U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: APPROVAL OF FLIGHT MANAGEMENT SYSTEMS IN TRANSPORT CATEGORY AIRPLANES

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1. PURPOSE. This advisory circular (AC) provides guidance material for the airworthiness approval of flight management systems (FMS) in transport category airplanes. Like all AC material, this AC is not mandatory and does not constitute a regulation. It is issued for guidance purposes and to outline a method of compliance with the rules. In lieu of following this method without deviation, the applicant may elect to follow an alternate method, provided the alternate method is also found by the Federal Aviation Administration (FAA) to be an acceptable means of complying with the requirements of Part 25. Because the method of compliance presented in this AC is not mandatory, the terms "shall" and "must" used herein apply only to an applicant who chooses to follow this particular method without deviation.

2. RELATED DOCUMENTS.

a. Related Federal Aviation Regulations (FAR). Portions of Part 25 and a portion of Part 121, as presently written, can be applied for the design, substantiation, and certification of FMS for transport category airplanes. Sections which prescribe requirements for these types of systems include:

§ 25.101	Performance: General.
§ 25.103	Stalling speed.
§ 25.105	Takeoff.
§ 25.107	Takeoff speeds.
§ 25.109	Accelerate-stop distance.
§ 25.111	Takeoff path.
§ 25.113	Takeoff distance and takeoff run.
§ 25.115	Takeoff flight path.
§ 25.117	Climb: general.
§ 25.119	Landing climb: All-engines-operating.
§ 25.121	Climb: One-engine-inoperative.
§ 25.123	En route flight paths.
§ 25.125	Landing.
§ 25.149	Minimum control speed.
§ 25.904	Automatic takeoff thrust control system (ATTCS).
§ 25.1301	Function and installation.
§ 25.1303	Flight and navigation instruments.
§ 25.1305	Powerplant instruments.

§ 25.1307	Miscellaneous equipment.
§ 25.1309	Equipment, systems, and installations.
§ 25.1321	Arrangement and visibility.
§ 25.1322	Warning, caution, and advisory lights.
§ 25.1323	Airspeed indicating system.
§ 25.1329	Automatic pilot system.
§ 25.1331	Instruments using a power supply.
§ 25.1333	Instrument systems.
§ 25.1335	Flight director systems.
§ 25.1351	Electrical Systems and Equipment: General.
§ 25.1353	Electrical equipment and installations.
§ 25.1355	Distribution system.
§ 25.1357	Circuit protective devices.
§ 25.1381	Instrument lights.
§ 25.1431	Electronic equipment.
§ 25.1523	Minimum flightcrew.
§ 25.1581	Airplane Flight Manual: General.
§ 25.1585	Operating procedures.
Part 121	Appendix G - Doppler Radar and Inertial Navigation Systems (INS).

b. Advisory Circulars.

AC 20-129	Airworthiness Approval of Vertical Navigation Systems
AC 20-XX	Airworthiness Approval of RNAV Systems Using a Single Colocated VOR/DME Sensor Input
AC 20-130	Airworthiness Approval of Multi-Sensor Navigation Systems
AC 20-101C	Airworthiness Approval of Omega/VLF Navigation Systems
AC 20-115A	Radio Technical Commission for Aeronautics Document RTCA/DO-178A
AC 20-121A	Airworthiness Approval of Loran-C Navigation Systems
AC 21-16B	Radio Technical Commission for Aeronautics Document RTCA/DO-160B
AC 25-4	Inertial Navigation Systems (INS)
AC 25.1309-1A	System Design and Analysis

AC 25.1329-1A	Automatic Pilot Systems Approval
AC 25-11	Transport Category Airplane Electronic Display Systems
AC 25-13	Reduced and Derated Takeoff Thrust (Power) Requirements
AC 61-XX	Procedures and Criteria for Determining the Type Rating Requirements for an Aircraft
AC 120-28C	Criteria for Approval of Category III Landing Weather Minima
AC 120-29	Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators
AC 90-82	Random Area Navigation Routes
AC 91-53A	Noise Abatement Departure Profile
AC 120-31A	Operational and Airworthiness Approval of Airborne Omega Radio Navigation Systems as a Means of Updating Self-Contained Navigation Systems
AC 120-33	Operational Approval of Airborne Long-Range Navigation Systems for Flight Within the North Atlantic Minimum Performance Specifications Airspace
AC 120-37	Operational and Airworthiness Approval of Airborne Omega Radio Navigational Systems as a Sole Means of Long Range Navigation Outside the United States

c. Technical Standard Orders.

TSO-C60b	Airborne Area Navigation Equipment Using Loran C Inputs
TSO-C94a	Omega Receiving Equipment Operating Within the Radio Frequency Range of 10.2 to 13.6 Kilohertz
TSO-C115	Airborne Area Navigation Equipment Using Multi-Sensor Inputs
TSO-C120	Airborne Area Navigation Equipment Using Omega/VLF Inputs

d. Industry Documents.

(1) Radio Technical Commission for Aeronautics (RTCA) document DO-160B, Environmental Conditions and Test Procedures for Airborne Equipment; RTCA document DO-178A, Software Considerations in Airborne Systems and Equipment Certifications; RTCA document DO-180A, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using a Single Co-Located VOR/DME Sensor Input; RTCA document DO-187, Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Multi-Sensor Inputs; RTCA documents DO-190, Minimum Operational Performance Standards for Airborne Area Navigation Equipment using Omega/VLF Inputs; RTCA document DO-194, Minimum Oping operationialerformance Standards for Airborne Area Navigation Equipment Usng Loran-C Inputs. These documents can be obtained from the RTCA, One McPherson Square, Suite 500, 1425 K Street Northwest, Washington, D.C. 20005.

(2) Aerospace Recommended Practice (ARP) 926A, Fault/Failure Analysis Procedure; ARP 1834, Fault/Failure Analysis Guidelines for Digital Equipment; ARP 1068B, Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft, and ARP 1570, Flight Management Computer System. Aerospace Standard AS 8044, Takeoff Performance Monitor (TOPM) System, Airplane, Minimum Performance Standard For. These documents are available from the Society of Automotive Engineers, Inc. (SAE), 400 Commonwealth Drive, Warrendale, PA 15096.

3. SCOPE. The material provided in this AC addresses system design aspects, characteristics, mechanization, and the criticality of system failure cases for FMS. Although not limited to a specific technology or function, the guidance material is primarily directed towards systems which, through sensor data, compute and integrate real time performance and/or navigation information into output commands that direct the operation and flight path of the airplane. The criteria contained in this AC is in addition to that provided in the ACs referenced in paragraph 2b.

4. BACKGROUND. The development of today's highly integrated FMS has been an evolutionary process whose origin dates back to the mid-1970s. During that period, the advent of airborne microprocessor based systems for the first time conveniently and economically allowed the storage of relatively large amounts of airplane and engine performance data and airport and navigation facility information. As the data capacity and versatility of airborne digital avionic systems expanded, the number of FMS computational and output functions increased proportionally. In today's highly integrated systems, engine and airplane performance parameters can be computed in real time and combined with lateral and vertical position computations to provide command outputs to the autothrottle and automatic flight guidance system to establish the airplane profile at a preprogrammed speed and spatial position for most modes of flight.

