

## Final Special Condition

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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 21 and 25

[Docket No. NM-26; Special Conditions No. 25-ANM-23]

Special Conditions: Airbus Industrie Model A320 Series Airplane

**PDF Format:**

#### ▼ Preamble Information

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final special conditions.

**SUMMARY:** These special conditions are issued for the Airbus Industrie Model A320 airplane. This airplane will have novel and unusual design features when compared to the state of technology envisioned in the airworthiness standards of Part 25 of the Federal Aviation Regulations (FAR). This notice contains the additional safety standards which the Administrator considers necessary to establish a level of safety equivalent to that provided by the airworthiness standards of Part 25.

**EFFECTIVE DATE:** December 15, 1988.

**FOR FURTHER INFORMATION CONTACT:** Gregory J. Holt, FAA, Standardization Branch, ANM-113, Transport Airplane Directorate, Aircraft Certification Service, 17900 Pacific Highway South, C-68966, Seattle, Washington 98168; telephone (206) 431-1918.

**SUPPLEMENTARY INFORMATION**

## **Background**

On February 7, 1984, Airbus Industrie, 1 Rond Point Maurice Bellonte, 31707 Blagnac Cedex, France, applied for type certification of their Model A320 by the Direction Generale de l'Aviation Civile (DGAC) under the provisions of Joint Airworthiness Requirements-25 (JAR-25) and by the FAA under the provisions of § 21.29 of the FAR and an existing bilateral airworthiness agreement with the government of France.

The bilateral agreement was reached in 1973 to facilitate French acceptance of aeronautical products exported from this country and reciprocal U.S. acceptance of such products imported from France. The bilateral agreement provides, in part, for U.S. acceptance of certification by the DGAC that the Model A320 complies with the applicable U.S. laws, regulations and requirements, or with the applicable French laws, regulations and requirements, plus any additional requirements the U.S. finds necessary to ensure that the Model A320 meets a level of safety equivalent to that provided by the applicable U.S. laws, regulations and requirements. The DGAC has elected to certify that the Model A320 complies with the French laws, regulations and requirements, plus any necessary special requirements.

The DGAC has advised that the French laws, regulations and requirements applicable to the Model A320 (i.e. the French type certification basis) consist of JAR-25 with changes 1 through 11 thereto and including the French National Variants, Joint Airworthiness Requirements-All Weather Operation (JAR-AWO), and Special Conditions and interpretations applied specifically to the Model A320. JAR-25 is a document developed jointly and accepted by the airworthiness authorities of various European countries, including France, for type certification of large airplanes. JAR-25 is based on Part 25 of the FAR, however there are certain specified differences in the requirements of the two documents. In addition, JAR-25 also contains requirements, known as National Variants, that are peculiar to individual accepting countries. "Orange Papers" are interim amendments which are eventually consolidated as a change to JAR-25. Special conditions are also applied where JAR-25 does not contain adequate or appropriate safety standards due to novel or unusual design features. In order to preclude confusion, these special conditions will be referred to herein as the "French Special Conditions." JAR-AWO contains additional requirements applicable to all weather operations.

The Airworthiness Authorities of Germany, England, and the Netherlands participated with France in a joint certification of the A320 in February 1988. U.S. type certification of the A320 is scheduled for December 15, 1988.

Based on the February 7, 1984, date of application for type certificate, the applicable U.S. laws, regulations and requirements, as established under the provisions of §§ 21.17 and 21.29 of the FAR, are Part 25 of the FAR with Amendments 25-1 through 25-56 thereto and the special conditions contained herein. When the applicable regulations do not contain adequate or appropriate safety standards because of a novel or unusual design feature, special conditions are prescribed under the provisions of § 21.16 of the FAR in order to establish a level of safety equivalent to that established in the regulations.

A comparison has been made of the French type certification basis and the above noted U.S. laws, regulations and requirements, including the respective French and U.S. special conditions. Based on this comparison, the FAA has prescribed the additional requirements that are necessary to ensure that the Model A320 meets a level of safety equivalent to that provided by the U.S. laws, regulations and requirements.

Noise certification is beyond the scope of the bilateral agreement; however, French test data are accepted by separate arrangement. The French noise certification basis is their "Arrete" (order) dated November 29, 1991 (ICAO Annex 16). The U.S. noise certification basis for the Model A320 is Part 36 of the FAR with Amendments 36-1 through 36-12 thereto and any subsequent amendments adopted prior to the date on which the U.S. type certificate is issued. French noise certification test data will be reviewed by the FAA for compliance with the U.S. noise certification basis.

The Model A320 must also comply with the engine emission requirements of special Federal Aviation Regulation No. 27 (SFAR 27) with Amendments 27-1 through 27-5 thereto and any subsequent amendments adopted prior to the date on which the U.S. type certificate is issued. Engine emission requirements are also beyond the scope of the bilateral agreement; however, certification of compliance by the DGAC will be accepted by separate arrangement. Lastly, the statutory provisions of Pub. L. 92-574, "Noise Control Act of 1972" require that the FAA issue a finding of regulatory adequacy pursuant to Section 611 of that Act.

The French type certification basis, together with the additional requirements discussed above, Part 36 of the FAR SFAR 27, and the Noise Control Act of 1972, will comprise the U.S. type certification basis for the Model A320.

## A320 Design Features

### *General*

The Model A320 airplane presented for U.S. type certification is a short to medium-range, twin-turbofan, transport category airplane with a seating capacity of 120 to 179 passengers, a maximum takeoff weight of 162,037 pounds, and a maximum operating altitude of 39,000 feet.

The structure of the A320 is generally of conventional design and construction, but with considerable use of composite materials. Elements of primary structure (the fin and horizontal tailplane) are constructed of composites as well as components such as flaps, spoilers, ailerons, engine cowls, and the leading and trailing edge access panels. In addition, the structural design makes limited use of overspeed protection and active controls in the form of load alleviation.

The model A320 utilizes fly-by-wire (FBW) flight controls for the elevators, ailerons, spoilers, tailplane trim, slats and flaps, speed brakes, trim in yaw, and engine control. The

aerodynamic surfaces are positioned relative to the pilot's command by electronic signals sent via airplane wiring from the flight control computers to hydraulic actuators. Conventional mechanical control is provided for the rudder and tailplane trim hydraulic actuators. Should a short-term interrupt occur in the electronic flight controls, flight could be maintained for a period of time through the use of mechanical control of rudder and airplane trim.

Normal electrical power is supplied by a constant frequency generator on each engine. An auxiliary power unit (APU) driven electrical generator is also available. A continuous source of electrical power is required by the A320 fly-by-wire flight controls. In the event of the loss of normal electrical power, a ram air turbine (RAT) is automatically deployed. The RAT provides hydraulic power which is used by a constant frequency generator to supply electrical power. Until the RAT powered generator comes on line (approximately 7 seconds), the flight control system is powered from the airplane's batteries. RAT deployment may also be selected manually by pushing switches either on the electrical or the hydraulic overhead panel. Hydraulic power to the flight control system is simultaneously provided by three independent hydraulic systems. Functions are shared among these systems in order to ensure airplane control in the event of loss of one or two systems. Two of the systems are pressurized by variable displacement pumps driven by the engine accessory gearbox, and the third system is powered by an electrically driven pump or by the RAT hydraulic pump in case of loss of normal electrical power.

The airplane has two basic engine configurations: the SNECMA-General Electric CFM56-5 engines, and the International Aero Engines; (IAE) V2500 engines. Both engine types have a takeoff rating of 25,000 pounds of thrust (sea level, static). The engine control system consists of a dual channel Full Authority Digital Engine Control (FADEC) mounted on the fan case of each engine. Each FADEC interfaces with various airplane computer systems. The FADEC provides gas generator control engine limit protection, power management, thrust reverser control, and engine parameter inputs for the flight deck displays. In addition to control of the engines from the flight deck through changes in power lever position, an autothrust mode is provided which commands thrust changes directly to the FADEC without a corresponding range in power lever position. In this mode of operation, the position of the power lever sets the upper limit for thrust, except when alpha floor is reached. At alpha floor, the engines are commanded to full thrust, regardless of lever position, as part of the high angle-of-attack (AOA) protection. The autothrust mode can be disengaged by pushing a button on the power lever or by moving the thrust lever to TOGA or IDLE. The engine FADEC and associated airplane related systems form the complete propulsion control systems.

Pitch and roll control inputs are made through flight deck side stick controllers mounted on the lateral consoles of the pilot and copilot positions, in place of central control columns. The flight instruments are displayed on six cathode ray tube (CRT) displays. Two CRTs are mounted directly in front of both the pilot and copilot and display primary flight instruments and navigational information. The other two CRTs are located in the center of the instrument panel and display engine parameters, warnings, and system diagnostics.

The proposed type design of the A320 contains novel or unusual design features not envisioned by the applicable Part 25 airworthiness standards and therefore special conditions are considered necessary.

## **Discussion of Comments**

Notice of Proposed Special Conditions No. SC-87-5-NM for the Airbus Industrie Model A320 series airplanes was published in the Federal Register on October 19, 1987 (52 FR 38772).

Some of the comments received were of an editorial or clarifying nature and have been incorporated where appropriate. A discussion of the remainder of the comments follows, corresponding to the specific special condition as proposed in Notice No. SC-87-5-NM.

### *1. Electronic Flight Controls*

*Paragraph 1(a).* One Commenter expresses concern about the electrical power availability for the flight test instrumentation while the test is being conducted without the availability of normal electrical power sources. The FAA acknowledges these concerns. The test configuration must be tailored to the airplane and the electrical power demands for the flight instrumentation.

One commenter states that the compliance section should provide guidance on the test duration. The FAA agrees. The duration of the test demonstration after the loss of normal engine generated electrical power may be negotiated with the FAA on a case-by-case basis for test durations greater than 4 hours.

Another commenter proposes a clearer definition of normal and standby power. The FAA does not believe that the special condition wording should be changed but provides the following discussion for clarification for this commenter. Normal engine generated electrical power includes power supplied by the engine driven generators. Standby electrical power includes other means to generate electrical power on demand using, for example, Auxiliary Power Unit (APU) generators, Ram Air Turbine (RAT) driven generators, Hydraulic Motor Generators (HMG), etc. Batteries are time-limited emergency power sources.

One commander suggests the FAA retain §§ 25.1351(d) (1), (2), and (3) in conjunction with this special condition. The FAA disagrees because of the reference made to a time period of not less than five minutes. This is no longer relevant with modern aircraft designs.

One commoner suggests a clarification of the parenthetical sentence under the discussion. The FAA agrees and proposes "A reasonable assumption can be made that transport airplanes will not have to remain in IMC for more than 30 minutes after experiencing the loss of normal electrical power,"

Another commenter suggests that after 30 minutes in IMC, the airplane should be capable of continuous flight in VMC for a time sufficient to reach an alternate airport. The FAA disagrees because it is not feasible to so estimate what that time might be, in view of airline service on a world-wide basis and the variety of factors that affect routes and schedules. The FAA maintains that electrical power availability must parallel flight endurance.

One commenter requests further clarification about flight following loss of normal electrical power. The FAA requires, that after 30 minutes of operation in IMC, the airplane should be demonstrated to be capable of continuous safe flight and landing in VMC. The length of time in VMC conditions must be computed based on the maximum flight duration capability for which the airplane is being certified. Consideration for speed reductions from the associated failure must be made and supported by performance calculations and a failure analysis.

*Paragraph 1(b)(1)(i).* One commenter suggests the removal of the words "when the failure or malfunctions occur within the operational flight envelope." The FAA agrees that this requirement could be too severe in cases of extreme failure combinations and flight envelope conditions. The words "operational flight envelope" have therefore been removed from the special condition. However, to ensure that the intent of the special condition is maintained, the manufacturer must present a document for FAA approval which contains: failure cases based on a failure analysis of the systems that affect the flight control systems, details of the analysis which was conducted to support the flying qualities, a listing of flight configurations with simulated faults, an overall description of the test facilities, and methodology used to validate the aerodynamic models used in the simulation.

*Paragraph 1(b)(1)(i)(B).* One commenter requests clarification of the wording of this paragraph. The FAA has revised the special condition to require that the airplane must be able to withstand the transient loads induced by the failure multiplied by a safety factor. It is further noted that acceptable airplane loads are defined under Special Condition 2(c). The factor of safety varies from 1.0 to 1.5 depending on the probability of failure of the system.

*Paragraph 1(c).* One commenter requests this paragraph be changed to read: "In addition to compliance with § 25.671, it must be shown that Electronic Flight Control System (EFCS) signals cannot be altered unintentionally, or that the altered signal characteristics are such that \* \* " The FAA concurs as this properly reflects the system involved. The special condition is revised accordingly.

