck display(s) shall be located so that they are clearly visible to the pilot and co-pilot when seated at the DEP (Design Eye Position).

3.1.5 Compatibility of Information: If the information being provided by the TOPM instrument requires simultaneous knowledge or monitoring of the status of a particular performance parameter from another instrument (e.g., airspeed), the location of the TOPM display relative to other pertinent displays shall be such that the monitoring can be accomplished easily and efficiently. Integration of the TOPM information into existing displays is acceptable.

3.1.6 Housing Insulation: Any metallic or conductive case housing the TOPM equipment shall be insulated from all electrical currents therein.

3.1.7 TOPM System Operation: The combination of parts, tangible or intangible, that work together to perform the TOPM function shall operate essentially as follows:

3.1.7.1 Input Data:

3.1.7.1.1 Data Entry: The acquisition by the TOPM of essential data, (airplane weight, flap position, temperature, altitude, runway length, etc.) shall, if appropriate, be automatic. Manual entry, and/or the manual override of certain data must be possible. The means for entering information into the TOPM shall be easily accessible, simple, and unambiguous so that confusion and error are minimized. The TOPM equipment shall include a means for the crew to verify that data (either manual or automatic) have been correctly received in the equipment.

3.1.7.1.2 Contaminated Runway Operation: A TOPM may accept reported contaminant depth as input data and account for the associated increased rolling and impingement drag during the takeoff run.

3.1.7.1.3 Stopping Performance Prediction: The Type III TOPM, when predicting stopping performance, shall be able to accept as input the degraded braking characteristics associated with contaminated (wet, ice, snow, etc.) runway surfaces.

3.1.7.1.4 Deliberate Configuration Deviations: It should also be possible to input into the Type III TOPM the appropriate braking characteristics resulting from deliberate configuration deviations known to exist when the takeoff is begun. (e.g., antiskid inoperative, certain brakes deactivated.)

3.1.7.2 Data - Processing:

3.1.7.2.1 Reference Airplane Performance: The reference or expected airplane performance, against which the TOPM will compare the achieved airplane performance, may be established by:

a. Manual entry into the TOPM

b. Recall from TOPM internal memory

c. Direct calculation by computers included in the TOPM System or derived from other available computer systems (PMCS, FMS).

3.1.7.2.2 Mechanization and Integrity of Output: The system shall be mechanized in such a manner as to preclude the display of output data unless all input data required for proper computation are provided.

3.1.7.3 Data Output:

3.1.7.3.1 Display Design Simplicity:

The display design shall:

a. utilize natural and meaningful symbology readily understood by the crew.

b. indicate to the crew in a timely manner the deviation between airplane reference performance and the achieved airplane performance thereby lending itself to effective control of the takeoff by the crew.

c. provide information immediately discernible to the crew such that there is no need to watch the display for a period of time to observe rates of change or relative motion.

3.1.7.3.2 Advisory Information: As indicated in paragraph 1.1, the TOPM system is intended only to monitor the progress of the takeoff and provide advisory information to the pilot to maximize the safety of each takeoff.

As an advisory system,

a) the presentation of the takeoff status shall be such that no potentially critical situation, which in the absence of corrective action by the pilot could jeopardize the safety of the takeoff, can arise without the pilot receiving prior information that the situation is developing.

b) two (or more) performance options may be presented on the display. When the display advises that one option has the greater merit, that option shall indeed offer the safer path. When the display indicates that the two options have the same merit, it shall mean, insofar as possible, that both options have the same probability of success, or equal risk of failure.

c) the TOPM shall not automatically initiate action to abort a takeoff.

d) the sole use of binary non-contextual signals during the takeoff roll should be avoided.

3.1.7.3.3 Predictive Performance Information: Predicted performance information that is displayed to effect a crew action shall take into account the time intervals realistically required by the crew and systems to respond. The display design should, where feasible, provide information showing the effect of any pilot action.

It is desirable that the display design also include the display of any surplus performance available. On some display formats, the display of surplus performance may be necessary for not only clarity, but also to assure compliance with its intended function.

3.1.7.3.4 Confidence (BITE) Test - Indication: The monitor installation should include a confidence (BITE) test, which will indicate that the system is functioning and that valid signals are available. It is preferable that this test function be automatic. A failure of the confidence test shall be clearly indicated by flags or warning lights, etc.

3.1.7.3.5 TOPM Failure Indication: The failure of a TOPM system during the course of a given takeoff shall be indicated to the crew.