5. AIRWORTHINESS CONSIDERATIONS.

a. Certification Program. This AC provides guidance for the approval of FMS which process data derived from a relatively large number of onboard performance and navigation sensors. Flight management systems may also provide modes which receive and transmit or display data processed in other ground based equipment or onboard systems provided for that purpose. Also, these systems may provide command outputs to other onboard systems, such as autothrottle and automatic flight guidance systems, which direct the operation of the engines and flight path of the airplane. The degree of system integration to perform these functions may be extensive and as a result, the applicants program should be directed toward airworthiness approval through the type certification or supplemental type certification process.

b. Certification Plan. A comprehensive certification plan should be developed by the applicant. It should include how the applicant plans to comply with the applicable regulations and should provide a listing of the substantiating data and necessary tests. Also, a comprehensive system description and an estimated time schedule should be included. A well developed plan will be of significant value both to the applicant and the FAA.

c. Design Guidance. Society of Automotive Engineers document ARP 1570, Flight Management Computer System, provides guidance for the design and implementation of the functions and displays of a flight management system.

d. System Integrity. Various types of system failure conditions must be addressed in consideration of the potential hazard they may induce during the course of normal system operation. Advisory Circular 25.1309-1A, System Design and Analysis, provides criteria to correlate the depth of analysis required with the type of function the system performs. Also, failure conditions which result from improper accomplishment or loss of function are addressed. System failure conditions for various functions are outlined below and when provided, each function must be considered individually and in combination with others. Since there may be any number of complex system integrations with existing airplane systems and sensors, the treatment of all the combinations possible is beyond the scope of this AC. If a reliability analysis is necessary, the equipment manufacturer should provide the reliability data for the analysis. Advisory Circular 25.1309-1A states that the flight test pilot should: (1) determine the detectability of a failure condition, (2) determine the required subsequent pilot actions, and (3) make a judgment if satisfactory intervention can be expected by a properly trained crew. In addition, failure of the FMS should not degrade the integrity of other safety related systems installed in the airplane. This includes common shared sensors.

e. Navigation. The FMS should be integrated with other onboard systems and functionally mechanized with the basic airplane such that all lateral, vertical, and autothrottle modes perform their intended function and permit the flightcrew to safely, readily and efficiently operate the airplane within its approved flight envelope. The functions addressed in this paragraph, particularly system status and failure annunciations, supplement those of the particular navigation system advisory circulars referenced in paragraph 2b.

(1) Lateral Navigation (LNAV). The navigation accuracy required for computed position can vary significantly from one area, airspace, or mode of operation to another. The approval sought for a proposed area of system operation, such as the U.S. National Airspace System (NAS), North Atlantic Minimum Navigation Performance Specification (NAT-MNPS), other areas affected by International Civil Aviation Organization (ICAO) specifications, enroute, or non-precision approach, should be evaluated for acceptable system navigation position accuracy for both the full-up system and degraded or reversionary modes mechanized either automatically within the system or manually by the flightcrew.

(i) Long Range Navigation. Systems which compute lateral navigation position information for extended operation over water or remote land areas using sensor inputs such as inertial, Omega/VLF, Loran C, or Global Positioning System (GPS), or combinations of such sensors, should be evaluated to demonstrate accuracy suitable for the airspace for which the approval is sought. A number of the FAA advisory circulars referenced in paragraph 2b provide guidance for the accuracy and approval of these types of sensors. Also, systems using inertial sensor inputs that will subsequently seek approval for an operating certificate under Part 121 of the FAR must comply with the accuracy requirements of Part 121, Appendix G, for inertial based systems with or without update provisions.

(ii) United States National Airspace System Navigation. Systems which are intended for enroute, terminal and approach operations in the NAS should meet the following accuracy criteria. It is only necessary to demonstrate system accuracy in one area if it can be shown that the basic sensor accuracy is platform and position independent within specified geographic constraints.

	Enroute (Random routes)	Enroute (J/V routes)	Terminal	Non-Precision Approach
Equipment error along and cross track (2 Sigma, 95% probability)	+ 3.8	+ 2.8	+ 1.7	+ 0.3 nmi (+ 0.5 for navigation data from a single colocated VOR/DME station only.)

(A) Sensor Qualification. Navigation position data may be computed from a variety of individual or combined sensor inputs. Systems using multi-sensor inputs should meet the criteria of AC 20-130, Airworthiness Approval of Multi-Sensor Navigation Systems For Use In the U.S. National Airspace System (NAS) and Alaska. Systems using inputs from only one sensor should meet the criteria for the particular sensor being used. A number of FAA navigation advisory circulars are listed in paragraph 2b. They provide guidance for approval of these sensors, however, Omega/VLF navigation systems have not demonstrated sufficient accuracy to use in terminal and approach operations.

(B) Non-Precision Approach. Present RNAV instrument approach procedures provide obstruction clearance based upon flight path accuracy established by waypoints referenced to a single colocated VOR/DME facility. Flight management system equipment may provide the capability to conduct various non-precision approaches (VOR, VOR/DME, NDB, and RNAV) utilizing data from a variety of sensor inputs.

(1) Use of Navaid. Other sensor inputs may be used to provide improved navigation performance, however, the specified reference facility for the approach being conducted must be utilized in the navigation solution. The applicant should demonstrate that the system accuracy is not degraded below that established by the use of the specified reference facility. Display of course guidance information should be smooth during transition among the various sensor inputs. The navigation system may be programmed with procedures for other types of non-precision approaches (VOR, NDB, etc.) This information may be displayed and used by the autopilot or flight director when conducting these types of approaches. For NDB approaches, data from the NDB which defines the approach procedures should be displayed in the pilot's primary field of view.

(2) Non-Use of Navaid. Flight management system equipment may be used to conduct non-precision approaches where the specified reference facility which defines the approach is not used. In this case, it is necessary for the applicant to show that the system accuracy and failure modes are compatible with the performance requirements and terminal instrument procedures criteria associated with the type of approach being conducted. Currently, only FMS utilizing position data from an appropriately updated inertial system or the global positioning system (GPS/NAVSTAR) are expected to be capable of meeting this criteria.

(C) Precision Approach. Navigation data for precision approaches is provided by ILS or MLS equipment. Present FMS may provide navigation information to intercept the precision approach system course, and may also provide for automatic tuning of the appropriate sensor receiver. Experience has shown that it is highly desirable to retain the FMS map display during precision approaches and missed approaches. The map display provides situation awareness information that is not readily available from other displays. In order to provide acceptable agreement between the FMS displayed track line and the ILS/MLS course centerline, the FMS should use ILS/MLS sensor data to compute FMS position. In addition, the ILS/MLS raw data must be displayed in the ADI/EADI or primary flight display (PFD). The autopilot/flight director guidance will be based upon ILS/MLS sensor inputs as opposed to FMS inputs during precision aproaches. The transition from FMS guidance to ILS/MLS guidance (when the precision approach mode is armed for automatic capture) by the autopilot/flight director should be smooth and without significant overshoot. However, experience has shown that the transition from FMS to ILS/MLS can be difficult or significantly delayed in the case of small intercept angles.

(D) Holding Patterns. The equipment should provide the capability to proceed to a selected waypoint and hold on a specified inbound course to a waypoint with a repeated crossing of the selected waypoint. If holding patterns are pilot selectable or included in the data base, they should be defined to ensure that the pattern remains within the appropriate protected airspace.

(E) North Reference Effects. Utilization of a magnetic declination computed within FMS equipment, which may differ from the station declination used for a particular VOR station or airport facility, may result in notable differences in the flight path displayed by the FMS when compared to published routes. The most significant navigation errors are caused by the requirement to navigate with respect to a course from VOR/DME defined waypoints when those courses are given in degrees from the north orientation of the VOR. This "station north," which is established by the orientation of the VOR antenna, may differ from the current local magnetic north computed by the FMS by several degrees. Due to the difference between the station declination and the local magnetic variation, a magnetic track of a certain number of degrees through a station may not be the same track as a VOR radial of the same number of degrees. The difference is usually less than a few degrees, however, this can be significant for instrument approach considerations. Even if the magnetic track through a station and the VOR radial were identical tracks at the station, at some distance from the station the two tracks would diverge because the earth's magnetic field changes with position on the earth. Since constant error limits should be met at any distance from the way points defining the route in use, any equipment/application which has course selection in degrees ("TO-FROM" operation), such as charted airways, should have technical or operational provision to ensure that the proper north reference is used to define the desired course.