*Paragraph 1(c)(1).* One commenter proposes that the wording of this special condition be changed from "Stable gain and phase margins are maintained" to "no residual oscillations exist". The FAA does not concur. Stable gain and phase margins insure that the selected loop gains have been investigated for stability of the system throughout the flight envelope. Residual oscillation may occur as a result of wear, tolerance build-up in

mechanical systems, etc. or other causes that are not related to the system's stability

*Paragraph 1(d).* One commenter suggests that the requirement for powered control integrity of hydraulic powered systems be deleted because such designs are covered by existing regulations. The FAA disagrees. The A320 has a reduced number of power control actuators (PCAs) when compared to previously certified airplanes with hydraulic flight controls (i.e., 3 PCA's on other recently certified large transports vs. 2 on the A320). Equivalent redundancy is achieved on the A320 by using computers and associated sensors which enhance the ability to detect faults. The electronic control system is now an integral part of the electro-hydraulic actuation system which requires a stronger technical emphasis when finding compliance.

Another commenter requests paragraph 1(d) be revised to add the statement that, in addition to compliance with the requirements of § 25.671 of the FAR, the airplane control system must be designed to allow for continued safe flight and landing after any failure condition to the flight critical powered system which is not shown to be extremely improbable. The FAA concurs with this change, and the special condition is revised accordingly.

One commenter expresses concern about the lack of a back-up system for the Fly-by-Wire (FBW) flight controls, and recommends that an independent mechanical back-up system be required. The FAA does not concur with this commenter's premise that there is lack of experience with FBW flight controls and that with today's technology, FBW flight controls cannot be made to be as reliable as conventional mechanical systems. Fly-by-wire flight controls are currently operating successfully in service in military aircraft, on the space shuttle, and on commercial airplanes and helicopters for secondary flight controls such as flaps, slats, spoilers, yaw dampers, and brakes. Furthermore, the A320 design has mechanical controls for the rudder and for back-up stabilizer trim. These controls allow for pitch trim and directional control to the airplane, independent of the FBW flight controls.

One commenter expresses concern for the consequences of an electrical fire in the electronic bay, in view of the greatly increased reliance on electrical power in this airplane. The FAA notes this commenter's concerns; however, the existing regulations, together with these special conditions, are sufficient to address these concerns, including interruption of electrical, hydraulic, and pneumatic power supplies to the essential flight systems. This situation is addressed in the airplane by physical separation of the computers in the electronic bay and separation of the wire bundles. There is also a smoke detection system and specific procedures to be followed in case of smoke from the electronic bay.

## *2. Active Controls*

*Paragraph 2(a)(1)(ii).* One commenter requests a definition for "the prescribed value of the current requirement." The FAA concurs with this comment and that statement has been replaced with the following: "for an airplane of similar characteristics without an

active control system."

*Paragraph 2(a)(1)(iv).* Two commenters state that if there were nonlinearities in loads beyond limit load, there could be a change in the traditional ultimate load factor of 1.5. They further state that the proposed special condition did not define this factor. The FAA did not propose a factor to replace the current ultimate load factor of 1.5. The factor is dependent upon the nonlinear response of the system and would vary depending upon the system the FAA is approving. The FAA therefore does not believe that it is appropriate to define the load factor in the special condition.

*Paragraph 2(a)(2)(i).* Two comments were received. The first commenter believes that if there is a failure in the active control system with no compensating corrective action, the failure would not have to be detected prior to the next flight but would be detected within a time interval directly related to the probability of failure and the impact on structural capability. The second commenter believes that the flightcrew must be aware of any failure conditions which affect the structural capability of the airplane, whether or not a compensating procedure exists. The FAA does not concur with either comment. It is not necessary for the flightcrew to be aware of a failure in the active control system during the flight on which the failure occurs if there is no available corrective action; however, the airplane should not be exposed to the failure condition for an extended period of time. The flightcrew must therefore be alerted to the failure condition prior to the next flight. The second commenter also states that the words "operational limitations" in the first sentence should be replaced with the words "flight limitations." Flight limitations refers to a limitation imposed upon the airplane after an inflight failure and is the correct term. The FAA concurs, and the special condition is revised accordingly.

*Paragraph 2(a)(2)(ii).* One commander discussed what was necessary to document compliance with the rule. The FAA agrees with the requirements the commenter discussed but it concerns the method of compliance and is outside the scope of the notice.

*Paragraph 2(a)(2)(ii)(A)(1).* One commenter believes that it is necessary to conduct a damage tolerance evaluation for compliance with § 25.571(b) to require limit loads be multiplied by a factor of 1.5. The commenter misunderstood this paragraph, and the FAA has revised this paragraph to state that the damage tolerance evaluation must be accomplished based upon the limit loads.

*Paragraph 2(a)(2)(ii)(B)(1)(i).* Two commenters state that in the figure the safety factor should be 1.5 for probability of failure equal to or less than  $10^{-3}$  to agree with the text. FAA concurs and the final special condition is revised to correct this error.

*Paragraph 2(a)(2)(ii)(B)(1)(ii).* One commenter objects to the statement, "\* \* \* the residual strength level must be at least 1g flight loads combined with 2/3 of the gust or maneuver conditions specified in FAR 25.571(b)." The commenter states that this requirement is more stringent than the criteria in Advisory Circular (AC) 25.672-1. The FAA concurs that combining 1g flight loads with 2/3 of the gust or maneuver conditions of § 25.571(b) can be more severe. The special condition is therefore revised to reflect



the criteria in AC 25.672-1.

*Paragraph 2(a)(2)(ii)(B)(2).* Three comments were received. The first commenter states that the minimum floor of  $1.15V_c$  for the flutter margin between  $V_c$  and  $V_D$  may penalize the use of a speed limiting system. The FAA agrees that this may be true in some cases; however, this special condition is necessary because the speed limiting may result in a margin between  $V_c$  and  $V_D$  that is too small to be used as an analytical fail-safe margin for flutter clearance. The analytical margin is provided because it is not possible to substantiate flutter speeds more accurately than 15 percent for fail-safe conditions. The margin is not directly related to the probability that the airplane may fly 15 percent faster; consequently, it is not proper to establish the minimum analytical margin based solely on the dive speed definition for this airplane.

The same commenter requests that the last sentence of this special condition be clarified or removed since it implies that  $V_D$  can become a variable as a function of the type of failure. The FAA disagrees. This sentence applies to types of failures that may not only affect flutter but also affect the performance of the speed limiting system. In these cases the value of  $V_D$  as used for flutter clearance must be the value of  $V_D$  that would be defined for the airplane with the speed limiting system operating at the reduced effectiveness. This should not be confused with "the"  $V_D$ , it is only the  $V_D$  that would be used as the fail-safe flutter clearance speed for analytical flutter substantiation.

Another commenter supports the 1.15 minimum floor, but believes that the transition between  $M_c + .05$  and  $1.15 V_c$  is not adequately addressed. Although the FAA did not provide a specific transition boundary, the transition is addressed in an equivalent manner. The special condition contains the statement "the fail-safe flutter speed at any altitude need not exceed the value of  $V_D$  that would result from compliance with § 25.335(b) without a high speed protection system." This statement was provided as a convenient method of establishing the transition boundary for an airplane that is relatively conventional without the speed protection system.

*Paragraph 2(b)(1).* One commenter states that realistic gust fields for the purpose of design and certification have not been defined. The commenter further states that existing gust criteria used with yaw dampers for load alleviation have provided adequate levels of safety. The FAA has not defined a gust field as part of the special condition; however, it is incumbent upon the applicant to propose and justify a gust field for FAA approval prior to certification.

*Paragraph 2(b)(2).* Two comments were received. One commenter states that realistic conditions of severe turbulence are not defined. The FAA did not define severe turbulence in the notice as the applicant is expected to propose and justify a level of severe turbulence for FAA approval. Both commenters object to the requirement to consider combinations of maneuvers and gusts. The FAA disagrees with these commenters. The load alleviation system must be evaluated for adequate power supply and control authority with combinations of maneuvers and gusts to assure that the system will perform its intended function.

*Paragraph 2(b)(4).* Two commenters believe that paragraph 2(b)(4) should be deleted. The first commenter states that monitoring this flight critical system is an inappropriate type certification requirement and that a system failure analysis must be performed to substantiate acceptable failure probabilities. This commenter also states that periodic data collection which may be required will be instituted through the FAA Maintenance Review Board. The second commenter states that in-service monitoring and implementation of corrective actions is standard procedure and covered by § 25.1529. The FAA does not agree with these commenters. Since the airplane design criteria for load levels are dependent on the reliability of the active controls, the probability of loss of system function must be evaluated in a realistic or conservative manner before certification. If the system proves less reliable in service than assessed for certification, adjustments in maintenance schedules, load levels, and/or operating limitations may be required. This necessitates monitoring of the systems for a sufficient period of time to substantiate an adequate level of reliability. Neither the FAA Maintenance Review Board nor the instructions for continued airworthiness contained in § 25.1529 contain requirements for reporting failures of components in an aircraft system. The monitoring equipment is necessary to assure an adequate safety record for this flight crucial system.

*Paragraphs 2(b)(5)(i) through (iv).* One commenter states that these paragraphs contain advisory material which should be removed from the special condition and handled as an Issue Paper. The FAA disagrees. These paragraphs are necessary to define an acceptable level of safety, and compliance is required for FAA certification.

A second commenter states that the requirements of paragraphs 2(b)(5) (i) and (iii) go beyond previous experience by requiring a flight test with extensive instrumentation and long flights in search of "adequate" turbulence. The FAA disagrees with this comment and expects the flight testing to demonstrate that the active control system does, in fact, provide the anticipated load relief. This can be accomplished by verifying loads achieved in flight with the loads from analysis.

A third commenter states that paragraph 2(b)(5)(iv) should be changed from "An investigation\* \* \*," to "An analytical or test evaluation \* \* \* " The commenter believes this paragraph requires testing of the active control system after structural damage. The FAA concurs. Testing is not the only way to achieve compliance with paragraph 2(b)(5)(iv), but the proposed change does provide additional clarification; therefore, the final special condition is revised accordingly.

*Paragraph 2(b)(5)(iv)5.* One commenter states that the reference for the definition of failure condition should be changed from Advisory Circular (AC) 25.1309-1 to AC 25.672-1. The FAA does not concur. The special condition was written based on the accepted definition provided in AC 25.1309-1.

### *3. Engine Controls and Monitoring*

*Paragraph 3(a).* One commenter suggests that the words "loss of thrust control" used in

the discussion portion of this special condition imply that the intent was to limit the reliability evaluation to only those control failures which would prevent continued safe flight and landing of the airplane. This commenter therefore recommends that the control failures in question be limited to only those associated with loss of more than 50 percent thrust. Another commenter contends that the reliability criteria should apply only to those failures which would prevent continued safe flight and landing of the airplane. The FAA does not agree. The flightcrew's inability to control thrust to the desired level would likely result in an in-flight shutdown (IFSD) and, for a twin-engine airplane such as the A320 an emergency being declared and subsequent diversion on a single engine. The intent of this special condition is to ensure that the probability of either single engine events or a multiple engine event is no more likely on a FADEC-equipped propulsion system than on current hydro-mechanical controlled engines certified to current standards.

One commenter suggests that the special condition for FADEC reliability is not necessary since compliance with the "single failures" requirements of § 25.901(c) and the "isolation" requirements of § 25.903(b) provides the same degree of safety as current propulsion systems. This commenter believes that requiring a level of reliability for one propulsion subsystem is not necessary or appropriate. The FAA does not agree. It is true that the "failsafe" and "isolation" requirements of Part 25 provide a degree of safety essential for transport category twin engine aircraft, regardless of the engine control type. This safety experience has been accumulated, however, on the vast majority of turbine engines incorporating hydro-mechanical control systems. The intent of this special condition is to clearly identify an expected level of reliability for an engine subsystem employing a technology which has not yet accumulated a large amount of service experience as an engine control. This special condition is in addition to the requirements of § 25.901(c) for a control system failing safely, and § 25.903(b) for isolation.

*Paragraph 3(b).* One commenter recommends that the thrust levers should move corresponding to autothrust commands. This commenter believes that the proposed wording "provide adequate cues for the flightcrew to monitor thrust changes during normal operation \* \* \* " is too subjective. The FAA agrees that the original proposal could more clearly state the objective of this requirement and has therefore reworded it to emphasize the adequacy of the cues needed to monitor the system. The FAA does, not agree, however, that the thrust levers would necessarily have to move during autothrust operation, provided the same (or greater) degree of information feedback regarding thrust command is being provided to the crew. It is the intent of this special condition to require a satisfactory degree of monitoring capability to be incorporated in the design in order to compensate for the lack of thrust lever motion during autothrust operation.