3.1.7.3.6 Supplemental Design Criteria for Displays: The graduations and markings on the TOPM display shall be arranged to provide the maximum degree of readability consistent with the accuracy of the system.

For other criteria affecting the TOPM display (colors, titles, lighting, etc.) refer to ARP 450D, ARP 582A, ARP 798, ARP 1068B and AS 8034.

3.1.8 TOPM System Reliability Requirements: It shall be shown that with a successful confidence (BITE) test, the probability of a system malfunction during the ensuing takeoff has been reduced to less than 10^{-3}.

The probability of hazardously misleading guidance information being displayed to the crew because of an unidentified TOPM system failure during a given takeoff or landing operation shall be shown to be less than the value shown in the appropriate category as follows:

CLASSIFICATION OF AIRPLANE AND TYPE OF OPERATION	PROBABILITY OF FAILURE
Part 25 airplanes operating under FAR 135 or FAR 121	10^{-5}
All Part 23 airplanes and Part 25 airplanes operating under FAR 91	10^{-4}

3.1.9 TOPM System Operating Procedures: A set of procedures which are consistent with the type, class, features and operation of the particular TOPM system being designed shall be developed.

3.1.10 Hazard Analysis: It shall be shown that hazards resulting from system failures, including human errors, reasonably anticipated as possible, have been considered and preventive actions taken accordingly.

3.2 Performance, Standard Condition:

3.2.1 Test Conditions: Because of the variances in airplane design with respect to electric power, flight deck layout, equipment racks, etc., the test conditions for system performance under standard conditions are stated in general.

Unless otherwise specified, TOPM system performance requirements shall be demonstrated under the following conditions:

3.2.1.1 Position: All tests shall be conducted with the equipment in its normal airplane operating position.

3.2.1.2 Electrical Conditions: Electrical tolerances and transient tests shall be conducted at the power ratings recommended by the airplane manufacturer.

3.2.1.3 Dielectric Tests, Overpotential: TOPM equipment shall not be damaged by the application of a test potential between electric circuits, and between electrical circuits and the metallic or conductive case. Since these tests are intended to assure proper electrical insulation of the circuit components in question, these tests shall not be applied to circuits where the potential will appear across elements such as windings, resistors, capacitors, etc.

3.2.1.3 (Cont'd.)

Circuits that operate at potentials below 15V are not to be subjected to over potential tests.

3.2.1.4 Vibration to Minimize Internal Friction: When mechanical type indicators or displays are used to present the information to the pilot, the tests for performance shall be conducted with the equipment subjected to a maximum vibration of 0.001 in. double amplitude at a frequency of 10 to 60 cps. The term "double amplitude" as used herein indicates the total displacement from positive maximum to negative maximum.

3.2.1.5 Display Behavior: Needles, symbols, and other indicators shall move smoothly and without sudden jumps. Display jitter shall be no greater than 0.6 milliradians when viewed within the design eye viewing envelope specified by the TOPM manufacturer.

3.2.1.6 Accuracy Requirements: The TOPM system displays information on the flight deck so that the current status of the takeoff can be determined. It is important that any TOPM system tolerances which can affect the accuracy of that flight deck display be limited so that the presence of a significant deficiency in airplane performance will not be hidden nor will the display imply a significant performance deficiency when none exists. Therefore, the probability that TOPM system tolerances will, of themselves, cause an error greater than ±5 percent in the apparent all-engine operating takeoff distance to rotation speed shall be 0.01 or less.

While the overall accuracy stated above is the basic requirement, it is desirable that accuracy of individual performance parameter displays fall within the ranges stated below.

Takeoff distance: ±100 ft or ±2% (whichever is greater).

Airspeed: ±4 kts or ±2% (whichever is greater).

Longitudinal Acceleration: ±0.2 ft/sec^2 or ±2% (whichever is greater).

3.3 Performance, Environmental Conditions:

3.3.1 Test Conditions: The environmental tests and performance requirements referenced in this subsection are intended to provide a means of determining the overall performance characteristics of the TOPM under conditions representative of those which may be encountered in actual operations. If the TOPM consists only of a computer software program, none of the requirements will apply except as they apply to the approved equipment using the software program (refer to RTCA DO-178A).

3.3.2 Performance Requirements: A TOPM shall continue to satisfy the requirements of Paragraph 3.2 over the range of environmental conditions defined in RTCA DO-160B as appropriate to the airplane type and installation.

3.3.3 Installation - Special Conditions: The above are minimum requirements. Careful review of the intended installation shall be given so as to assure requirements such as the following are also met.