(2) Vertical Navigation (VNAV). The vertical navigation function relates to a vertical profile defined by two waypoints. The FMS should meet the following vertical navigation performance criteria regardless of the proposed use of the computed and displayed information or its interface with the pitch axis of the flight guidance/control system. The error of the airborne VNAV (path computation) equipment, excluding altimetry, should be less than that shown below on a 99.7 percent probability basis:

Altitude Region	Level Flight Segments and Climb/Descent Intercept of Specified Altitudes	Climb/Descent Specified Vertical Profile (angle)
At or below 5,000 ft	± 50 ft	± 100 ft
5000 to 10,000 ft	± 50 ft	± 150 ft
Above 10,000 ft	± 50 ft	± 220 ft

Guidance on approval of VNAV systems is contained in AC 20-129, Airworthiness Approval of Vertical Navigation Systems.

(i) Cruise Altitude Departure. Adequate annunciation of an impending automatic departure from a cruise altitude should be provided for all systems having vertical navigation modes. Examples of adequate annunciation are systems that display the airplane position and top of descent/bottom of climb point continuously, as in a horizontal situation indicator map mode, or systems that continuously provide a dedicated display of distance to the top of descent/bottom of climb point or other separate and unique annunciation of "vertical waypoint alert" displayed in the flightcrew's primary field of view. Systems that provide vertical navigation modes that automatically capture a preprogrammed vertical profile should require an overt flightcrew action within 5 minutes of the top of descent/bottom of climb point to activate the descent/climb unless the system is mechanized to the altitude selector in such a manner that a transition to descent or climb will not occur unless the altitude selector has been reset by the flightcrew to the new altitude. In addition, the system should contain design features that provide overspeed/underspeed protection (may be included in the autopilot system).

(ii) Speed Selection. If the system provides for pilot selection of speed, it should not be possible to select a speed above V_{MO}/M_{MO} or a speed below the speed 1.2 V_{S1} for the existing airplane configuration.

(3) Navigation Data Base. An FMS with complete capabilities will generally include a nonvolatile mass storage device containing the navigation data necessary to define a flight plan anywhere within a specified geographic area. For IFR operations, the data should include information such as the

location, magnetic variation, frequency and elevation of navaids and Victor and Jet airways. The data base may also include predetermined flight plans, standard terminal arrival routes (STAR), standard instrument departures (SID) and approach procedures. There should be a means for displaying to the flightcrew the dates for which the data is current and a means for updating the data base at least on a 56 day cycle. At present, there are no provisions for FAA approval or oversight of data bases as originated by manufacturers.

(i) Flight Plan. The flightcrew accesses the data base to construct a flight plan for the intended flight prior to departure or to modify an existing flight plan while in flight. The FMS should provide a means to allow the flightcrew to easily define additional waypoints and insert them into the flight plan. The accuracy of the data defining waypoints, navaids, intersections, etc., is described in navigation advisory circulars such as AC 20-121A, Airworthiness Approval of Loran-C Navigation Systems, and generally specifies the location to the nearest 0.1 minute of latitude and longitude or the equivalent in terms of bearing and distance from a defined location or navaid. Note that the criteria of ARP 1570, Flight Management Computer System, states that the flight plan constructed by the flightcrew should not be changed or erased by electrical transients or the loss of electrical power.

(ii) Data Base Modification. The flightcrew should not be able to modify information in the data base except to add or delete information identified as pilot defined data or to flag existing data so it will not be used when defining a flight plan.

(iii) Precision Approach Data. Precision approach procedures may be included for reference in the navigation data base and may be used by the FMS for procedures such as transition to an ILS or MLS or for missed approach procedures. However, the capabilities required for an FMS to conduct a precision approach without direct use of the ILS or MLS sensors and display has not been defined.

(4) Controls and Display. Acceptable criteria for system controls and displays are found in paragraphs 3, 4, and 5 of SAE document ARP 1068B, Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft.

(i) Automatic Frequency Tuning. Systems may be mechanized to employ automatic navaid selection and/or tuning to enhance navigation accuracy. When provided, the implementation should not allow the automatic feature to override the frequency that has been manually selected by the flightcrew. Some systems may also provide for remote tuning of communication transcievers through the FMS. This feature is acceptable as long as a means is provided to manually tune the radios to the emergency frequencies (121.5 and/or 243.0 MHz) regardless of the frequencies tuned by the FMS.

(ii) Time and Distance Display. The display of time or distance to go should relate to a navaid or waypoint located on the programmed airplane course unless adequate annunciation is provided to the contrary. The display of the frequency of an off-track navaid previously selected by the flightcrew is not considered adequate annunciation for this purpose.

(iii) System Status Display. A means should be provided to indicate upon demand, the specific sensors and/or stations currently used in the navigation calculations as well as the status of all sensors and/or stations being tracked.

(iv) Position Update. It is recommended that the ability to manually update the FMS position be provided. Individual sensor position should not be used unless recommended by its particular advisory circular.

(5) Annunciation. The FMS should provide the means to annunciate the status of the selected navigation mode and to alert the flightcrew to system failures which could affect the navigation of the airplane. In the approach mode, the lack of adequate navigation signals or sources should be annunciated by means of a flag displayed on the primary navigation display.

(i) Loss or Reduction of Function. Adequate annunciation should be provided for system failures that result in a loss or reduction of function. This includes the case when the system automatically reverts to a reversionary mode which can result in reduced navigation accuracy performance or a reduction in the airspace or geographical area that has been approved for normal system operation.

(ii) Mode Annunciation. When the aircraft is being controlled in pitch, roll, thrust or airspeed by FMS functions, the annunciation of these modes or submodes of FMS operation shall be presented in a clear and unambiguous manner in the flightcrews primary field of view.

(iii) Excessive Deviation Annunciation. It is desirable to have the FMS provide a means to annunciate a significant position deviation from the computer programmed flight path of the airplane. The annunciation threshold should consider hazardous deviations such as full-scale deflections of the course deviation indicator.

(iv) Waypoint Alert. A means should be provided to annunciate an approaching waypoint crossing. In addition to a dedicated waypoint alert light, an electronic horizontal situation indicator map mode which continuously displays airplane and waypoint position, would be acceptable for the purpose.

(v) Sensor and Station Quality. The system should annunciate when the quality of the navigation signals or sources, including signal to noise ratio and station geometry, has degraded to the level where the accuracy for which the navigational mode was approved can no longer be assured.

(6) Failure Modes. An equipment installation failure modes and effects analysis should be provided; the extent of which is dependent upon the degree of integration of the navigation system with the FMS and other new or existing airplane systems and sensors.

(7) Navigation Integrity. The computation and display of hazardously misleading navigation information should be shown to be improbable. For this purpose, hazardously misleading information relates to a

computed navigation position with errors that exceed the accuracy criteria for the area or airspace for which the approval is sought. Guidance on this is provided in AC 25.1309-1A.

(i) Lateral Navigation. The computation and display of hazardously misleading lateral navigation information or the loss of all lateral navigation position information should be shown to be improbable. Lateral navigation position information is not limited to that available from the FMS. It may include other information available in the airplane which the flightcrew can use to determine lateral position with an accuracy appropriate to the route being flown.

(ii) Vertical Navigation. Altimetry is the basic vertical navigation source for the airplane. The computation and display of hazardously misleading vertical navigation information on the FMS, flight director or HSI, should be shown to be improbable. The loss of the FMS VNAV function may be probable.