Two commenters suggest the addition of a new paragraph 3(b)(5) highlighting the need to consider critical flight phases such as takeoff, approach, and landing. One of these commenters recommends that the ATS system should provide thrust lever motion at flight phases below 1500 feet above ground level (AGL) because this is where current autothrottle systems are most effective and important in providing "tac" feedback to the pilot through movement of the thrust levers. The FAA agrees that takeoff, approach, and

landing are especially important flight phases to be considered in assessing the effectiveness of the ATS command cues, as well as the ease and effectiveness of the disconnect. The FAA does not agree, however, that this may only be accomplished by means of physically moving the thrust levers. The special condition has been reworded to make it more clear as to the objectives of monitoring and override capability, and a new paragraph (5) has been added to address takeoff, approach, and landing.

*Paragraph 3(c).* One commenter acknowledges that the "black cockpit" concept is preferred, whereby items are not displayed unless they are required. This same commenter considers, however, that engine instruments are important enough to be continuously displayed. The FAA agrees that propulsion instruments, because of their role in communicating to the crew needed information relating to the engine's condition, are of vital importance. This is especially true since, for some engine conditions, rapid crew response is necessary in order to avoid engine failure. The FAA does not agree, however, that this can only be achieved by the permanent display of all engine parameters. The special condition has been reworded to more clearly state the objectives necessary for inhibited and shared propulsion displays for the A320.

Another commenter recommends that the loss of all propulsion system displays be shown to be extremely improbable. The FAA agrees, and paragraph 3(c) now contains the "extremely improbable" objectives for those failure conditions which would provide hazardously misleading information, rather than limit the requirement to only loss of all propulsion system displays."

#### *4. Protection from Lightning and Unwanted Effects of Radio Frequency (RF) Energy*

*RF Comments.* One commenter notes that the RF threat only addresses the critical functions, and that the essential functions were omitted from consideration. The FAA believes that not specifying RF protection levels for the essential and nonessential functions is reasonable, since a failure of this category will not result in critical maneuvers or cause loss of control. It is noted that the FAA specifies minimum requirements; the manufacturer is well advised to consider additional requirements to protect his designs from RF interference for the essential and nonessential functions.

Several commenters express concern regarding the severity of the requirements that critical systems must not be affected when exposed to electromagnetic radiation. The intent of the special condition is to ensure that systems performing critical functions are not adversely affected by RF. The word "adversely" is not used in this special condition because it is a difficult word to define quantitatively. The determination of whether a critical system is adversely affected must be made on a case-by-case basis. An example of an acceptable condition would be a case where a computer input is perturbed by RF spurious signals, but the output signal remains within the design tolerances with the result that the system affected is able to continue in its selected mode of operation unaffected by the perturbation. It is not permissible that exposure to electromagnetic radiation could result in a large system upset. Pilot intervention to restore the system following an upset is not an acceptable means to restore that system to its normal state of operation.

One commenter expresses concern that no consideration was made to account for RF attenuation by the aluminum airframe. The FAA has proposed two methods to simulate the RF threat. One is based on 200 volts per meter average field strength from 10KHz to 20 GHz, applied without fuselage shielding, and the other method is to apply average and peak voltages in nine specified frequency ranges, taking into account the effects of fuselage shielding.

One commenter expresses the need for an international agreement for the control and location of large output RF emitters. The FAA has no disagreement with this comment, but it is beyond the scope of this action.

One commenter believes the threat cannot be precisely defined and proposes that an interim requirement of 100 volts per meter, applicable to Electronic Engine Control (EEC) and its wiring, exclusive of airframe shielding, be used until more formal standards can be developed. Another commenter proposed to accept the RTCA-DO-160B test procedures and field strength levels to validate the Electronic Flight Control System (EFCS). A third commenter suggests that 100 volts per meter be used when applied directly at the system level, without the benefit of airframe shielding. Based on the Electromagnetic Compatibility Analysis Center (ECAC) study referenced in the notice and the high degree of integration of the electronic systems on this aircraft, the FAA has determined that the 200 volts per meter standard is necessary.

One commenter notes that the U.S. model representing peak and average values of electromagnetic threat is more severe than the equivalent European model and requests considerations for re-examination of the threat presented in this special condition. The FAA, in defining the external envelope, considered the information provided by a variety of organizations regarding strength and characteristics of RF emissions, including the ECAC group. So far the information obtained from these groups has not indicated a need to change the U.S. threat model.

Another commenter proposes to differentiate between the source of the threat defining a likely RF encounter, including airports and enroute flights, as opposed to hypothetical RF encounters which involve powerful emitters outside the normal airway traffic patterns of civil transport airplanes. The FAA has elected to define the most severe threat as a design requirement which includes all potential encounters, in view of the impracticality of imposing a complex set of operational restrictions. Only those system that have been determined to perform flight critical functions need to be hardened to this level of electromagnetic threat.

The same commenter discusses a means of showing compliance when it can be demonstrated that a safe flight and landing can be achieved, and when the threat exceeds the normal RF environment. The effects of the threat would be evaluated in terms of mode changes and recoverable interrupts, which affect one or several of the subsystems. The FAA disagrees. Such an approach would make the determination of compliance highly subjective and difficult to evaluate: Furthermore, the precise behavior of systems

which are affected by RF levels equal to those specified in the special condition is not predictable in the actual operating environment. The FAA has adopted a different approach, specifying that critical systems must not be affected when exposed to levels of electromagnetic radiation specified by this special condition. RF exposure at these levels should not cause a system upset involving reconfiguration of the control laws or system capability degradation.

Another commenter notes that the external threat model has average and peak levels of 100 volts per meter at two frequency ranges. The alternate model requires 200 volts per meter over all frequencies. The commenter requests that the alternate model be adjusted downward to 100 volts per meter over the entire frequency range. The FAA disagrees and will require 200 volts per meter over the frequency range of 10 KHz to 20 GHz. Furthermore, the tests must be conducted with either the external or internal threat model over the total frequency range.

Another commenter states that the field effects of RF emitters which are located within existing prohibited areas should not be considered and thus removed from the field strength data in the external threat model. The FAA disagrees because RF emitters can be turned on at any time, emitting various field strengths and signal characteristics. It is noted that a number of emitters are installed onboard naval vessels and are free to move.

### **Lightning Protection Comment**

One commenter expresses concern regarding the special condition requirement that critical systems must not be affected when exposed to lightning. It is argued that a minor upset that it is not perceptible to the flightcrew and which returns to normal operation after the upset is an "effect" and thus would not meet the requirement. The intent of the special condition is to ensure that systems performing critical functions not be adversely affected by lightning. The word "adversely" is not used in the special condition because it is a difficult word to define explicitly. The determination of whether a critical system is adversely affected must be made on a case-by-case basis. An example of an acceptable condition would be a case where a computer input is perturbed by lightning spurious signals, but the output signal remains within the design tolerances and is able to continue in its selected mode of operation unaffected by the perturbation. It is not permissible that a lightning strike could result in a major system upset, even though the effect would not prevent continued safe flight and landing.

One commenter proposes new wording to distinguish between lightning effects that would prevent the system from functioning and those systems that would continue with reduced capability. The FAA has considered this approach but adopted a distinction which recognizes systems that perform critical functions and essential functions.

Another commenter believes that the requirements specifying the acceptable level of lightning strike effect on the affected systems are vague. The FAA has revised the wording and specifies that systems which perform critical functions must be designed so that they are not affected. Essential systems are allowed to recover automatically or by

pilot action.

## 5. *Flight Characteristics*

*Paragraph 5(a).* One commenter questions the need for a handling qualities rating system special condition and proposes the subject be addressed through an issue paper. Another commenter believes the proposed special condition lacks detail as to how the handling qualities ratings are to be used, specifically under what test conditions the airplane handling qualities must be satisfactory, adequate, or controllable. The FAA disagrees. The special condition should contain only the basic requirements for a handling qualities rating system. The detailed information, as it applies to the A320, is contained in an Issue Paper. The A320 will be the first airplane in which the FAA will use a systematic handling qualities rating system approach for flight control system failure states, and it is believed that a detailed special condition would not allow latitude in the application of the requirements.

*Paragraph 5(b).* One commenter recommends that the wording "suitable handling qualities" be changed to "satisfactory" handling qualities, degrading to "adequate;" and then degrading to "controllable" handling qualities. The FAA disagrees. The effect of the special condition requiring "suitable dynamic and static longitudinal stability" is essentially the same as the commenter's proposal. Although the proposed special condition for a handling qualities rating (5(a)) is specifically for flight control system failure states, the ratings of satisfactory, adequate, and controllable, and their definitions, are applicable for all handling qualities tasks.

*Paragraph 5(c).* One commenter suggests that the rudder pedal force limit for sideslip be limited to 150 pounds, rather than 180 pounds. This commenter points out that this change was proposed during the promulgation of Amendment 25-42, effective March 1, 1978. Under Amendment 25-42, the rudder pedal force limit was changed from 180 pounds to 150 pounds for air minimum control speed under § 25.149, but was not changed for static lateral-directional requirements under § 25.177. The FAA does not agree with this commenter. Special conditions are developed for novel or unique features for which the present regulations do not provide adequate standards. The A320 design is not novel or unique in regard to the rudder system; therefore, the present regulations are applicable.

*Paragraph 5(d).* One commenter suggests that the wording of this special condition be changed to require flight control position annunciation "unless it can be shown that no flight condition exists in which near-full surface authority (not crew commanded) is being utilized for prolonged periods." The FAA does not agree. The intent of this special condition is to require control surface position annunciation for any unforeseen flight condition or configuration, as well as those flight conditions which can be analyzed. The FAA questions whether every possible flight condition or configuration can be analyzed; and, due to the lack of surface deflection feedback to the sidestick controller, flightcrews must be immediately aware of control surface saturation that is not crew commanded so that appropriate action may be taken.

Another commenter suggests replacing the words "near full surface authority" with "near-maximum achievable deflection." This commenter points out that actuators are rarely sized to provide full deflection at all possible operating conditions. While the commenter's suggestion is valid and control surfaces are subject to blow down, etc., the design of a control surface annunciation which would account for all "achievable deflections" would be extremely complex and would not add significantly to the intent of the special condition. The special condition has been revised to require annunciation when a flight condition exists where, without being commanded by the crew, control surfaces are coming so close to their limits that return to the normal flight envelope or continuation of safe flight requires a specific crew action.

The same commenter suggests adding a paragraph 5(e) to require that saturation of the flight control surfaces will not occur so frequently as to significantly degrade the proper functioning of the system. The FAA disagrees. Special Condition 1(b), Electronic Flight Control System (EFCS) Failure and Mode Annunciation, adequately addresses control surface saturation and a specific flight special condition is not required. This commenter also suggests adding a Paragraph 5(f) to deal with handling qualities transients when flight control system mode changes occur. The FAA disagrees. Special Conditions 1(b) and 6(a) are adequate to deal with handling qualities requirements for flight control mode system changes.

## *6. Flight Envelope Protection*

*Paragraph 6(a)(2).* One commenter recommends requiring provisions by which the limit protection can be overridden. According to this commenter, studies show that pilots want to be able to override the limit protection. This commenter does not give specifics regarding which parameters are considered most important. This comment is addressed to the "failure state" portion of this special condition (general limiting requirements) and may be offered in belief that the FAA requirement (against undue parameter limiting) will not be successfully implemented or complied with. The selected limit values (NZ, AOA, pitch, roll, high speed) for the NORMAL control state are broad enough to satisfy safe and controllable maneuvering. For failure states, this special condition, as well as the handling qualities rating method of Special Condition 5(a), are available to determine suitable safe characteristics. It should also be noted that in the A320 design, limit protections are dropped for certain failure states. It may also be helpful to note that if abnormal altitudes are unexpectedly encountered, Special Condition 6(a)(3) also requires recovery capability.

*Paragraph 6(b).* Several commenters request the traditional use of  $V_{MIN}$ , be retained as an alternate means of  $V_S$ , definition. The FAA disagrees. These special conditions address design features which are such that traditional  $V_{MIN}$  testing would not be an acceptable alternate to  $V_{S1-g}$ .

*Paragraph 6(b)(1)(i).* One commenter requests that a delta symbol be inserted before "F<sub>G</sub>" in the equation, and that a note be added to indicate that the delta F<sub>G</sub> is the



increment in gross thrust required to reduce the net thrust to zero. The commenter cites the § 25.103(a)(1) reference to zero (net) thrust at the stalling speed as the justification for this change. The following two FAA comments should aid understanding as to why the equation was provided, and why it still remains valid for this part of the special condition.