3.3.3.1 Surface Temperature: The surface temperature of any TOPM equipment installed in the flight deck should not exceed 120 degrees Fahrenheit.

3.3.3.2 Radio Interference: The TOPM equipment shall not be a source of objectionable interference under operating conditions at any frequencies used by the airplane, either by radiation, conduction, or feedback in any electronic equipment installed in the same airplane in accordance with RTCA DO-160B.

3.3.3.3 Magnetic Effect: The magnetic effect of any TOPM equipment installed in the flight deck shall not adversely affect the performance of any other instruments installed in that flight deck.

3.3.4 Verification Testing: The TOPM system shall be verification tested in a representative working environment to assure the attainment of high operational efficiency, to assure the elimination of design and human factor errors, and to assure that effective control of takeoffs can be realized. It is during this verification test that the procedures appropriate for a TOPM design shall also be demonstrated.

4. SAMPLING AND METHODS OF TEST OR INSPECTION:

4.1 Responsibility for Test Inspection: The manufacturer of the product shall be responsible for performing all required tests specified herein to verify the performance requirements specified under Section 3.

4.2 Effect of Tests: As a minimum performance requirement, the test samples shall complete all tests under Section 4 without maintenance and without necessity to re-calibrate the instrument.

4.3 Test Samples: The tests shall be conducted on a sample of the equipment that is in full conformity with production specifications. If the tested item incorporates features that are still experimental or in the development stage, any tests involving the non-production features shall be repeated later on a production instrument or evidence presented to substantiate that the test results are valid for the production instrument.

4.4 Test Procedures, Standard Test Conditions: All instruments shall be subjected to tests by the equipment manufacturer to demonstrate specific compliance with this standard, including the following requirements where applicable.

4.4.1 Dielectric Tests: Each equipment shall be tested by the methods of inspection listed in paragraphs 4.4.1.1 and 4.4.1.2.

4.4.1.1 Insulation Resistance: The insulation resistance measured at 200V DC for 5 sec between all electrical circuits connected together and the metallic case shall not be less than 5 megohms. Insulation resistance measurements shall not be made to circuits where the potential will appear across elements such as windings, resistors, capacitors, etc., since this measurement is intended only to determine adequacy of insulation.

4.4.1.2 Overpotential: For this test the potential shall be a sinusoidal voltage of a commercial frequency with the rms value of five times the maximum circuit voltage. Hermetically sealed instruments shall be tested at five times the maximum circuit voltage up to a maximum of 2000v rms. The potential shall start from zero and be increased at a uniform rate to its test value. It shall be maintained at this value for 5 sec and then reduced at a uniform rate to zero.

4.4.2 Sealing Tests: Hermetically sealed components shall be tested for leaks by means of a mass spectrometer type of helium leak detector or equivalent. The leak rate shall not exceed 76 micron cubic feet per hour per cubic foot of filling gas at a pressure differential of one atmosphere.

4.4.3 TOPM External Interference: Interference effects, in terms of temperature, radio, and magnetic effects, will be tested by operating the TOPM in the normal manner for a period of time at least twice as long as a normal takeoff operation and observing case surface temperatures and any interference with other instruments or radios.

4.4.4 Performance Measurement and Display: The ability of the TOPM to measure achieved takeoff performance, compare it to the airplane reference performance and then display the deviations in an operational environment shall be established by appropriate flight tests covering representative operational configurations and conditions.

4.5 Test Procedures - Environmental Test Conditions: Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160B, "Environmental Conditions and Test Procedures for Airborne Equipment." General information on the use of DO-160B is contained in Sections 1.0 through 3.0 of that document. A procedure to document, by means of the Environmental Qualification Form, the environmental test categories which the equipment has passed is contained in Appendix A of DO-160B.

4.5 (Cont'd.)

TEST	SECTION NUMBER
Altitude	4.0
Temperature	4.0
Temperature Variation	5.0
Humidity	6.0
Shock	7.0
Vibration	8.0
Explosion Protection	9.0
Waterproofness	10.0
Fluid Susceptibility	11.0
Sand and Dirt	12.0
Salt Spray	14.0
Magnetic Effect	15.0
Power Input Test	16.0
Voltage Spike Conducted Test	17.0
Audio Frequency Conducted Susceptibility Test	18.0
Induced Signal Susceptibility	19.0
Radio Frequency Susceptibility	20.0
Emission of Radio Frequency Energy	21.0

For the following tests, reference is made to the requirements specified in Section 5 of AS 8034, "Minimum Performance Standards for Airborne Multipurpose Electronic Displays".