NOTE: The FMS and aircraft altimetry architecture can be used to preclude the display of hazardously misleading vertical navigation information by the FMS. An example would be the installation of independent altimetry systems with an appropriate comparator and display or the use of an independent altitude alerting function installed on the airplane (independent of the VNAV computer and its associated air data sensor).

(iii) Long Range Navigation. When proposed as stand alone or primary means, the simultaneous computation and display of hazardously misleading information from two or more independent data sources or the loss of all navigation position information should be shown to be improbable.

(iv) Position Display. When used as a primary means, the integrity of the components that display navigation position information; such as alphanumeric displays, weather radar, cathode ray tubes, electronic flight instruments, etc., must be considered when evaluating the reliability of the navigation system.

(v) Navigation Data Base. Corruption of the information contained in the data base is considered to be a major failure condition. Failures of the system which results in unannunciated changes to the data must be improbable. Differences between the update of the data base and the information contained in the update medium must be improbable.

f. <u>Performance Management</u>. Systems are available to aid the flightcrew in computing and displaying, and in some cases setting thrust and speed schedules for achieving maximum airplane performance or best economy over the entire flight profile of the airplane. These functions are called performance management and when incorporated in a single unit are called performance management systems. The provided modes may include takeoff, climb, cruise, descent, holding patterns, approach, and go-around functions. The performance management functions may, in addition to displaying computed information, generate control signals for coupling to the autothrottle and autopilot systems to achieve the desired values of thrust and speed, in order to minimize flightcrew workload. Performance management may also provide powerplant overboost protection, buffet margin information, speed limits and control for each configuration of flaps, slats and landing gear, and airplane overspeed and underspeed protection. The performance management logic should provide protection against exceeding 250 knot IAS below 10,000 feet MSL, however pilot override of this feature should be provided.

(1) Ground Procedures. The flightcrew input data required to be manually entered into the computer will generally vary according to the number and types of output functions provided. These generally include airport ambient temperature, airplane zero fuel weight, flight distance, takeoff flap position, amount of thrust reduction, type of departure profile, etc. The arrangement of the display and the method of parameter input should lead the flightcrew in such a manner as to reduce the potential for human error. The display of the entered parameters should clearly identify the data units. The computer should contain reasonableness logic to prevent the airplane from being operated beyond its certificated envelope limits. This aspect will be unique for the airplane/engine combination. After the initialization procedures are complete, a means should be provided (pilot activated or automatic integrity check) to show that all the displays and interfaces with the autothrottles, flight directors, instrument bugs, etc., are functioning properly. This paragraph is applicable to all subsystems or functions contained in this AC.

(2) Takeoff Mode. The takeoff mode generally displays some or all of the takeoff speeds and appropriate engine thrust settings based upon the sensed or manually entered values of airport ambient temperature, airplane weight and thrust reduction as may be applicable. The following aspects should be considered in order to ensure that the takeoff performance is acceptable.

(i) Takeoff Autothrottle. The autothrottle servo configuration may impact the performance of the system when operating in some modes. Single servo systems have difficulty setting takeoff power on all engines since the first engine to reach the power commanded will stop the autothrottle advance which may leave the other engines low on power. Such a system would be usable only as an aid for setting takeoff power.

(ii) Engine Failure. The method of detecting an engine failure should be reviewed to establish the validity of the scheme. Low EGT sensing may not account for a slowly failing engine, or simulated failure during training. Automatic bleed-shut-off sensing may not account for Minimum Equipment List (MEL) items, etc. This type of review will aid in establishing the AFM limitations and procedures, and possible MEL revisions.

(iii) Takeoff Pitch Attitude. Some systems may derive and display an initial takeoff rotation pitch attitude based upon a predicted angle of attack and gradient without an actual angle of attack input. This method has been acceptable for initial pitch guidance only as this method does not account for less than predicted thrust, entered airplane weight too low, windshear, etc., which could lead to excessive pitch attitude. As a result, airspeed must be used as the primary reference and this should be clearly stated in the AFM.

(iv) Engine-Out Flap Retraction. The FMS control laws should account for the available gradient and lower acceleration performance for an engine-out condition at each approved takeoff and climb flap/slat setting. As the flaps/slats are retracted to a new setting, the system should command a pitch attitude which results in the capture of the revised target speed at a reduced rate such that the airplane will maintain the minimum gradient required for that condition.

(v) Takeoff Speed Command Modes. Table 2 provides recommended transition and steady state tolerance criteria for low altitude autopilot or flight director speed command modes. The tolerance criteria is based upon normal flightcrew training and operational procedures and the consideration that the automatic system should command airplane performance which is commensurate to that which has been traditionally established for manual operation under the same conditions. Although the tolerance criteria is specified for still air, some allowance for local atmospheric conditions should be considered and a subjective evaluation should be made for this purpose. The demonstration of system performance, however, should not be made in atmospheric conditions which cause airplane upsets or disturbances to the extent that dynamic and steady state speed tracking performance cannot be readily determined.

(A) Takeoff. The system should provide commands that lead to the airplane smoothly acquiring a pitch attitude that results in a takeoff reference speed of V_2 + X by the time the airplane has reached approximately 35 feet altitude. In the event of an engine failure during takeoff, the reference speed should be:

(1) V_2 - X for an engine failure at or above V_2 + X.

(2) V_2 for an engine failure at or below V_2. This speed should be attained by the time the airplane has reached approximately 35 feet altitude.

(3) Airspeed at engine failure for failure between V_2 and V_2 + X.

Note: X is the all-engine speed additive from the AFM which has generally been 10 knots or higher.

(B) Takeoff Noise Thrust Cutback. The system should provide commands that result in an indicated airspeed of V2 + X at all takeoff flap settings prior to thrust cutback. This speed should be maintained after thrust cutback even if the critical engine fails subsequent to the event. Speed tolerances are provided in Table 2. Advisory Circular 91-53A, Noise Abatement Departure Profile, provides detail criteria concerning airplane flight profile, altitude, and thrust reduction constraints and the availability criteria for an automatic thrust advance feature. Handling qualities of a particular airplane may necessitate additional considerations for takeoff noise thrust cutback.

(C) Reduced Thrust Takeoff. Reduced thrust takeoffs are generally made for the purpose of reducing powerplant maintenance. Depending upon actual airplane takeoff weight, the thrust should be at least 75 percent of the takeoff thrust or derated takeoff thrust if such is the performance basis, for the existing ambient conditions. The assumed temperature method is commonly used for this purpose. In the event of the failure of the critical engine, the airplane will be able to maintain the minimum climb gradient required by the FAR without further advancing thrust on the remaining engines. See AC 25-13, Reduced and Derated Takeoff Thrust (Power) Requirements, for specific guidance for this type of operation.

(D) Automatic Takeoff Thrust Control System. The FMS may provide automatic takeoff thrust control system (ATTCS) functions which will allow for reductions in takeoff thrust up to 10 percent of the takeoff thrust. The ATTCS function is armed by the flightcrew and is designed to automatically advance the thrust on the remaining engine(s) to the takeoff thrust after an engine failure. Part 25, Appendix I contains the rules for ATTCS.

(E) Derated Takeoff Thrust. A derated takeoff thrust is a takeoff thrust less than the maximum takeoff thrust and for which a set of independent takeoff limitations and performance data may exist in the FMS computer memory. When this data is used for a derated takeoff, the thrust setting parameter which establishes thrust for takeoff, is considered a takeoff operating limit. Advisory Circular 25-13, Reduced and Derated Takeoff Thrust (Power) Requirements, provides certification guidance for this type of operation.