First, the equation, as presented in the special condition, is a correct expression of the aerodynamic lift capability of the airplane. In fact, if the 1-g stall speed is to be defined as speed at  $C_{LMAX}$ , divided by  $\sqrt{N_{ZW}}$ , then alternate  $C_L$  expressions would suffice to determine the speed at which  $C_{LMAX}$  occurred as long as ignoring, modifying, or retaining the thrust term only shifted the level of  $C_{LMAX}$ , and not the speed at which it occurred. The exact expression of the  $C_L$  equation only becomes a concern for those who wish to reconstruct the requested 1-g stall speed ( $V/\sqrt{N_{ZW}}$ ) from exactly such an equation. Once the speed at  $C_{LMAX}$  has been noted and corrected for the load factor, it can be retrieved from an intermediate expression, which might assume  $N_{zw} = 1.0$  and only involve GW (or Mach) as the primary independent variable.

Secondly, Special Condition e(b)(2)(iii) allows IDLE thrust, not exclusively zero net thrust, as required by § 25.103(a)(1), to be used in the determination of stalling speed.

A second commenter notes that " $F_G$ " and " $iF_G$ ," are undefined terms in the  $C_L$  equation of Paragraph 6(b)(1)(i). The FAA assumes that these terms are commonly used symbology. For clarification, " $F_G$ " means gross thrust and " $iF_G$ " means incidence of the gross thrust relative to the airplane fuselage reference line. AOA (angle of attack) is also measured relative to the fuselage reference line.

Several commenters note that the new  $V_{S1}$  usage has not been uniformly applied throughout all Part 25 subparts. As configured for operation, the A320 is prevented from stalling by the incorporation of an angle-of-attack limiting feature. This feature would then not allow demonstration of the stall speeds used for structural design. During development flight testing, Airbus deactivated the stall protection feature and demonstrated compliance with the existing rules as currently interpreted both in the clean and flaps down configurations. Therefore, the special condition was not proposed for Subparts C&D.

*Paragraph 6(b)(2).* Table B.2. One commenter strongly disagrees with the 25 degree bank limit before ALPHA floor operation at  $V_2$ , because the operation of ALPHA floor in either all engines operating or engine-out cases is beneficial to safety. The commenter suggests a 20 degree bank limit as being a much more appropriate value, and that if the FAA requirement prevails, the ALPHA floor feature might be deleted which would be detrimental to safety. The FAA does not agree that requesting a 25 degree bank capability (free of ALPHA floor) at  $V_2$ , takeoff condition is unreasonable. Neither does the FAA look at removal of this feature as the only answer to achieving a 25 degree bank capability, since a deficiency (if one were to exist at all) can be made up by a slight  $V_{2MIN}$  increase. The 25 degree  $V_2$  bank requirement is reasonably consistent with the 40 degree bank objectives for landing, and on all-engine takeoff climb capability at  $V_2 + 10$  to 15.

Specifically, the theoretical (zero thrust) ALPHA floor settings for a landing condition ( $V_{REF} = 1.23 V_{S1-g}$ ) and a takeoff condition ( $V_{2MIN} = 1.13 V_{S1-g}$ ) for 40 degree and 25 degree bank, respectively, would be about  $1.077 V_{S1-g}$  and  $1.076 V_{S1-g}$ . If a 20 degree bank were allowed, the takeoff relationship would be mismatched at  $1.096 V_{S1-g}$ .

Another way of looking at the lower 20 degree recommendation is that in straight flight  $V_{MIN}$  engine-inoperative climb, only about 4 + kts margin would exist for airspeed variation before automatic thrust increase at ALPHA floor during a FLEX (reduced thrust) takeoff. This could easily be eroded in gusty conditions. The 25-degree requirement strikes an appropriate balance between non-nuisance operation and compatibility with other operating speeds. The French DGAC A320 requirement was also published as 25 degrees at  $V_{2MIN}$

One commenter notes Table B.2 has an undefined term. "WAT." The term "WAT" (Weight-Altitude-Temperature) is thought to be uniformly understood as the collective independent term for establishing a climb-limited takeoff. The term "WAT" will be defined as such in future regulatory and advisory documents.

One commenter recommends that the Table B.2 enroute maneuvering bank angle in the enroute configuration at final takeoff speed be reduced from 40 degrees to 30 degrees. The reason offered is that the speed in question represents a short duration condition for the airplane, in its acceleration to the enroute speed (engine-inoperative) and that 30 degrees bank compatible with  $V_2$ , has been demonstrated for many years. Since 1981, the FAA has sought to ensure adequate maneuverability at operating speeds by confirming the Table B.2 bank angles. For final climb, the target has been 40 degrees, not 30 degrees. When performance speed factors on stall speed were reformulated because of the 1-g basis, instead of minimum speed in the stall, all factors were reduced by about .94, except for the  $V_{FTO}$  factor which was reduced slightly less. For compatibility with the 40 degree bank objective at  $V_{REF}$ , ( $1.23 V_{S1-g}$ ), the  $V_{FTO}$  factor was reduced from 1.25 to 1.23. A full .94 reformatting for  $V_{FTO}$  would reduce the factor to 1.18. With a  $V_{2MIN}$ , factor of 1.13, second segment and final climb would not share a compatible 30 degree capability. Optimum  $V_{FTO}$  or enroute climb speeds are normally well in excess of  $1.18 V_{S1-g}$ , even for gear down dispatch. By authorizing an excessively low  $V_{FTO}$  (and consequent bank capability), the FAA would be widening the speed gap between AFM performance for final and enroute climbs. Also, for gear down dispatch, normally there is no restriction against flight into icing conditions. Since icing effects are normally not flight tested to confirm predictions for effects on gear down L/D, it does not seem warranted to reduce the  $V_{FTO}$  to such a minimum condition of 30 degrees/ $1.18 V_{S1-g}$ . Finally, because of buffet characteristics, the .94 relational factor between  $V_{S1-g}$ , and  $V_{MIN}$  does not generally prevail for flaps up, as it does for flaps down. For these reasons, the FAA has determined that the proposed bank/speed factor values for the A320, flaps up, are still appropriate.

*Paragraph 6(b)(2)(viii).* One commenter requests the  $V_{FTO}$  factor on  $V_{S1-g}$  be reduced from 1.23 to 1.18. The FAA has responded to this comment in conjunction with the bank objective of Table B.2.

*Paragraph 6(b)(2)(xi).* Two commenters request deletion of this requirement, suggesting that § 25.143 of the FAR and AC 25-7, Flight Test Guide, already cover the operational assessment adequately. The FAA disagrees that § 25.143 and AC 25-7 provide adequate regulatory coverage, in view of the fact that this airplane incorporates significant EFCS mode changes and a limiter between approach AOA and AOA for  $C_{LMAX}$ . While definitive quantitative requirements, such as for path angle/delta speed, have not been promulgated, a reasonable assessment can be made in this critical area. The joint European Authorities have published a somewhat similar special condition which deals with the effects of atmospheric disturbance on low, speed flying qualities.

*Paragraph 6(b)(2)(xii).* One commenter recommends changing 40% to 30% in the reformulation of § 25.145(b)(1). This is a valid comment and the change has been accomplished for compatibility with other special condition changes.

Two commenters recommend changing  $V_{MIN}$ , to  $V_{sw}$  in §§ 25.145(b)(6), 25.175(c), and 25.175(d). One commenter believes a typographical error was made in the notice, and the other commenter believes  $V_{sw}$  is needed for consistency with the 1-g stall speed reformulations. The FAA disagrees with both commenters. The published requirements, using  $V_{MIN}$  as the end point, are correct. The A320, in the normal EFCS state, has no artificial stall warning and probably will not have natural stall warning at the equivalent speed. The term  $V_{MIN}$ , relates to steady state minimum speed on the AOA limiter, is a higher speed than the  $V_{MIN}$ , which would be measured in a full stall, and reasonably correlates with previous requirements.

*Paragraph 6(b)(2)(xiv).* Two commenters provide similar objections to the power-off, straight ahead 5KTS/ 5% stall-free margin requirement. These commenters state that 2KTS/2% is historically equivalent to the FAR, when reformatted to the 1-g basis. For turning flight stalls, the commenters object to the term "stall-free characteristics" as being undefined, and would essentially substitute a qualitative or non-hazardous finding for safe flight, once recovery is initiated one second after warning onset. The FAA disagrees. The stall warning requirements are intended for failure states, of which there could be many, including non-standard, aerodynamic and EFCS configurations. Forward c.g. stalling speeds are not usually developed for these variations, which could present difficulties in basing warning margins solely on the "normal" 1-g stall speed. If warning margins were based upon 1-g stall speeds, the commenter's suggested 2KTS/2% margins would be inadequate for a normal state airplane, as well as for a failure state airplane. This is because realistic margin to useable lift, not just equivalent margin to stall end point, as derived from current minimum speed rules, must be considered. As to the argument that "stall-free characteristics" is an undefined term, if stall characteristics have been defined and evaluated for years, then absence of those same characteristics should not suddenly present a definition problem.

## *7. Side Stick Controllers*

*Paragraph 7(b).* One commenter suggests that this special condition requires that the side

sticks be connected because of delays which unconnected side stick controllers can cause. Another commenter recommends the wording be changed to require that the pilots are aware of their own inputs, as well as the other pilot's inputs, at all times. This commenter believes confusion exists if one pilot is not aware of the other pilot's inputs. A third commenter suggests the wording be changed to require overriding control inputs by either pilot with no unsafe characteristics during time critical control phases: e.g., landing flare and evasive maneuvers. All of the commenters are concerned about the lack of side stick controller interconnection, especially during critical phases of flight. The FAA is aware of concerns about the lack of feedback or coupling in the A320 side stick controller design. Studies and research conducted by several organizations have shown that although some form of controller coupling is highly desirable, the lack of coupling is not, in itself, an unsafe design. The special condition does not contain a firm requirement for side stick controller coupling, but it does require that the side stick controller design of the A320 be adequately evaluated.

#### *8. Flight Data Recorder*

One commenter states that since the rudders on the A320 are conventional in design, it should therefore suffice to record either the pedal position or the surface position. The FAA notes that inputs from the pilots, as well as command signals from the different computers to the rudder trim, rudder travel limitation, yaw damper and autopilot servo loops are also imputed to the rudder servos. For this reason, the FAA requires that the pilot inputs and the surface position be recorded

Another commenter questions the need for additional parameters to record electrical inputs to control surfaces and engine commands in addition to the surface movements. The A320 is a flight-through-computer airplane. For that reason, there is no longer a linear relationship between pilot input and output of the computer to the surface servo actuators. It is therefore necessary to record the output of the sidestick, rudder pedals, throttles, and flap handles, as well as the surface positions, in order to reconstruct the pilot inputs and surface response.

One commenter requested prior to the expiration of the comment period, an extension in order to provide an in depth analysis of what was considered necessary for an adequate analysis of system failures in case of an accident. This commenter states that their organization participated as observers in the investigation of the fatal accident of an A320 airplane in France. As a result of the insight into the uniqueness of the control systems of this airplane gained through analysis and augmented by the above accident participation, they request a number of additional parameters and changes in sampling rates. This commenter also states that Version 2 of the DFDR (design) characteristics comes closest to their requirements. The FAA recognizes that major change requests submitted late in a type certification process can cause undue hardship on a manufacturer and is therefore very reluctant to agree to additions or changes. However, it is also considered that this situation is unique in that an accident was investigated prior to issuance of the U.S. type certificate, and a need for changes appears to be justified. Furthermore, Version 2 of the DFDR parameter is required by another airworthiness authority and thus already an

available design. This commenter requests that Version 2 be modified to change certain sampling rates and to add others. Incorporation of those comments would utilize all of the remaining storage capacity of the DFDR system in an appropriate sampling mix of parameters which, in the view of the FAA, would enhance data retrieval for the purposes of aviation safety. Accordingly, this special condition has been revised, with the manufacturer's concurrence, to include all of the above requested parameters, except for auto-brake setting and brake pressure (left and right alternating).

Under standard practice, the effective date of these final special conditions would be 30 days after publication in the **Federal Register**. As the intended U.S. type certification date for the Airbus A320 is approximately December 15, 1988, the FAA finds that good cause exists to make these special conditions effective upon issuance.

Except as discussed above, the special conditions for the A320 are adopted as proposed.

### **Conclusion**

This action affects only certain novel or unusual design features on one model series of airplanes. It is not a rule of general applicability, and affects only the manufacturer who applied to the FAA for approval of these features on the airplane.

### **List of Subjects in 14 CFR Parts 21 and 25.**

Air transportation, Aircraft, Aviation safety, Safety.

### **▼ Final Special Conditions Information**

#### **The Special Conditions**

Accordingly, the following special conditions are issued as part of the type certification basis for the Airbus Industrie Model A320 series airplane.

#### **PARTS 21 AND 25 - (AMENDED)**

The authority citation for these special conditions is as follows:

Authority: 49 U.S.C. 1344, 1348(c), 1352, 1354(a), 1355, 1421 through 1431, 1502, 1651(b)(2), 42 U.S.C. 1857f-10, 4321 et. seq.; E.O. 11514; 49 U.S.C. 106(g) (Revised Pub. L. 97-449, January 12, 1983).