TEST	PARAGRAPH NUMBER
X-Ray Radiation	5.21
U.V. Radiation	5.22
Display Unit Fogging	5.23
Thermal Shock	5.24
Dielectric Test	5.25

4.6 Reports and Declarations:

4.6.1 Summary Report: The equipment manufacturer shall prepare a summary report declaring the following:

a. The Part number which identifies the equipment (see Paragraph 3.1.2)

b. The Type number which identifies the equipment (see Paragraph 1.2.1)

c. The Class number which identifies the equipment (see Paragraph 1.2.2)

d. A statement that all standard condition performance tests have been successfully completed (see Paragraph 3.2)

e. A specific statement for each standard condition performance test that was not successfully completed

4.6.1 (Cont'd.)

f. An Environmental Qualification Form, in accordance with RTCA DO-160B, indicating which environmental tests were conducted and where applicable, the resulting environmental category of the equipment. (See Paragraph 4.5)

g. Compliance with Requirements of RTCA Document DO-178A and submission of supporting data. (See Paragraph 3.3.1)

4.6.2 Substantiating Test Data/Analysis: The equipment manufacturer shall compile and make available for review all the following:

a. The test results and technical data which substantiate the declarations of Paragraph 4.6.1

b. Built-in Test Equipment (BITE) Effectiveness Analysis (see Paragraph 3.1.7.3.4)

c. Reliability Substantiation Analysis (see Paragraph 3.1.8.)

d. Design Tolerance/Sensitivity and Interface Analysis

e. Failure Modes and Effects Analysis

f. Verification test results summarizing any human factor or design faults uncovered/corrected (see Paragraph 3.3.4.)

g. Hazard Analysis Report (see Paragraph 3.1.10)

APPENDIX A

This Appendix is supplementary information and is not a mandatory part of this Aerospace Standard.

THE FOLLOWING IS EXTRACTED FROM THE NTSB ACCIDENT REPORT OF THE AIR FLORIDA ACCIDENT AT WASHINGTON NATIONAL AIRPORT, 13 JANUARY 1982. (The numbered footnotes are also quoted from the report.)

Takeoff Acceleration Monitor: The Safety Board believes that this accident clearly illustrates fallacies in the takeoff field length criteria and decision speed concept employed by air carrier operators to assure an acceptable level of safety during take off. The minimum field length from which air carrier aircraft can takeoff is established so that an aircraft experiencing an engine failure during the take off roll can either stop safely within the runway length or continue to accelerate with power from the remaining engines and takeoff safely. In preparation for the takeoff, the flight crew computes the decision speed (V_1), the speed above which the aircraft can continue the takeoff safely if an engine fails.

There are two significant fallacies in the takeoff criteria. One, the aircraft accelerate-stop performance upon which the decision speed and runway length computations are based is determined during the aircraft type certification tests on a clean dry runway. The stopping performance is determined without the use of reverse thrust and is thus considered by the FAA and the airframe manufacturers to be conservative on a clean dry runway. However, this conservative margin is obviously degraded on runways having a braking coefficient reduced by snow, ice, or even liquid contamination. Thus, on a snow-covered runway, there are no assurances that the aircraft can be stopped from the V_1 speed within the limits of a minimum length runway. In fact, since stopping data on slippery runways are not provided in objective terms, the pilot is not able to determine the existing margin of safety for takeoff under conditions such as existed at Washington National Airport on January 13. However, data provided by the aircraft manufacturer during the investigation showed that runway 36 was longer than required for Flight 90 using the minimum field length criteria for a clean dry runway and that a B-737 aircraft at the accident aircraft weight performing normally should have been capable of accelerating to V_1 and stopping on runway 36 using reverse thrust even if the braking coefficient was reduced to 0.1 - equivalent to that expected on clear ice.

The second fallacy in the takeoff criteria is, however, more significant to the circumstances of this accident. The accelerate-stop performance and thus the field length and decision speed computations are based upon the demonstrated and theoretical acceleration of the aircraft using normal takeoff power. If, for any reason, the aircraft acceleration is less than that used for the computation, the runway distance used to achieve V_1 will be increased and the length of runway available for stopping will be decreased. Thus, with subnormal acceleration, such as occurred during the takeoff of Flight 90, there is no assurance that the aircraft can stop from V_1 on the remaining runway even if the runway surface is clean and dry. Since a takeoff may have to be rejected at an airspeed much lower than V_1 when aircraft acceleration is subnormal to assure adequate stopping distance, the pilot must be able to recognize the subnormal acceleration rate early during the takeoff roll.