(F) Transition. The system should provide commands during periods of transition that are commensurate with that which would be expected from manual operation during the same condition. When speed deviations occur as the result of atmospheric conditions or delayed pilot response, corrective guidance should be provided that would minimize the time and magnitude of the deviation while being compatible with normal airplane maneuvering capabilities. The evaluation of this aspect is considered to be subjective and a qualitative assessment should be made during the flight demonstration.

(3) Climb Mode. The performance management function may provide a menu for manual or automatic selection of the climb speed schedule. This schedule may include minimum cost, fuel or time, maximum angle or gradient, maximum rate or provide for a selectable airspeed, Mach number or flight path angle. The function may control the selection of climb thrust such as maximum climb thrust, fixed or variable derated thrust or a performance based derated thrust.

(4) Cruise Mode. The performance management function may control the selection of cruise altitude based upon such factors as minimum cost, fuel or time, maximum range or endurance or selected airspeed or Mach number. The system should compute a maximum altitude based upon buffet margin.

(i) One-Engine-Inoperative Driftdown. The performance management function may control the driftdown with one engine inoperative. This may be based upon the best estimate of engine and airplane performance using actual airplane sensor data.

(ii) Two-Engine-Inoperative Driftdown. For airplanes with three or more engines, the performance management function may control the driftdown with two engines inoperative. This may be based upon the best estimate of engine and airplane performance using actual airplane sensor data.

(5) Descent Mode. The performance management function may select a descent schedule based upon minimum cost, fuel, time or a manually selected airspeed, Mach number or flight path angle. The computer should provide logic that would prevent the power being automatically reduced below safe levels or the minimum required when descending with ice protection systems operating per AFM instructions.

(6) Landing Approach. The system should provide commands that result in an indicated airspeed of V_{REF} + XX for all landing flap settings. This speed should be maintained even if the critical engine fails during stabilized approach.

Note: V_{REF} + XX is the landing approach reference speed plus the wind speed/gust additive, which may be manually entered.

(7) Landing Approach Go-Around. The airplane performance following addition of go-around thrust, during the landing approach go-around maneuver, with or without the simultaneous loss of an engine, should be such that the indicated airspeed is not reduced below that which existed upon initiation of the maneuver. The automatic and manual go-around procedures and speeds should be the same. The tolerances are specified in Table 2 and the go-around case assumes that the maneuver is initiated from stabilized approach.

(8) Annunciation and Display. The performance management primary flight modes selected by the flightcrew such as takeoff, climb, cruise, descent and landing approach modes, should be displayed in the pilot's primary field of view. Performance management submodes such as reduced thrust takeoff, derated thrust takeoff and those modes providing automatic takeoff thrust control system functions should also be displayed but may be presented on the CDU. In addition, airplane performance information that was processed or computed by the FMS should be readily retrievable for display by the control display unit during any phase of the flight. Adequate annunciation should be provided for system or sensor failures which result in a loss or reduction of a performance management function. The central caution and warning system or other dedicated indicators may be used to annunciate some of the more significant performance management failure cases particularly when the FMS is extensively integrated with other airplane systems and sensors. More routinely, a message light on the FMS control display unit may be used to alert the flightcrew to other system faults where immediate flightcrew action is not necessary. In this case, an indication should remain if a fault persists and another means such as a flashing message light should be provided to alert the flightcrew to further malfunctions.

(9) System Accuracy. When the computed data is used as the primary reference for takeoff, landing approach, or command mode information, the resolution of the displayed data and the accuracy of the AFM curve fitting routines for performance parameters such as speed, engine thrust, and engine limit data should be equal to or better than those values which can be

determined manually by the flightcrew when using the airplane performance information available on the flight deck. This criteria is commensurate with the methods used to establish the original type certificated performance of the airplane/engine combination. It is incumbent upon the applicant to provide the necessary documentation to the FAA to show that the computer memory contains authentic performance data for each airplane/engine combination for which the approval is sought. Table 1 provides generic guidance for representative computed and displayed performance parameters that are generally acceptable to the FAA.

(10) Performance Management Integrity. With the exception of the takeoff and landing modes, the integrity required of computed airplane performance parameters generally depends upon the proposed use of the displayed information. When proposed as primary means, the flightcrew is not required to verify the validity of the displayed information with the airplane flight manual information. When proposed as advisory, the displayed information is supplemental to the AFM. Additionally, the integrity of a command system is established below for systems that compute and provide outputs that drive instrument indicators (bugs) or otherwise display a symbology for the purpose of directing the flightcrew to take an action that affects the performance or flight path of the airplane.

(i) Primary Information. The computation and display of hazardously misleading primary information such as takeoff V speeds, landing approach reference speeds, engine thrust, engine limit data or other related airplane performance data should be improbable. This includes system output data provided as a command mode for other instruments or displays. Flightcrew confirmation is required of all information that would be necessary to manually determine the same takeoff and landing performance data from the approved AFM performance charts prior to utilization by the FMS. An acceptable means of ensuring flightcrew conformation of these data is a key stroke for each required item. The computation and display of takeoff V_1 speed requires additional consideration in that the data required to compute this variable extends beyond normal airplane dependent parameters. Some systems may employ onboard airplane sensors to provide some of the airport, runway, and environmental data necessary for the computation of takeoff V_1 speed. When used as such, the onboard airplane sensor reliability must support the integrity criteria that has been specified above. Although the computed data is primary, approval does not negate the requirement for the flightcrew to have access to the airplane flight manual information on the flight deck.

(ii) Advisory Information. Takeoff and landing approach mode performance parameters are a special case in that they must meet the integrity criteria of paragraph 5e(10)(i) of this AC regardless of how the use of such computed data is proposed. Data computed for the climb, cruise and descent modes may be considered to be advisory and therefore do not have to meet the integrity criteria of paragraph 5f(10)(i) of this AC. These modes, however, should be shown to perform their intended function.

(iii) Automatic Takeoff Thrust Control System Failure Conditions. Some failure conditions involving the ATTCS takeoff mode function are major when considered independently and catastrophic when considered coincident with the loss of an engine. For this purpose, the supporting analysis may use the exposure time between takeoff decision speed minus one second (V_1-1) and the airplane reaching an altitude of 400 ft AGL.

g. Autothrottle System (ATS). The FMS may incorporate a new ATS or utilize an existing system that has been modified for various flight modes. In either case, the integration and compatibility of the ATS with the various flight management, performance management and autopilot modes must be taken into account.

NOTE: The criteria provided in this paragraph may not apply to turbo propellor or reciprocating engine powered airplanes. While the basic principals apply, the specific criteria may be different.

(1) Takeoff Mode. The ATS operates in a thrust control mode at high power settings and the system is designed to set the thrust by the time the throttle clamp speed is attained. A number of unique considerations apply to the takeoff mode.

(i) The ATS design should provide an autothrottle clamp (inhibit) speed during takeoff. The clamp speed should be the speed used during type certification for the determination of airplane performance and evaluation of engine limits. Subsequent minor throttle adjustments by the flightcrew may be required. If the designer chooses to select another speed for throttle clamp, one of the following should apply.

(A) The applicant may redemonstrate airplane performance and verify engine limit evaluations at the new clamp speed through climb to 400 ft. AGL.

(B) The difference in performance between the selected clamp speed and the original performance related speed up to 400 feet AGL is negligible.

(ii) Adequate annunciation should be provided for the system failure condition where the throttles either fail to clamp at the takeoff inhibit speed or the throttles become unclamped during the takeoff mode below 400 ft. AGL.

(iii) Caution should be exercised in providing a single ATS servo clutch for all throttles for the takeoff mode. Since most systems control on the lead engine, throttle stagger may result in unacceptable thrust differential after throttle clamp.

(iv) Engine overboost and engine overspeed protection should be provided.

(v) Logic should be provided to account for flap placard speeds.