##### *1. Electronic Flight Controls.*

(a) *Operation Without Normal Electrical Power.* In lieu of compliance with § 25.1351(d) of the FAR, it must be demonstrated by test or combination of test and analysis that the airplane can continue safe flight and landing with inoperative normal engine generated electrical power (electrical power sources excluding the battery and any other standby

electrical sources), The airplane operation should be considered at the critical phase of flight and include the ability to restart the engines.

*Discussion:* This special condition requires that the emergency electrical power system be designed to supply: (1) Electrical power required for immediate safety, which must continue to operate without the need for crew action following the loss of the normal electrical power system: (2) electrical power required to continued safe flight and landing: and (3) electrical power required to restart the engines. For compliance purposes, a test demonstration of the loss of normal engine generated power is to be established such that:

1. The failure condition should be assumed to occur during night instrument meteorological conditions (IMC) at the most critical phase of flight relative to the electrical power system design and distribution of equipment loads on the system.
2. After the unrestorable loss of the source of normal electrical power, it must be possible to restart the engines and continue operations in IMC until visual meteorological conditions (VMC) can be reached. (A reasonable assumption can be made that turbojet transport airplanes are able to enter into VMC conditions 30 minutes after experiencing the failure.)
3. After 30 minutes of operation in IMC, the airplane must be demonstrated to be capable of continuous safe flight and landing in VMC conditions. The length of time in VMC conditions must be computed based on the maximum flight duration capability for which the airplane is being certified. Consideration for speed reductions resulting from the associated failure must be made.

*(b) Electronic Flight Control System (EFCS) Failure and Mode Annunciation.*

(1) In lieu of compliance with § 25.672(c) of the FAR it must be shown that after any single failure or combination of failures of the flight control system that are not shown to be extremely improbable -

(i) The airplane has the following characteristics:

(A) Suitable handling qualities:

(B) The airplane is able to withstand the transient loads induced by the failure multiplied by a safety factor.

(C) VD/MD is not exceeded.

(ii) The airplane has suitable handling qualities for continued safe flight and landing.

(2) In addition to compliance with § 25.672 of the FAR -

(i) If the design of the electronic flight control system or any other automatic or power-operated system has submodes of operation that significantly change or degrade the flight or operating characteristics of the airplane, a means must be provided to indicate to the crew the current submode of operation. Crew procedures must be available to ensure safe and proper operation for the annunciated flight control submode; and

(ii) The total loss of the electronically signaled flight control system (including its electrical or hydraulic power supplies), must be designed to be extremely improbable if its loss would prevent continued safe flight and landing.

*Discussion:* Suitable handling qualities, for the purpose of Special Condition 1(b)(1) above, are those determined from compliance with Special Condition 5a, *Flight Characteristic Compliance Determination by Handling Qualities Rating System for EFCS Failure Cases*. Note that Special Condition 5a is also in lieu of § 25.672(c). The safety factor for the purpose of Special Condition 1(b)(1) above is determined from compliance with Special Condition 2(ii)(B)(1)(i), *Effect of Electronic Flight Control System on Structure*. The safety factor is a function of the system's probability of failure.

(c) *Command Signal Integrity:* In addition to compliance with § 25.671 of the FAR, it must be shown that Electronic Flight Control System (EFCS) signals cannot be altered unintentionally, or that the altered signal characteristics are such that:

(1) Stable gain and phase margins are maintained for all aerodynamically closed-loop flight control systems.

(2) The control authority characteristics are not degraded to a level that will prevent continued safe flight and landing. failures which refer to (1) and (2) above which would otherwise prevent the airplane from continued safe flight and landing need not be considered

*Discussion:* It should be noted that:

(1) The wording "signals cannot be altered unintentionally" is used in this special condition to emphasize the need for design measures to protect the fly-by-wire control system from the effects of electromagnetic interference (EMI) and radio frequency energy (RE), fluctuations in electrical power, accidental damage caused by contained rotary machinery debris (engine burst is addressed in § 25.903(d) of the FAR), environmental factors such as temperature, local fires, and any other spurious signals or disruptions that effect the command signals as they are being transmitted from their source of origin to the Power Control Actuators.

(2) A gain margin is the minimum change in loop gain, at nominal phase, which results in an instability beyond that allowed as a residual oscillation.

(3) A phase margin is the minimum change in phase, at nominal loop gain, which results in an instability.

(4) "Control authority characteristics" refers to the ability of the aerodynamic control surfaces to move the airplane.

(5) "Aerodynamically closed loop" are those elements (electrical signals, cables, bellcranks, etc.) which connect sensors and command signals to the Power Control Actuator that moves the aerodynamic control surface (aileron, spoiler, stabilizer, etc.).

(d) *Powered Control Integrity:* In addition to compliance with the requirements of § 25.671 of the FAR the airplane control system must be designed to allow for continued safe flight and landing after any failure condition to the flight critical powered system which is not shown to be extremely improbable, unless it is associated with a wholly-unrelated failure condition that would itself prevent continued safe flight and landing.

(e) *Maximum Control Surface Displacement.*

(1) In lieu of compliance with § 25.331(c)(1) of the FAR the airplane is assumed to be flying in steady level flight (point A., § 25.333(b)) and, except as limited by pilot effort in accordance with § 25.397(b), the pitching control is moved to obtain the extreme positive (nose up) pitching acceleration. The maximum possible elevator deflections commanded by the Electronic Flight Control System (EFCS) must be considered during this maneuver using the most adverse system tolerances. The dynamic response, or at the option of the applicant, the transient rigid body response of the airplane must be taken into account in determining the tail load. Airplane loads which occur subsequent to the normal acceleration at the center of gravity exceeding the maximum positive limit maneuvering load factor,  $n$ , need not be considered. It should also be established that maneuver loads included by the system itself (e.g., abrupt changes in orders made possible by electric rather than mechanical combination of different inputs) are acceptably accounted for, up to  $V_D/M_D$ .

(2) In lieu of compliance with § 25.349(a) of the FAR, the following conditions, speeds spoiler and aileron deflections (except as the deflections may be limited by pilot effort) must be considered in combination with an airplane load factor of zero and of two-thirds of the positive maneuvering factor used in design. In determining the required aileron and spoiler deflections, the torsional flexibility of the wing must be considered in accordance with § 25.301(b). It should also be established that moreover loads induced by the system itself (e.g. abrupt changes in orders made possible by electric rather than mechanical combination of different inputs) are acceptably accounted for, up to  $V_D/M_D$ .

(i) Conditions corresponding to steady rolling velocities must be investigated. In addition, conditions corresponding to maximum angular acceleration must be investigated. The investigation must include the maximum possible aileron and spoiler deflections commanded by the EFCS, using the most adverse system tolerances. For the angular acceleration conditions, zero rolling velocity may be assumed in the absence of a rational time history investigation of the maneuver.



(ii) At  $V_{<?>}$  sudden deflection of the aileron and spoiler to the maximum possible positions are assumed.

(iii) At  $V_c$ , the aileron and spoiler deflections must be that required to produce a rate of roll not less than that obtained in paragraph (ii).

(iv) At  $V_D$ , the aileron and spoiler deflections must be that required to produce a rate of roll not less than one-third of that in paragraph (ii).

*Discussion:* These special conditions require the manufacturer to consider the critical deflection rates and deflections of the control surfaces, considering the entire A320 flight control system, as opposed to only the pilot's input, when demonstrating compliance with §§ 25.331 and 25.349 of the FAR.

## 2. Active Controls.

In addition, to compliance with the structural requirements of Subpart C and D of the FAR, the airframe must be designed to meet the criteria in this special condition. These criteria are divided into two groups:

*Basic Criteria:* These criteria are considered necessary to define a certification basis. The objective of these criteria is to control, in a consistent way, the risk of catastrophic structural failure associated with each failure condition.

*Supplementary criteria:* The purpose of the supplementary criteria is to examine areas where the basic criteria may not be sufficient and to check certain situations which are considered realistic but not covered in the normal requirements. The precise need for additional requirements associated with these criteria and their level of severity will depend on the sensitivity of the airplane to these conditions and on the conclusion that these problems may show the airplane to have a lower level of safety compared to an airplane without active flight controls. These supplementary criteria will form the basis of required investigations to be performed by the manufacturer and will be evaluated by the certification authorities.

### (a) Basic Criteria.

#### (1) With the system operative.

(i) *Determination of limit loads.* Limit loads must be derived in all normal operating configurations of the systems from all deterministic limit load conditions specified in Part 25, taking into account any special behavior of such systems or associated functions or any effect on the structural performance of the airplane which may occur up to limit loads. In particular, any significant nonlinearity (aerodynamic, aeroelastic, rate of displacement of control surfaces, and any other system limit nonlinearities) must be accounted for when deriving limit load conditions.

(ii) *Load conditions defined on a statistical basis.* In cases where Mission Analysis is used for continuous turbulence, all the systems failure conditions associated with their probability must be accounted for in a rational or conservative manner in order to ensure that the probability of exceeding limit load is not higher than for an airplane of similar characteristics without an active control system.

(iii) *Strength requirements.* The airplane must meet the strength requirements of Part 25 (static strength, residual strength) using the appropriate factors specified in Part 25 to derive ultimate loads from the limit loads defined above.

(iv) *Nonlinearities above limit load.* When some systems present a nonlinear behavior beyond limit loads (e.g., saturation), an increase of the safety factors may be found necessary in order to ensure a protection of the airplane beyond the limit conditions comparable to an airplane not equipped with such systems, taking into account the physical limitations of the airplane established in a conservative way. It must also be shown that, between limit load and 1.5 times limit load, nonlinearities in the load alleviation function, including aeroelastic effects, will not result in a smaller load increment than the increment achieved at limit load due to load alleviation,

(2) *With the system in failure conditions.*

(1) Warnings must be provided to annunciate the existence of failure conditions which affect the structural capability of the airplane and for which the associated reduction in airworthiness can be minimized by suitable flight limitations. Failure conditions which affect the structural capability of the airplane and for which there is no suitable compensating flight limitation need not be annunciated to the flightcrew, but must be detected before the next flight.

(ii) In addition, the following conditions must be met for all failure conditions not shown to be extremely improbable and which have an impact on structural performance.

(A) *At the time of occurrence.* Starting from 1-g level flight conditions, a realistic scenario, including pilot corrective actions, must be established to determine the loads and speeds occurring at the time of failure and immediately after failure.

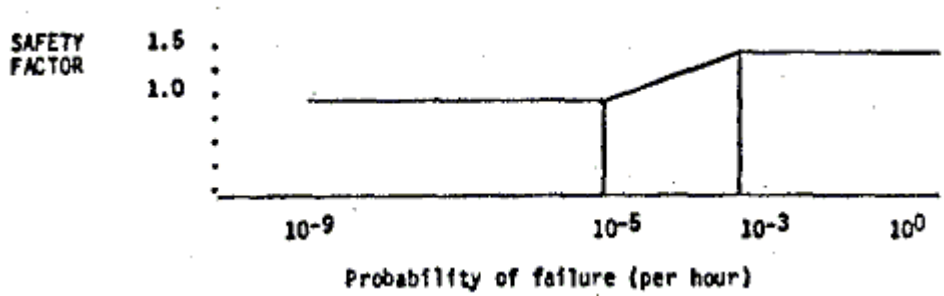
(1) The airplane must be able to withstand these loads, multiplied by a 1.5 factor of safety, to obtain ultimate loads. These loads without the 1.5 factor must also be included in the damage tolerance evaluation required by § 25.571(b) of the FAR, if the failure condition is probable.

(2) A flutter and divergence justification must be made in accordance with paragraph (2)(ii)(B) applied to failure conditions not shown to be extremely improbable. For failure conditions which result in speed increases beyond VC/MC, freedom from flutter and divergence must be shown to the speeds indicated by paragraph (2)(ii)(B) with VC/MC replaced by the maximum speed obtained during the above realistic scenario.

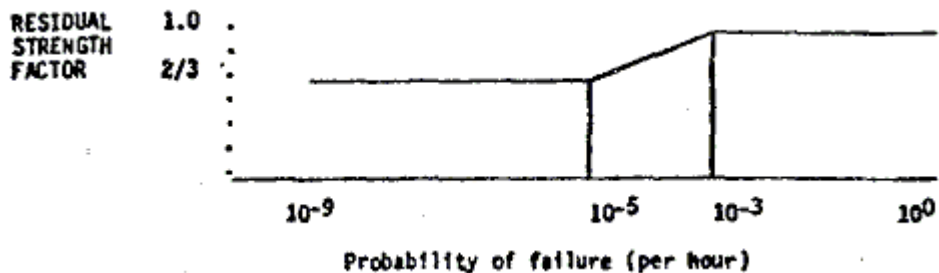
(B) *For continuation of the flight.* The new airplane configuration and associated flight limitations, if any, must be taken into account and the justification must cover:

(1) *A static and residual strength substantiation.* These investigations must take into account the loads induced by the failure condition (resulting from any single or combination of system failures not shown to be extremely improbable) in those cases where these loads will continue up to the end of the flight, in combination with the deterministic limit conditions specified in Part 25 (as maneuvers, discrete gust, design envelope for continuous turbulence, etc.)