(vi) Table 1 provides performance criteria for the ATS commanded parameters.

(2) Climb Mode. The ATS may be selected to operate in either speed or thrust control modes. Since high power settings are normally used, overboost protection should be provided and may be required depending upon specific powerplant characteristics. The ATS logic should provide flight envelope speed protection based upon airplane configuration.

(3) Cruise Mode. The ATS may be selected to operate in either speed or thrust control modes. The system should be free of excessive throttle oscillations/hunting and it should be compatible with the autopilot pitch axis relative to speed on pitch/speed on throttles. Engine overboost, and flight envelope speed protection should be provided.

(4) Descent Mode. The ATS may be selected to operate in either speed or thrust control modes. The design should consider that a minimum thrust descent is compatible with minimum engine speed limits and cabin pressure altitude control and anti-ice bleed air requirements including accountability that the system may automatically switch from flight to ground idle if such a feature is provided. Flight envelope speed protection should be provided.

(5) Landing Approach Mode. The ATS may be selected for the speed or angle of attack control modes and the operating points may be set either manually or automatically. The system should be designed to control speed to within + 5 knots of the target speed but not less than the higher of V_{REF} or $1.3V_S$ of the landing configuration. At the landing flare maneuver, the throttle retard rate should be consistent with the recommendations of the powerplant and airframe manufacturer.

(6) Go-Around Mode. In the FMS go-around mode, the ATS should operate in the thrust control mode. The system should automatically transition from the speed mode to the thrust control mode upon selection of the FMS go-around mode. The selection of the go-around mode may be a flight guidance function. The go-around thrust rating is usually selected manually by the flightcrew during landing approach; however, it may be automatically selected as a system feature. Actuation of the FMS go-around thrust rating selection may be independent of the go-around mode, however, when the go-around mode is actuated, the selection of the go-around thrust rating should be automatic.

(7) Speed Floor Protection. If the system provides for pilot selection of speed, it should not be possible to select a speed below $1.2\ V_{S1}$. Additional features may be provided by the ATS limiting the lowest speed that the system will command commensurate with the recommended minimum maneuvering speed for the airplane as a function of the maneuver being performed and the flap/slat position but not less than $1.2\ V_{S1}$. This protection may be provided by maximum angle of attack schedule.

(8) ATS Integrity. The autothrottle failure condition of uncommanded throttle movement between takeoff throttle clamp speed and 400 ft. AGL is considered major in accordance with AC 25.1309-1A and should be shown to be improbable. A slow throttle retard, such that pilot recognition of throttle movement would be in doubt in conjunction with an engine failure is considered catastrophic in accordance with AC 25.1309-1A, and should be shown to be extremely improbable. In this case, the cascade effect of engine failure,

electrical system disturbance and autothrottle system operation should be considered. Continuous unannunciated overboost is considered a major failure condition and should be shown to be improbable. Failure conditions of other modes of the ATS may be considered to be minor and may be probable.

h. Takeoff Performance Monitor. The FMS may provide the function of computing and displaying achieved airplane performance information to the flightcrew in real time. Airplane performance data derived from sensors is used to compute achieved performance. This data is compared to the computed airplane reference performance for the actual airplane configuration, weight, and takeoff thrust to be applied, and airport/runway environmental conditions such as temperature, wind and runway slope, and surface condition. The display of the computed data provides the flightcrew with additional information to assist in determining if the achieved airplane performance is acceptable.

(1) System Accuracy. The system displays information on the flightdeck so that the current status of the takeoff can be determined. It is important that system tolerances which can affect the accuracy of that flightdeck 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 the system tolerances will, of themselves, cause an error greater than ± 5 percent in the apparent all-engine operating takeoff distance to rotation speed should be 0.01 or less. While this overall accuracy is the basic criteria, it is desirable that the accuracy of the individual performance parameter displays fall within the ranges as follows:

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

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

(iii) Longitudinal Acceleration: ± 0.2 feet per second squared or ± 2% (whichever is greater).

(2) Runway Considerations. If the time to a specific takeoff speed is computed and displayed, that speed should be sufficiently below decision speed V_1 to allow the flightcrew adequate time to decide if the difference between actual and computed performance is acceptable. The FAA feels that approximately 5 seconds is sufficient for this purpose. The computed time should agree with the airplane performance information developed in paragraph 5h(4) of this AC, to within 1 second. This accuracy criteria assumes near ideal runway conditions and if approval is sought for other conditions, the following considerations should be addressed in order to reduce the potential for unnecessary high speed rejected takeoffs.

(i) Runway Slope. Runways may have a constant or variable gradient and the accuracy of the airplane reference performance can be adversely affected. Runway gradient may be accounted for just as takeoff field length variables are accounted for. This may be satisfied with a flightcrew computer entry or by computer modeling or a combination of the two. If the approval is sought for near constant gradient runways, the computer logic should account for the condition. If the runway has a variable gradient, the computer should contain a mathematical model of the condition and a means should be provided for the flightcrew to insert the data into the computer describing the point along the runway where the takeoff will be initiated. These considerations are not necessary for runways where the applicant can show that the computed reference performance can meet the accuracy criteria of paragraph 5h(1) of this AC.

(ii) Contaminated Runways. If the applicant seeks approval for operation on precipitation contaminated runways, the computer logic should account for the change in drag caused by standing water, slush, or snow. Since, in some cases, there is a continuous variation of contamination along the length of a runway, accountability for such conditions may not be possible. The FAA has not developed criteria for the treatment of such conditions relative to takeoff performance monitors. It is the responsibility of the applicant to show that the performance criteria of paragraph 5h(1) of this AC is maintained for approval of system operation under such conditions. The FAA will allow for an AFM limitation that prohibits the use of the system under these conditions at the applicant's discretion.

(3) System Threshold. If the function is provided, the system should alert the flightcrew when the achieved performance is less than the reference performance by 5 percent. This alert should occur as early in the takeoff roll as possible as the field length and decision speed V_1 computations are based upon the manufacturers demonstrated values using known takeoff power and power application procedures. If the reference performance is less than that used for the computation, the runway distance used to reach V_1 will be greater and the corresponding length of remaining runway to decelerate and stop will be less.

(4) Takeoff Thrust. The implementation of the takeoff monitoring function should consider the manner in which the flightcrew will set thrust at the beginning of the takeoff roll. The thrust used for the AFM should be used for this purpose. Several models may be developed such as setting thrust statically or during a slight rolling takeoff, etc. If more than one model is developed, it may be a flightcrew selectable computer input. Airplane performance information should be developed that provides the same information as the computer model(s) so that it is available on the flight deck and the flightcrew can independently determine the computed airplane performance.

(5) Airmass Analysis. The applicant should perform airmass analysis to show the effects of a typical runway gust condition such as 10 knots/gust to 20 knots in order to show the suitability of the concepts used.

(6) Annunciation and Display. A real time digital or analog display of achieved and reference performance should be provided in the flightcrew's primary field of view. The nature of the display should be such that it provides information to the flightcrew as opposed to commanding a rejected takeoff or continued takeoff as in either case the final decision remains with the flightcrew. All forms of annunciation and display should be inhibited when the airplane reaches V_1 speed. If a display alerts the flightcrew that the system threshold of paragraph 5h(2) of this AC has been exceeded, it should be amber in color. It may also include an aural caution.

(7) Function Integrity. Unannunciated system failure conditions are considered major in accordance with AC 25.1309-1A since the display of the computed data no matter how it is presented will influence the flightcrew's decision to continue the takeoff roll or initiate a rejected takeoff. As a result, the computation and display of hazardously misleading information or the unannunciated loss of function should be improbable. The integrity of the external sensors should be considered. Computer software should be Level 2.

i. Fuel State. For each airplane model, the accuracy and resolution of the displayed fuel state computations should be equal to or better than that provided by the flight deck instrumentation approved at the time the original type certificate was issued.

(1) The FMS may utilize fuel and weight parameters in calculating airplane range and performance predictions which may be used in controlling the airplane. These predictions are calculated in real time and are continuously refined by the system throughout the flight. It also may utilize these inputs in arriving at engine out and drift down performance predictions, however the inputs should not be used as a basis for fuel load planning or airplane range predictions by the airplane operator.

(2) Fuel flow inputs from the airplane systems may be utilized by the FMS in order to refine airplane range and performance calculations.

(3) Fuel quantity may be used by the FMS and may be obtained directly from the airplane systems or entered into the system manually. These displays should not be substituted for the basic airplane fuel systems displays or gauges during airplane operation or fuel loading.

(4) Fuel quantity low and fuel imbalance warnings may be incorporated into the FMS. Reserve fuel requirements may also be utilized by the FMS. This input may be entered manually and may incorporate a low limit warning feature.

(5) Airplane gross weight and zero fuel weight may be used by the FMS and may be obtained directly from airplane systems or may be inserted manually. These parameters are the basis for all airplane performance calculations that are accomplished in real time.

(6) Fuel remaining at destination and fuel required for an alternate airport may be features incorporated into the FMS. Actual airplane range should not be based on these predictions.

j. Flight Deck Checklists. The FMS may provide additional features such as takeoff, landing and emergency flight deck checklists. These checklists may be displayed on the FMS control display unit, electronic flight instruments or by other means found acceptable to the FAA. Certification guidance is provided in AC 25-11, Transport Category Airplane Electronic Display Systems.

k. Flight Management System Data Link. Airborne data links can be used by the FMS to provide a medium for the automated acquisition of flight plan navigational and airplane performance related data. The avionic functions which acquire and process such data should be developed and maintained to the criticality level of the processed data itself unless the applicant can show that a means can be provided to ensure that the integrity of the data is maintained. The imposition of an operational requirement for independent verification of such data by the flightcrew does not constitute an adequate means for this purpose, however, the data should not be used by the FMS until the data has been manually acknowledged by the flightcrew. An example of such an airborne data link is the ARINC Communications, Addressing, and Reporting System commonly called ACARS.

l. Software Based Systems. An acceptable means for obtaining approval for the development of software based systems is to follow the design methodology contained in RTCA document DO-178A, Software Considerations in Airborne Systems and Equipment Certification, at the criticality level for which the approval is sought.

(1) Software Changes. The provisions of this paragraph apply to FMS equipment which utilizes a digital computer to provide flight management information. The computer program (software) operates the computer and provides the basic functions of these systems. The software for navigation, performance management, autothrottle, and takeoff performance monitor functions of the FMS equipment described in paragraphs 5e(7), 5f(10), 5g(8), and 5h(7) of this AC should be verified and validated to at least the Level 2 requirements as defined by RTCA DO-178A. Any changes to software which affects these functions are considered to be major changes to the equipment. Unless software partitioning has been previously established, any change to Level 1 or Level 2 software of the FMS equipment should be verified and validated to the appropriate level and should be demonstrated as not having inadvertantly affected the remaining navigation, performance management, autothrottle, and takeoff performance monitor functions. Changes to software used for other FMS functions in equipment having established partitioning from software which provides navigation, performance management, autothrottle, and takeoff performance monitor functions, are considered to be minor and do not require prior approval by the FAA, providing the manufacturer of the FMS equipment has a software configuration management and quality assurance program approved by the FAA. All software changes should be identified in the outside of the associated line replaceable unit in accordance with the criteria of RTCA DO-178A. Software changes in TSO approved equipment must be reported to the cognizant Aircraft Certification Office. If the equipment displays a software identifier to the flightcrew, the AFM should indicate the approved identifier. Software changes incorporated in equipment already installed in an aircraft may require additional evaluation and possible flight manual revision prior to returning the aircraft to service, depending upon the scope of the change.

(2) Software Identifier. If the FMS or its sensors are designed to display a software program identifier to the flightcrew, the program identifier should be displayable by the FMS control display unit and the AFM should indicate the approved identifier.

m. Equipment Installation. An equipment installation failure modes and effects analysis should be provided, the extent of which is dependent upon the degree of integration of the FMS with new or existing airplane systems and sensors.

n. Test and Evaluation.

(1) Environmental Tests. The major components comprising the FMS should be qualified to the appropriate sections of RTCA document DO-160B, Environmental Conditions and Test Procedures for Airborne Equipment, or equivalent. The environmental qualifications should be compatible with the environment in which the equipment is installed.

(2) Ground Tests. The applicant should provide a ground test plan that includes the tests necessary to verify that the FMS as installed in the airplane performs its intended function and that there are no adverse effects to existing airplane systems and sensors.

(i) Simulators have been used extensively for evaluating the large matrix of FMS computed EPR, N_1, engine overboost schedules, takeoff and landing speed schedules, buffet boundary schedules, V_{MO}/M_{MO} and flap/gear speed limits, etc. All of these parameters may vary with weight, altitude, and temperature, and in some cases engine bleed, center of gravity and load factor. Therefore, actual flight testing will at best provide only a small cross section of conditions that should be evaluated. The accuracy of the simulated inputs should be established by a validation program.

(ii) The thrust setting system (EPR or RPM) and airspeed/Mach system or Digital Air Data Computer system should be calibrated prior to the flight test evaluation.

(iii) Operational weight and balance records have been acceptable to use for flight test without the need for a dedicated weighing.

(3) Flight Tests. The applicant should provide a flight test plan that includes tests to verify that the FMS performs its intended function and that there are no adverse effects to other airplane systems and sensors. These tests should include, but are not limited to the following:

(i) Flight test evaluations should be made to determine that prior approvals of existing airplane systems have not been compromised. This aspect could require extensive reevaluation if integration of the FMS required changes to existing airplane systems or sensors having prior approval for automatic functions such as flight director takeoff, Category II or Category III landing modes.

(ii) Flight test evaluations should be made for all normal system operating modes such as speed command, attitude/thrust in combination with lateral and vertical navigation modes for takeoff, climb, cruise, descent and approach as may be applicable.

(iii) The advisory circulars which specify the flight test and evaluation requirements for navigation systems employing single or multisensor inputs are listed in paragraph 2b of this AC. If approval is sought for certain sub-(reversionary) operating modes utilizing single or a reduced combination of sensor inputs, the evaluation must include an appropriate number of data points for each configuration for which the approval is sought. The exact number of data points should be agreed upon between the applicant and the FAA and will depend upon the characteristics of the system.

(iv) The data obtained from the flight demonstration should be referenced to the flight deck instrumentation for airplane configuration and airspeed that the flightcrew normally uses to determine airplane performance when operating the airplane manually. Unless it can be shown that the type certificated airplane performance was determined in another manner, the data should not be corrected for actual flap/slat position or airspeed system position error.

(v) If the FMS approval is sought with mix of autopilot or autothrottle computers, each combination should be included during the evaluation.

(vi) The evaluation should include a sufficient number of simulated engine out conditions for the takeoff mode to demonstrate that the AFM engine out speed is smoothly captured and maintained. The effects of electrical transients upon the FMS due to the simulated loss of the engine and its associated generator should be assessed.

(vii) At least one actual engine shutdown should be accomplished to evaluate bus and/or generator load switching effects on the FMS. This test may be accomplished on the ground, provided there is nothing associated with flight logic that would invalidate such a simulation.

(viii) An FMS controlled buffet boundary protection margin should be demonstrated for all applicable flight modes by commanding a relatively large speed change at a point close to the boundary. Protection margin over or undershoot transients should not result in buffet.