(i) For the static strength substantiation, each part of the structure affected by failure of the EFCS must be able to withstand the above specified loads multiplied by a factor between 1 and 1.5 depending on the probability of the failure conditions. The factors shown in the following figure may be used.

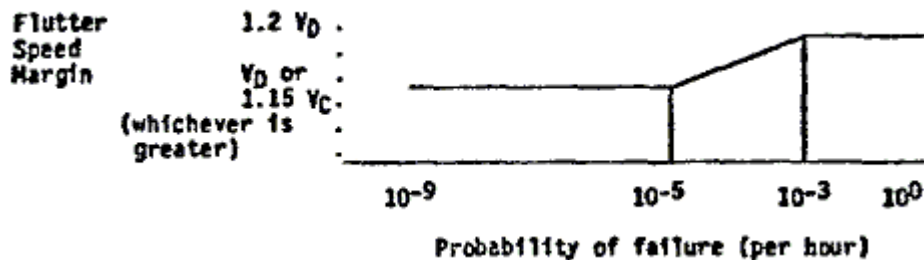


(ii) For structure affected by failure of the EFCS and with structural damage in combination with the EFCS failure conditions, a factor must be applied for the same purpose to the loads used for the justification of the airplane without system failure condition. In any case, the residual strength level must be at least 2/3 of the gust or maneuver conditions, combined with the normal operating cabin differential pressure (including the expected external aerodynamic pressures), specified in § 25.571(b) of the FAR. The residual strength factors shown in the following figure may be used.



(2) *Flutter and divergence substantiation.* Due to High Speed Protection, the speed margin between VC and VD, compared with an airplane without much protection, may be reduced. Therefore, compliance with § 25.629(d) must be shown to a speed of 1.15 VC or to VD, whichever is greater. However, at altitudes where VD is limited by Mach

number, compliance may be shown to MD or MC + .05, whichever is greater. The failsafe flutter speed at any altitude need not exceed the value of VD that would result from compliance with § 25.335(b) without high speed protection. In addition, a margin up to 20% above VD/MD, depending on the probability of failure must be provided for any system failure condition affecting the EFCS, the Load Alleviation Function (LAF), or High Speed Protection function. For probable failure conditions which affect the High Speed Protection function, this value of VD/MD must be the particular value defined for this failure condition. The margins shown in the following figure may be used.



(3) *Damage propagation substantiation.* If the time likely to be spent in this failure condition is not small compared to the damage propagation period, or if the loads induced by the failure condition may have a significant influence on the damage propagation, then the effects of the particular failure condition must be addressed and the corresponding inspection intervals adjusted to adequately cover this situation.

(C) *Known failure conditions.* The airplane may be considered to be airworthy in a system failure condition which reduces the structural performance if the effects of flight and operational limitations, when combined with those of the failure condition allow the airplane to meet all Part 25 structural requirements. The consequences of subsequent system failures must also be considered.

(b) *Supplementary Criteria.*

(1) *Realistic Gust Fields.* Realistic representations of gust and turbulence must be accounted for. This is both to provide confidence that design assumptions based on idealized turbulence will not lead to optimistic estimates of the degree of load alleviation likely to be achieved and to avoid unnecessary constraints on control system design.

(2) *Availability of control authority and power supply to control systems.* Adequate power supply to the control systems (e.g., hydraulic power) and adequate control authority must be available for load alleviation and flight control under realistic conditions of severe turbulence. Maneuvers, gusts, and combinations of maneuvers and gusts must be considered.

(3) *Effects of control input on loads in turbulence.* The effects of loads induced by control activity during flight in turbulence on the LAF effectiveness in reducing the total loads in turbulence must be assessed.

(4) *System Reliability.* If the systems prove less reliable in service than assessed for certification, adjustments in maintenance schedules, load levels, and/or operating limitations may be required. The systems must be monitored for a sufficient period of time to substantiate an adequate level of reliability. Details of the reliability verification program must be based on system criticality and the degree of conservatism inherent in the system design and analysis. Periodic checks for system reliability may be required throughout the service life of the systems.

(5) *Test demonstration.* The purpose of the test demonstration is to show that the airplane meets the regulatory requirements by carrying out performance and fault tests at selected conditions. The tests shall include, in addition to those normally required by Part 25, the following simulator, ground, and flight demonstrations.

(i) The system effectiveness in alleviating loads must be demonstrated by (flight tests for selected conditions within the airplane design envelope. Airplane response to oscillatory as well as hardover failures must be similarly verified by tests, unless these conditions are shown to be extremely improbable.

(ii) Maneuvering to limit load factors or load factors which produce light buffeting at both low speed and high speed must be explored for system effectiveness.

(iii) If the airplane is proposed to be dispatched with failures in the EFCS (MEL configurations), the tests described in paragraph (i) above must include selected conditions in the MEL configuration.

(iv) An analytical or test evaluation must be made to determine that EFCS signals at various frequencies will not cause structural feedback resulting in control system instability. The frequency range must include the highest and lowest frequencies (including system failures not shown to be extremely improbable) which result in movement of a control surface and the lowest structural or rigid body frequency of the airplane. The effects of structural damage considered under §§ 25.571 (b) and (e) must be included. The investigation must cover all points in the v-n envelope.

The following definitions apply to the terms as they are used in this special condition.

1. *Structural performance.* Capability of the airplane to meet the requirements of Part 25 relating to structures.

2. *Flight limitations.* Limitations which can be applied to the airplane flight conditions following an in-flight occurrence and which are included in the flight manual (e.g. speed limitations, avoidance of severe weather conditions. etc).

3. *Operational limitations.* Limitations, including flight limitations, which can be applied to the airplane operating conditions before dispatch (e.g., payload limitations).

4. *Probabilistic terms.* The probabilistic terms (probable, improbable, extremely improbable) used in this special condition should be understood as defined in AC 25.1309-1.

5. *Failure condition.* The term "failure condition" should also be understood as defined in AC 25.1309-1, but this special condition applies only to system failure conditions which have a direct impact on the structural performance of the airplane (e.g., failure conditions which induce loads or change the response of the airplane to inputs such as gusts or pilot actions).

*Discussion:* The criteria in this special condition address only the direct structural consequences of the system's responses and performances and therefore cannot be considered in isolation but must be included in the overall safety evaluation of the airplane. The presentation of these criteria may, in some instances, duplicate standards already established for this evaluation. However, this presentation is used: (1) to keep explicit the links between the different items to be covered and the continuity with former requirements; and (2) to place in a proper context the specific additional structural requirements. These criteria are applicable to primary structure which, if failed, would prevent continued safe flight and landing. It is advisable to use the same basis for the whole of the structure, but some relief may be considered for cases leading to structural failures which would not prevent continued safe flight and landing.

(c) *Dive Speed Definition.* In lieu of compliance with § 25.335(b)(1) of the FAR, if the flight control system includes functions which act automatically to initiate recovery before the end of the 20-second period specified in § 25.335(b)(1) the greater of the speeds resulting from the following conditions may be used:

(i) From an initial condition of stabilized flight at  $V_C/M_C$  the airplane is upset so as to take up a new flight path 7.5 degrees below the initial path. Control application, up to full authority, is made to try and maintain this new flight path. Twenty seconds after initiating the upset, manual recovery is made at a load factor of 1.5 g (0.5 g acceleration increment), or such greater load factor that is automatically applied by the system with the pilot's pitch control at neutral. The speed increase occurring in this maneuver may be calculated, if reliable or conservative aerodynamic data is used. Power, as specified in § 25.175(b)(1)(iv) of the FAR, is assumed until recovery is made, at which time power reduction and the use of pilot controlled drag devices may be assumed.

(ii) From a speed below  $V_C/M_C$ , with power to maintain stabilized level flight at this speed, the airplane is upset so as to accelerate through  $V_C/M_C$  at a flight path 15 degrees below the initial path (or at the steepest nose down attitude that the system will permit with full control authority if less than 15 degrees). Recovery may be initiated two seconds after operation of high speed, attitude, or other alerting system by application of a load factor of 1.5 g (0.5 g acceleration increase), or such greater load factor that is automatically applied by the system with the pilot's pitch control at neutral. Power may be reduced simultaneously. All other means of decelerating the airplane, the use of which is authorized up to the highest speed in the maneuver, may be used. The interval between

successive pilot actions must not be less than one second.

*Discussion:* Special Condition 2c above has been adapted from DGAC Special Condition SC-A 2.2.3 for the A320 dated April 4, 1986.

### 3. *Engine Controls and Monitoring.*

(a) *Full Authority Digital Engine Control System (FADEC).* In addition to compliance with the requirements of §§ 25.901(c) and 25.903(b) of the FAR, the components of the propulsion control system for each engine, both airframe and engine furnished, that effect thrust in either the forward or reverse direction and are required for continued safe operation, must have the level of integrity and reliability of a hydromechanical system (HMC) meeting current airworthiness standards.

*Discussion:* An acceptable method to demonstrate compliance with this special condition is to show that the engine control system, when installed in the A320, has a level of design integrity equivalent to propulsion controls presently in commercial airline service. The inherent level of design integrity for present day propulsion controls is demonstrated by an in-service loss of thrust control approximately once per 100,000 hours of operation. A similar level of integrity must be demonstrated for a FADEC control system considering all dispatchable states. This level of reliability for the loss of thrust control on one engine will result in an overall airplane propulsion control system reliability that is consistent with the guidance associated with § 25.1309(b)(1), assuming an independence of the failure conditions that contribute to the loss of thrust control. Proper compliance with §§ 25.901(c) and 25.903(b) should not result in any control system functions for one engine that are critical to continued safe flight and landing, that are totally dependent on FADEC system reliability to meet the objectives of § 25.1309(b)(1). Sources of information which are necessary in order to establish a meaningful determination of reliability include assessing service experience of like controls in similar environments, testing (e.g., bench, flight, etc.) and analysis. Service experience of a complex system such as the FADEC could involve similar units in a similar installation, military experience of like installations, or possibly identical installations on other aircraft. In each of these cases, the type and degree of exposure would depend upon various factors such as service history of previous systems produced by the manufacturers involved, or the number and type of failures observed during the service evaluation. The minimum dispatch configuration will have to be taken into account.

(b) *Engine Thrust Levers During Autothrust System Operation.* In lieu of compliance with § 25.1143(c) of the FAR, it must be established by analysis and test that the A320 automatic thrust system:

(1) Provides adequate cues for the flightcrew to monitor thrust changes without the need for exceptional diligence during normal operation and provides capability for the flightcrew to recognize a malfunction or inappropriate mode of operation and take corrective action without the need for exceptional skills.

(2) Provides a means for the flightcrew to disengage or otherwise override the automatic thrust system and regain manual control of engine thrust through normal motion of the thrust levers as defined in § 25.779(b) of the FAR.

(3) Provides visual cues for any disengagements, and provides visual and aural alerts during uncommanded disengagements.

(4) Functions reliably and does not allow the exceedance of any approved engine operating limit during normal system operation.

(5) Compliance with paragraphs 1 through 3 above shall include consideration of faults within the automatic thrust system which could affect any or all engines during critical flight operations, such as takeoff, approach and landing.

(c) *Display of Powerplant Parameters.* In addition to compliance with the requirements of §§ 25.1305, 25.1321, and 25.1337 of the FAR -

(1) The powerplant parameter displays required for certification must be arranged and isolated from each other so that no single fault, failure, malfunction, or probable combinations of failures, of any system or component that effects the display or accuracy of any propulsion system parameter for one engine shall result in the permanent loss of display or adversely effect the accuracy of any parameter display for the remaining engines.

(2) No single fault, failure, or malfunction, or probable combinations of failures, shall result in the permanent loss of display or adversely affect the accuracy of more than one propulsion unit parameter display for any single engine.

(3) Combinations of failures which would result in the display of hazardously misleading information for any powerplant parameter that affects more than one engine must be extremely improbable.

(4) Each powerplant parameter display required for certification that is not continuously displayed must have an operating limit or threshold established so that the appropriate engine, auxiliary power unit (APU), or fuel system parameters are automatically displayed for any condition that requires immediate crew awareness. In addition, those parameter displays must be manually selectable by the flightcrew.

(5) For designs incorporating shared displays, the engine parameters must have higher display priority for concurrent propulsion and airplane system failures, unless it is shown that crew attention to another propulsion or airplane system display is more critical for continued safe operations of the airplane. If the engine parameters are not concurrently displayed, it must be established that this condition does not jeopardize the safe operation of the airplane.

(6) Propulsion system parameters essential for determining the health and operational



status of the engines and for taking appropriate corrective action, including engine restart, must be automatically displayed after the loss of normal electrical power.

(7) If individual fuel tank quantity information is not continuously displayed, there must be adequate automatic monitoring of the fuel system to alert the crew of both system malfunctions and abnormal fuel management.

*Discussion:* Section 25.1305 specifies the required powerplant instruments. Section 25.1321(c)(2) requires that powerplant instruments vital to the safe operation of the airplane must be plainly visible to the appropriate crewmembers, and § 25.1309(a) requires that the powerplant instruments function properly and perform their intended functions under any foreseeable operating condition. The instruments function properly if they accurately display the required parameter. The instruments are considered to be performing their intended function if they are displayed when the crew needs them to determine the health or operational status of the engines, or to monitor correct fuel system operation. Any foreseeable operating condition encompasses the entire range of normal airplane and engine operation, as well as engine or airplane system failures. Vital powerplant instruments are not plainly visible to the appropriate crewmembers if they are not being displayed.

#### *4. Protection From Lightning and Unwanted Effects of Radio Frequency (RF) Energy.*

(a) In the absence of specific requirements for protection from the unwanted effects of RF energy, the following apply:

(1) Each electronic system which performs critical functions must be designed and installed to ensure that the operation and operational capabilities of these critical systems are not affected when the airplane is exposed to externally radiated electromagnetic energy,

(2) For the purpose of this special condition, critical functions are functions whose failure would contribute to or cause a failure condition which would prevent the continued safe flight and landing of the airplane.

*Discussion:* It is not possible to precisely define the RF energy to which the airplane will be exposed in service. There is also uncertainty concerning the effectiveness of airframe shielding for RF energy. Based on surveys and analysis of existing RF emitters, an adequate level of protection exists when compliance with the above special condition is shown for the field strengths specified in either paragraph 1 or 2 below:

1. A minimum RF threat of 200 volts per meter average electric field strength from 10 KHZ to 20 GHZ.

a. The threat must be applied to the system elements and their associated wiring harnesses without the benefit of airframe shielding.

b. Demonstration of this level of protection is established through system tests and analysis.

2. An alternate means of compliance is presented which considers the effect of shielding. That threat has the following field strengths for the frequency ranges indicated.

<b>Frequency</b>	<b>Average (V/m)</b>	<b>Peak (V/m)</b>
10 KHz - 3 MHz	100	100
3 MHz - 30 MHz	1,000	1,000
30 MHz - 100 MHz	100	100
100 MHz - 200 MHz	200	3,000
200 MHz - 1GHz	2,000	6,000
1 GHz - 2 GHz	2,000	14,000
2 GHZ- 8 GHz	600	14,000
8 GHZ-10 GHZ	2,000	14,000
10 GHz - 40 GHz	1,000	8,000

To establish the values in paragraph 2 above, an analysis was performed using a model of U.S. airspace and the Electromagnetic Compatibility Analysis Center (ECAC) data base, which contains the characteristics of all U.S. emitters. This analysis assumed a minimum separation distance between the airplane and emitters as follows: in the airport environment, 250 ft. for fixed emitters and 50 ft. for mobile emitters; for the air-to-air environment, 50 ft. from interceptor aircraft and 500 ft. from non-interceptor aircraft; for the ground-to-air environment, 500 ft.; and for the ship-to-air environment, 1,000 ft. The results of this analysis were then combined with the results of a study of emitters in European countries. The above values are therefore believed to represent the worst case levels to which an airplane would be exposed in the operating environment.

(b) In addition to compliance with the requirements of §§ 25.581 and 25.954 of the FAR concerning lightning protection-

(1) Each electronic system which performs critical functions must be designed and installed to ensure that the operation and operational capabilities of these critical systems are not affected when the airplane is exposed to lightning.

(2) Each electronic system which performs essential functions must be protected to ensure that the operation and operational capabilities of these essential functions can be recovered automatically or by simple pilot action after the system has been exposed to lightning. Fault annunciation must be provided if crew action is required.

(3) For the purpose of this special condition, the following definitions apply:

(i) *Critical Functions.* Functions whose failure would contribute to or cause a failure

condition which would prevent the continued safe flight and landing of the airplane.

(ii) *Essential Functions*. Functions whose failure would contribute to or cause a failure condition which would significantly impact the safety of the airplane or the ability of the flightcrew to cope with adverse operating conditions.

*Discussion*: The current airworthiness regulations address lightning protection for fuel vapor ignition (§ 25.954) and for damage caused to the structural and skin details of the airplane (§ 25.581). However, application of the design requirements of these rules does not provide an equivalent level of safety to fly-by-wire applications when compared to the traditional designs which utilize mechanical means to connect the flight controls and the engines to the flight deck.

The following "threat definition" is proposed as a basis to sue in demonstrating compliance with this special condition.

The lightning current waveforms defined below, along with the voltage waveforms in JAR AMC-S5 or Advisory Circular (AC) 20-53A, will provide a consistent and reasonable requirement which is acceptable for use in evaluating the effects of lightning on the airplane. These waveforms depict threats that are external to the airplane. How these threats affect the airplane and its systems depend upon airplane geometry, the system's installation configuration, materials, shielding, etc. Therefore, tests (including tests on the completed airplane or an adequate simulation) and/or verified analysis need to be conducted in order to obtain the resultant internal threat to the installed systems. The individual systems may then be evaluated with this internal threat in order to determine their susceptibility to upset and malfunction.

In addition to the use of the Severe Strike/Restrike, Component A or D, to address the direct effects per AC 20-53A, the possible effects or upset that an avionics system or data transmission might experience needs to be identified. To evaluate the induced effects to these systems, three considerations are required:

1. *First Return Stroke*: (Severe Strike-Component A or Restrike-Component D). As identified above, this external threat needs to be evaluated to obtain the resultant internal threat and to verify that the level is sufficiently below the equipment "hardness" level; then

2. *Multiple Stroke Flash*: A lightning strike is often composed of a number of successive strokes, referred to as a multiple-stroke. Although multiple strokes are not necessarily a salient factor in a damage assessment, they can be the prim" factor in a system upset analysis. Multiple strokes can induce a sequence of transients over an extended period of time. While a single event upset of input/output signals may not affect system performance, multiple signal upsets over an extended period of time (2 seconds) may affect the systems under consideration. Repetitive pulse testing and/or analysis need to be carried out in response to the multiple stroke environment to demonstrate that the system response meets the safety objective. This external multiple stroke environment consists of

24 pulses and is described as a single Component A followed by 23 randomly spaced restrikes of 1/2 magnitude of component D (Peak Amplitude of 50,000 amps), all within 2 seconds. An analysis or test needs to be accomplished in order to obtain the resultant internal threat environment for the system under evaluation.

And,

3. *Multiple Burst*: In-flight data-gathering projects have shown bursts of multiple, low amplitude, fast rates of rise, short duration pulses accompanying the airplane lightning strike process. While insufficient energy exists in these pulses to cause direct (physical damage) effects it is possible that indirect effects resulting from this environment may cause upset to some digital processing systems.

The representation of this interference environment is a repetition of low amplitude, high peak rate of rise, double exponential pulses which represent the multiple bursts of current pulses observed in these flight data gathering projects. This component is intended for an analytical (or test) assessment of functional upset of the system. Again, it is required that this component be translated into an internal environmental threat in order to be used. This "Multiple Burst" consists of 24 random sets of 20 strokes within a period of 2 seconds. Each set of 20 strokes is made up of 20 "Multiple Burst" waveforms randomly distributed within a period of one millisecond. The individual "Multiple Burst" waveform is defined below.

The following current waveforms constitute the "Severe Strike" (Component A), Restrike/ "Swept Stroke" (Component D), "Multiple Stroke" (1/2 Component D), and the "Multiple Burst" (Component H ).

These components are defined by the following double exponential polynomial equations:

$$i(t) = I_0 (a^{-at} - e^{-bt})$$

where:

t = time in seconds,

i = current in amperes, and

	Severe Strike (Component A)	Restrike (Component D)	Multiple Stroke (1/2 Component D)	Multiple Burst (Component H)
$I_0$ , amp	= 218,810	109,405	54,703	10,572
a, sec <sup>-1</sup>	= 11,354	22,708	22,708	187,191
b, sec <sup>-1</sup>	= 647,265	1,294,530	1,294,530	19,105,100
This equation produces the following characteristics:				
$i_{peak}$	= 200 KA	100 KA	50 KA	10 KA
and,				
$(di/dt)_{max}$ (amp/sec)	= $1.4 \times 10^{11}$	$1.4 \times 10^{11}$	$0.7 \times 10^{11}$	$2.0 \times 10^{11}$

(di/dt, (amp/sec)	=	@t = 0 <sub>+sec</sub> 1.0 x 10 <sup>11</sup>	@t = 0 <sub>+sec</sub> 1.0 x 10 <sup>11</sup>	@t = 0 <sub>+sec</sub> 0.5 x 10 <sup>11</sup>	@t = 0 <sub>+sec</sub>
Action integral (amp <sup>2</sup> sec)	=	@t = .5 <sub>μs</sub> 2.0 x 10 <sup>6</sup>	@t = .25 <sub>μs</sub> 0.25 x 10 <sup>6</sup>	@t = .25 <sub>μs</sub> .0625 x 10 <sup>6</sup>	

### 5. Flight Characteristics.

(a) *Flight Characteristic Compliance Determination by Handling Qualities Rating System for EFCS Failure Cases.* In lieu of compliance with § 25.672(c) of the FAR, a handling qualities rating system will be used for evaluation of EFCS configurations resulting from single and multiple failures not shown to be extremely improbable. The handling qualities ratings are:

- (1) Satisfactory. Pull performance criteria can be met with routine pilot effort and attention;
- (2) Adequate. Adequate for continued safe flight and landing; fail or specified reduced performance can be met, but with heightened pilot effort and attention.
- (3) Controllable. Inadequate for continued safe flight and landing, but controllable for return to a safe flight condition, safe flight envelope and/or reconfiguration so that the handling qualities are at least Adequate. Handling qualities will be allowed to progressively vary with failure state atmospheric disturbance level, and flight envelope. Specifically within the normal flight envelope, the pilot-rate handling qualities must be satisfactory/adequate in moderate atmospheric disturbance for probable failures, and must not be less than adequate in light atmospheric disturbance for improbable failures.

(b) *Longitudinal Stability.* In lieu of compliance with the requirements of §§ 25.171, 25.173, 25.175, and 25.181(a) of the FAR, the airplane must be shown to have suitable dynamic and static longitudinal stability in any condition normally encountered in service, including the effects of atmospheric disturbance.

#### (c) *Lateral-Directional Stability.*

- (1) In lieu of compliance with § 25.171 of the FAR the airplane must be shown to have suitable static lateral-directional stability in any condition normally encountered in service, including the effects of atmospheric disturbance.
- (2) In lieu of compliance with § 25.177(b) and 25.177(c), the following applies: In straight, steady, sideslip (unaccelerated forward slips) the rudder control movements and forces must be substantially proportional to the angle of sideslip, and the factor of proportionality must lie between limits found necessary for safe operation throughout the range of sideslip angles appropriate to the operation of the airplane. At greater angles, up to the angle at which full rudder control is used or a rudder pedal force of 180 pounds is obtained, the rudder pedal forces may not reverse and increased rudder deflection must

produce increased angles of sideslip. Unless the airplane has suitable sideslip indication, there must be enough bank and lateral control deflection and force accompanying sideslipping to clearly indicate any departure from steady unyawed flight.

(d) *Control Surface Awareness.* In addition to compliance with §§ 25.143, 25.671, and 25.672 of the FAR, when a flight condition exists where, without being commanded by the crew, control surfaces are coming so close to their limits that return to the normal flight envelope and/or continuation of safe flight requires a specific crew action, a suitable flight control position annunciation shall be provided to the crew, unless other existing indications are found adequate or sufficient to prompt that action.

**Note:** The term suitable also indicates an appropriate balance between nuisance and necessary operation.

## 6. *Flight Envelope protection*

In the absence of specific requirements for flight envelope protection, the following apply:

### (a) *General Limiting Requirements.*

#### (1) *Normal Operation.*

(i) Onset characteristics of each envelope protection feature must be smooth, appropriate to the phase of flight and type of maneuver, and not in conflict with the ability of the pilot to satisfactorily change airplane flight path, speed, or attitude as needed.

(ii) Limit values of protected flight parameters (and if applicable, associated warning thresholds) must be compatible with:

(A) Airplane structural limits;

(B) Required safe and controllable maneuvering of the airplane; and

(C) Margin to critical conditions. Unsafe flight characteristics/conditions must not result if dynamic maneuvering, airframe and system tolerances (both manufacturing and in-service), and non-steady atmospheric conditions, in any appropriate combination and phase of flight, can produce a limited flight parameter beyond the nominal design limit value.