(ix) The performance management climb, cruise and descent modes should also be evaluated during the flight test demonstration. Unlike the more critical takeoff, landing approach and go-around modes, the primary emphasis should be on the safety and operational characteristics of the speed schedules as opposed to the verification of the actual minimum cost, fuel or time schedules. The flight test should include a functional check of speed, fuel and time schedules as applicable. The operational suitability of these modes should also be evaluated. These modes should affect flightcrew workload and the ease and simplicity of their operation can impact the determination of the minimum flightcrew per § 25.1523.

(x) If an FMS approach autothrottle mode is provided, the control speed should be within + 5 knots of the programmed speed but not less than the computed threshold (minimum) speed. Reference Chapter 2, paragraph 11c(2) of AC 120-29, Criteria for Approving Category I and II Landing Minima for FAR 121 Operators. If the autothrottles are revised as a result of the FMS installation, a qualitative evaluation of Category II and/or autoland characteristics should be made if the airplane has been previously approved for such modes. If a new autothrottle is installed, a quantitative assessment may also be included in the evaluation.

(xi) If the FMS is used to set power for takeoff by the use of coupled autothrottles, it should be demonstrated that the rate of power increase is sufficient to set the power prior to autothrottle clamp which generally occurs in the 60 to 80 knot range. This becomes increasingly important when operating at high performance conditions associated with light weight, low altitude, maximum takeoff power, and rolling takeoff procedure.

(xii) An evaluation of the fuel state computations should be made for reasonableness when compared with flight planning data.

(xiii) Installation of FMS that are heavily integrated into the airplane displays and controls may result in a change in pilot type rating for the particular airplane. Contact should be made as early as possible with the Flight Standards Board for the particular airplane type in accordance with the details described in AC 61-XX, Procedures and Criteria for Determining the Type Rating Requirements for an Aircraft.

o. Airplane Flight Manual Supplement (AFMS). The AFMS should provide the appropriate system limitations and a comprehensive description of all normal and submodes of system operation including what actions are expected by the flightcrew for each case. A reduction in the amount of material covered may be allowed if the equipment manufacturer's pilot operating manual is required to be on board the aircraft and if the initial version and subsequent revisions are approved by the FAA. The following items, if applicable, should also be addressed in the AFMS.

(1) The compatibility of powerplant intermix and derate with the FMS performance management function.

(2) The AFMS should indicate those functions that have not been evaluated for accuracy by the FAA. The following is an example statement: "The accuracy of the FMS range and fuel management information have not been evaluated by the FAA; therefore, airplane range calculations and fuel management must not be predicted upon its use."

(3) The navigation functions, airspace and geographical areas approved for the FMS primary and/or sub-(reversionary) navigation modes should be clearly identified in the AFMS.

(4) The AFMS should describe how the FMS computed and displayed takeoff performance monitor information can vary as the result of varying wind conditions along the runway and the different techniques of applying thrust.

(5) Display of software identifier should be included in the AFMS.

LEROY A. KEITH
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APPENDIX 1
TABLE 1
COMPUTED PERFORMANCE CRITERIA

PARAMETER	COCKPIT READABILITY	FMS COMPUTES TO THE AFM VALUES WITHIN:	FMS ERRORS RESULTING FROM SENSOR ACCURACY	FMS CONTROLS TO THE COMPUTED COMMANDS WITHIN (STEADY STATE*):	
EPR	.01	See Note 1	See Note 2	See Note 3	
THRUST SET (%)	.1	See Note 1	See Note 2	See Note 3	RPM
EGT (C)	1	-----	+ 8	-----	
LIMITING (%)	1	+ 0, -1.0	+ .5	+ 1	RPM
IAS (KTS)					
V_1, V_R	1	+ 1	+ 2	+5, -2	V_2
	1	+ 2, -0	+ 2 @ 100 KTS	+5, -0	
T.O. & LDG DISTANCE (FEET)	10	See Note 4	See Note 4	-----	
PERF. LIMIT WT	See Note 5	See Note 5	See Note 5	-----	

Dual systems displays may differ by the extremes of the sum of columns 3 and 4.
*Control accuracy on "steady state" basis; gusts and other short term disturbances may exceed these during transients.

NOTE 1: Computes thrust setting values to an accuracy that does not introduce appreciable error in the displayed value of the thrust setting parameter when compared to the value shown on the thrust setting charts contained in the AFM. Typically ± .005 EPR or ± .25% RPM.

NOTE 2: Errors introduced by sensor inaccuracy may not exceed those associated with the accuracies/readabilities historically deemed acceptable for the display of parameters used in setting thrust by means of reference charts contained in the AFM. Typically ± .005 EPR or ± .25% RPM.

NOTE 3: Controls all engines to computed commands with an accuracy equal to or better than the pilot's ability to set thrust manually without undue concentration or effort when relying on the thrust setting information contained in the AFM. Typically .01 EPR or .5% RPM. For single serve systems see paragraph 5f(2)(i) of this AC.

NOTE 4: Not shorter than the distance determined by the AFM.

NOTE 5: Not greater than the weight determined from the AFM.

TABLE 2

LOW ALTITUDE SPEED COMMAND TOLERANCES (STILL AIR)

MODE	CONDITION	TRANSITION IAS (KTS)	STEADY STATE IAS (KTS)
TAKEOFF	CRITICAL ENGINE FAILURE $V_{EF} < V_2$	Before 35 feet, as close as practical to the speed profile demonstrated during performance tests.	$V_2\ ^{+5}_{-0}$
	CRITICAL ENGINE FAILURE $V_2 < V_{EF} < (V_2 + X)$	V_{EF} -5 (Note 1.)	$V_{EF}\ ^{+5}_{-2}$ (Note 2.)
	CRITICAL ENGINE FAILURE $V_{EF} > (V_2 + X)$	$(V_2 + X)$ -5 (Note 3.)	$(V_2 + X)\ ^{+5}_{-2}$
	All Engines Operating	N/A	$(V_2 + X)\ ^{+5}_{-2}$ (Note 4.)
TAKEOFF, NOISE THRUST CUTBACK	Critical Engine Failure During Thrust Cutback	$(V_2 + X)$ -5 (Note 3.)	$(V_2 + X)\ ^{+5}_{-2}$
	All Engines Operating	$(V_2 + X)$ -2	$(V_2 + X)\ ^{+5}_{-2}$ (Note 4.)
LANDING APPROACH GO-AROUND (Initiated at V_{REF} + XX during stabilized approach)	Critical Engine Failure During Transition	$(V_{REF}$ +XX) $^{+5}_{-5}$ (Note 5.)	V_{REF} +XX) $^{+5}_{-2}$
	All Engines Operating	$(V_{REF}$ +XX) $^{+5}_{-5}$ (Note 6.)	V_{REF} +XX) $^{+5}_{-2}$
LANDING APPROACH	All Engs Operating & Critical Engine Failure	N/A	V_{REF} +XX) $^{+5}_{-5}$ (Note 7.)

NOTES:

1. Less than V_{EF} -2 not to exceed 10 sec.; Less than V_2 not to exceed 5 sec; Not less than V_2 -2
2. Not less than V_2
3. Less than $(V_2 + X)$ -2 not to exceed 10 sec.
4. Except in pitch limited conditions
5. Less than $(V_{REF}$ +XX) -2 not to exceed 10 sec.; Less than $1.2V_{S1}$ not to exceed 5 sec.; Not less than $1.2V_{S1}$ -2
6. Less than $(V_{REF}$ +XX) -2 not to exceed 10 sec.; Not less than $1.2V_{S1}$
7. Not less than $1.3V_{SO}$
8. X = All engine speed additive from the AFM
9. XX = Landing approach wind speed/gust additive