(iii) The airplane must be responsive to intentional dynamic maneuvering to within a suitable range of the parameter limit. Dynamic characteristics such as damping and overshoot must also be appropriate for the flight maneuver and limit parameter in question.

(iv) When simultaneous envelope limiting is engaged, adverse coupling or adverse priority must not result

(2) *Failure States.* EFCS (including sensor) failures must not result in a condition where a parameter is limited to such a reduced value that safe and controllable maneuvering is no longer available. The flightcrew must be alerted by suitable means if any change in envelope limiting or maneuverability is produced by single or multiple failures of the EFCS not shown to be extremely improbable.

(3) *Abnormal Attitudes.* In case of abnormal attitude or excursion of any other flight parameters outside the protected flight boundaries, the operation of the EFCS, including the automatic protection functions, must not hinder airplane recovery.

(b) *Angle-of-Attack Limiting.*

(1) *FAR Part 1, § 1.2, Abbreviations and Symbols.*

(i) In lieu of the definition of  $V_S$  in § 1.2, the following applies in subparts B, E, F, and G of FAR 25: " $V_S$  means the reference stalling speed:"

*Discussion:* This calibrated speed is determined in the stalling maneuver and expressed as  $V_{CLMAX} / \sqrt{N_{ZW}}$ , where  $V_{CLMAX}$  is the speed occurring where  $C_L$  is first a maximum, and  $N_{ZW}$  is the flight path normal load factor (not greater than 1.0) at the same point;  $C_L$  can

be expressed as 
$$\frac{N_{ZW}W - F_G \sin(AOA + i_{rc})}{qS}$$

Conditions associated with the determination of the stalling speed are those provided in § 25.103 of the FAR.

(ii) In lieu of the definition of  $V_{SO}$  given in § 1.2, the following applies: " $V_{SO}$  means the reference stalling speed in the landing configuration."

(iii) In lieu of the definition of  $V_{S1}$ , given in § 1.2, the following applies: " $V_{S1}$ , means the reference stalling speed in a specific configuration."

(iv) In addition to the definitions given, the following also apply:

" $V_{REF}$  means the steady landing approach speed, selected by the applicant for manual landing, for a defined landing configuration."

" $V_{MIN}$  means the minimum speed obtained by conducting a stalling maneuver."

" $V_{SW}$  means the speed at which onset of natural or artificial stall warning occurs."

(2) FAR Part 25-Airworthiness Standards; Transport Category Airplanes.

(i) In lieu of compliance with § 25.21(b), the following applies: "The flying qualities will be evaluated at speeds based upon the forward CG stalling speed."

(ii) In lieu of compliance with § 25.103(a), the following applies: " $V_S$  is the reference stalling speed with -"

(iii) In lieu of compliance with § 25.103(a)(1), the following applies "Stalling speed determined at not greater than IDLE thrust (NOTE: automatic go-around thrust application feature must be disengaged)."

(iv) In lieu of compliance with § 25.103(b)(1), the following applies: "From a stabilized straight flight condition at any speed not less than  $1.16 V_S$  (or speed of AOA protection onset, if greater) nor more than  $1.30 V_S$ , apply elevator control to decelerate the airplane so that the speed reduction at the stall does not exceed one knot per second."

(v) In lieu of § 25.107(b)(1). the following applies: " $1.13V_S$  for -"

(vi) In addition to compliance with §§ 25.107(c) (1) and (2), the following also applies: "A speed selected by the applicant which provides fixed-speed maneuvering capability, which is free of stall warning and Alpha floor, not less than the values shown in TABLE B.2."

**Note:** Unless AOA protection system production tolerances are acceptably small, so as to produce insignificant changes in performance determinations, the flight test settings for features such as Alpha floor and stall warning should be set at the low AOA tolerance limit; high AOA tolerance limits should be used for characteristics evaluations.

**TABLE B2**

<b>Configuration</b>	<b>Speed</b>	<b>Maneuvering bank angle</b>	<b>Maximum thrust representative of:</b>
Takeoff	$V_2$	30° (stall warning) 25° (Alpha floor)	WAT-limited $V_2$ climb.
Takeoff	* $V_2$ *XX	40°	Climb rating (all engines).
Enroute	+ $V_{FTO}$	40°	WAT-limited final climb.
Landing	$V_{REF}$	40°	-3° flight path.

\*Airspeed approved for all-engines initial climb.

+ Airspeed at end of final takeoff (FTO) flight path for engine-out performance.

Note.-FWD CG symmetrical thrust is acceptable.

(vii) In lieu of compliance with § 25.119(b), the following applies: "A climb speed of not more than  $V_{REF}$ ."

(viii) In lieu of compliance with § 25.121(c) the following applies: "Final takeoff. In the enroute configuration at the end of the takeoff path determined in accordance with § 25.111, the steady gradient of climb may not be less than 1.2 percent at a speed not less



than: \*  $1.23 V_S$  or \* a speed which provides fixed-speed maneuvering capability which is free of stall warning and Alpha floor, not less than the value shown in TABLE B.2, and with -"

(ix) In lieu of compliance with § 25.121(d)(3), the following applies: "A climb speed established in connection with normal landing procedures but not exceeding  $1.4V_{S1}$ ."

(x) In lieu of compliance with § 25.125(a)(2), the following applies: "A stabilized approach, with a calibrated airspeed of not less than  $V_{REF}$ , must be maintained down to the 50-foot height.  $V_{REF}$  may not be less than: (a)  $1.23 V_S$ , or (b) the speed selected by the applicant which provides a fixed-speed maneuvering capability, which is free of stall warning and Alpha floor, not less than the value shown in TABLE B.2."

(xi) In addition to compliance with the requirements of § 25.143, the following also apply: "(1) The airplane must be shown to have suitable flight-path stability and control characteristics both in normal flight and when windshear is encountered in a takeoff or landing configuration. This may be shown by an appropriate combination of simulation and flight test." NOTE: Suitable characteristics are those no worse than conventionally controlled airplanes in similar conditions." (2) Operation of automatic features (such as significant EFCS stability or control changes) must not adversely affect normal flight operations, including during expected levels of atmospheric disturbance."

(xii) In lieu of the speeds given in the following Part 25 regulations, comply with speeds as follows:

§ 25.145(a),  $V_{MIN}$  in lieu of  $V_S$

§ 25.145(b)(1)-(4),  $1.3V_{S1}$  in lieu of  $1.4 V_{S1}$

§ 25.145(b)(1), Change 40 percent to 30 percent.

§ 25.145(b)(6),  $1.3 V_{S1}$  in lieu of  $1.4V_{S1}$ .

§ 25.145(b)(6),  $V_{MIN}$  in lieu of  $1.1 V_{S1}$ .

§ 25.145(6),  $1.6V_{S1}$  in lieu of  $1.7V_{S1}$ .

§ 25.145(c),  $1.13V_{S1}$  in lieu of  $1.2V_{S1}$ .

§§ 25.147(a), (a)(2), (c), (d),  $1.3V_{S1}$  in lieu of  $1.4V_{S1}$ .

§ 25.145(c),  $1.13V_S$  in lieu of  $1.2V_S$ .

§§ 25.161(b), (c)(1), (c)(2), (c)(3), (d),  $1.3V_{S1}$  in lieu of  $1.4V_{S1}$ .

§§ 25.175(a)(2), (b)(1), (b)(2), (b)(3), (c)(4),  $1.3V_{S1}$  in lieu of  $1.4V_{S1}$ .

§ 25.175(b)(2)(ii),  $(V_{MO} + 1.3V_{S1})/2$  in lieu of  $(V_{MO} + 1.4V_{S1})/2$ .

§ 25.175(c),  $V_{MIN}$  and  $1.7V_{S1}$  in lieu of  $1.1V_{S1}$  and  $1.8V_{S1}$ .

§ 25.175(d),  $V_{MIN}$  and  $1.7 V_{S0}$  in lieu of  $1.1V_{S0}$  and  $1.3V_{S0}$ .

§ 25.175(d)(5),  $1.3V_{S0}$  in lieu of  $1.4V_{S0}$ .

Note: The stability requirements for §§ 25.173 and 25.175 are further amended by the special condition associated with longitudinal stability.

§ 25.177(a), (b)(1),  $(1.13V_{S1}$  in lieu of  $1.2V_{S1}$ .

§ 25.201(a)(2),  $1.5V_{S1}$ , in lieu of  $1.6V_{S1}$ .

(xiii) In lieu of compliance with § 25.203(c), the following applies: "With the EFCS operating normally and autothrust ON, the airplane must be shown to have suitable handling characteristics when decelerating at various rates and up to 1.5<sub>g</sub> in turning flight to the AOA Limit."

(xiv) In lieu of compliance with § 25.207(a), the following applies: "With the AOA limiter operating normally, stall warning is not required. For failure states with the AOA limiter inoperative, sufficient stall warning margin must be provided in the following straight and turning flight conditions:

(1) Stall-free characteristics must be shown in power-off, straight ahead stall approaches to a speed five percent (but not less than five knots) below  $V_{SW}$ .

(2) Stall-free characteristics must be shown in turning flight stall approaches, at entry rates up to three knots per second, when recovery is initiated not less than one second after the onset of stall warning."

(xv) The requirements of § 25.207(c) are not applicable.

(c) *Normal Load Factor (g) Limiting*. In addition to compliance with the requirements of § 25.143, the following apply:

(1) The positive limiting load factor must not be less than 2.5g (2.0g with high-lift devices extended) for the EFCS normal state.

(2) The negative limiting load factor must be equal to or more negative than minus 0.5g (0.0g with high lift devices extended) for the EFCS normal state.

*Discussion:* This allows an incremental plus or minus 1.5g for maneuvering flaps up, and plus or minus 1.0g flaps extended. This Special Condition does not impose an upper bound for the limiter, nor does it require that the limiter exist. If the limiter is set at a value beyond the structural design limit maneuvering load factor "n" or §§ 25.333(b) and 25.337(b) and (c), there should be a very positive tactile feel built into the controller and obvious to the pilot that serves as a deterrent to inadvertently exceeding the structural limit.

(d) *High-Speed Limiting*. In addition to compliance with the requirements of § 25.143 of the FAR, the following applies: "Operation of the high-speed limiter during all routine and descent procedure flight must not impede normal attainment of speeds up to overspeed warning."

(e) *Pitch and Roll Limiting*. In addition to compliance with the requirements of § 26.143 of the FAR, the following applies "Operation of the pitch and roll limiter must not:

(1) Impede normal maneuvering for pitch angles up to the maximum required for normal

maneuvering, including a normal all-engine takeoff, plus a suitable margin to follow for satisfactory speed control.

(2) Restrict or prevent attainment of roll angles up to 65 degrees or pitch attitudes necessary for emergency maneuvering."

#### 7. *Side Stick Controllers.*

(a) *Pilot Strength.* In lieu of the "strength of pilots" limits of § 25.143(c) for pitch and roll, and in lieu of specific pitch force requirements of §§ 25.145(b) and 25.175(d), the following applies: "It must be shown that the temporary and maximum prolonged force levels for the side stick controllers are suitable for all expected operating conditions and configurations, whether normal or non-normal."

(b) *Controller Coupling.* In the absence of specific requirements for controller coupling, the following applies: "The electronic side stick controller coupling design must provide for corrective and/or overriding control inputs by either pilot with no unsafe characteristics. Annunciation of controller status must not be confusing to the flightcrew."

(c) *Pilot Control.* In the absence of specific requirements for side stick controllers, the following applies: "It must be shown by flight tests that the use of sidestick controllers does not produce unsuitable pilot-in-the-loop control characteristics when considering precision path control/tasks and turbulence."

(d) *Autopilot Quick-Release Control Location.* In lieu of compliance with § 25.1329(d) of the FAR, quick release (emergency) controls must be on both side stick controllers. The quick release means must be located so that it can readily and easily be used by the flightcrew.

#### 8. *Flight Recorder.*

(a) In addition to compliance with the requirements of § 25.1459(a) of the FAR, the flight recorder must record the following parameters in addition to those required by Appendix B of Part 121:

(1) Pilot and copilot sidestick pitch controller, pitch control surface position, pilot and copilot sidestick roll controller, aileron surface position, spoiler surface position, rudder pedal position, rudder surface position, auto thrust system commanded thrust parameter, total air temperature (TAT), and frame counter.

(2) The following for each engine installation: Actual thrust (N1/N2) electronic, engine control, commanded thrust, and thrust lever position.

(b) In lieu of compliance with § 25.1459(a)(4) of the FAR, there must be an aural or visual means for preflight checking that data are being recorded.

