(5) Finally, assuming that a suitable runway is available, it should be possible to control the aeroplane until it comes to a complete stop on the runway. A means of positive deceleration should be provided.

A suitable runway should have the lateral dimensions, length and load-bearing capability that meets the requirements defined in the emergency procedures of the AFM.

It is not necessary to consider adverse environmental conditions (e.g. wet or contaminated runway, tailwind) when demonstrating compliance for the on-ground phase.

9. EVALUATION OF CONTROL AUTHORITY AWARENESS — CS 25.671(e)

CS 25.671(e) requires an indication to the flight crew when a flight condition exists in which near-full-flight-control authority (whether or not it is pilot-commanded) is being used. Suitability of such an annunciation should take into account that some pilot-commanded manoeuvres (e.g. rapid roll) are necessarily associated with intended full performance, which may saturate the surface. Therefore, simple alerting systems, which should function in both intended and unexpected flight control-limiting situations, should be properly balanced between needed crew awareness and nuisance alerting. Nuisance alerting must be minimised per CS 25.1322 by correct setting of the alerting threshold.

Depending on the application, suitable indications may include cockpit flight control position, annunciator light, or surface position indicators. Furthermore, this requirement applies to the limits of flight control authority, not necessarily to the limits of any individual surface travel.

When the aeroplane is equipped with an unpowered manual flight control system, the pilot may be de facto aware of the limit of control authority. In this case, no other means of indication may be required.

10. EVALUATION OF FLIGHT CONTROL SYSTEM MODES OF OPERATION — CS 25.671(f)

Some flight control systems, for instance, electronic flight control systems, may have multiple modes of operation not restricted to being either on or off. The applicant should evaluate the different modes of operation and the transition between them in order to establish if they are intuitive or not.

If these modes, or the transition between them, are not intuitive, an alert to the flight crew may be required. Any alert must comply with CS 25.1322. This includes the indication to the flight crew of the loss of protections.

11. DEMONSTRATION OF ACCEPTABLE MEANS OF COMPLIANCE

It is recognised that it may be neither practical nor appropriate to demonstrate compliance by flight test for all of the failure conditions noted herein. Compliance may be demonstrated by analysis, simulation, a piloted engineering simulator, flight test, or a combination of these methods, as agreed with EASA. Simulation methods should include an accurate representation of the aeroplane characteristics and of the pilot response, including time delays as specified in paragraph 7.e(1)(iii) of this AMC.

Compliance with CS 25.671 may result in AFM non-normal and emergency procedures. Verification of these procedures may be accomplished in flight, or, with the agreement of EASA, using a piloted simulator.

a. *Acceptable Use of Simulations.* It is generally difficult to define the types of simulations that might be acceptable in lieu of flight test without identifying specific conditions or issues. However, the following general principles can be used as guidance for making this kind of decision:

(1) In general, flight test is the preferred method to demonstrate compliance;

(2) Simulation may be an acceptable alternative to flight test, especially when:

(i) a flight test would be too risky even after attempts to mitigate these risks (e.g. 'simulated' take-offs/landings at high altitude);

(ii) the required environmental conditions, or the representation of the failure conditions, are too difficult to attain (e.g. wind shear, high crosswinds, system failure configurations);

(iii) the simulation is used to augment a reasonably broad flight test programme;

(iv) the simulation is used to demonstrate repeatability.

b. *Simulation Requirements.* In order to be acceptable for use in demonstrating compliance with the requirements for performance and handling qualities, a simulation method should:

(1) be suitably validated by flight test data for the conditions of interest; furthermore,:

(i) this does not mean that there must be flight test data at the exact conditions of interest; the reason why a simulation method is being used may be that it is too difficult or risky to obtain flight test data at the conditions of interest;

(ii) the level of substantiation of the simulator to flight correlation should be commensurate with the level of compliance (i.e. unless it is determined that the simulation is conservative, the closer the case is to being non-compliant, the higher the required quality of the simulation);

(2) be conducted in a manner appropriate to the case and conditions of interest:

(i) if closed-loop responses are important, the simulation should be piloted by a human pilot;

(ii) for piloted simulations, the controls/displays/cues should be substantially equivalent to what would be available in the real aeroplane (unless it is determined that not doing so would provide added conservatism).

12. SPECIFICITIES OF AEROPLANES WITH FLY-BY-WIRE FLIGHT CONTROL SYSTEMS

a. Control Signal Integrity.

If the aeroplane is equipped with a conventional flight control system, the transmission of command signals to the primary and secondary flight control surfaces is made through conventional mechanical and hydromechanical means.

The determination of the origin of perturbations to command transmissions is relatively straightforward since failure cases can usually be classified in a limited number of categories that include maintenance error, jamming, disconnection, runaway, failure of mechanical element, or structural failure of hydraulic components. Therefore, it is almost always possible to identify the most severe failure cases that would serve as an envelope to all other cases that have the same consequences.

However, when the aeroplane is equipped with flight control systems using the fly-by-wire technology, incorporating digital devices and software, experience from electronic digital transmission lines shows that the perturbation of signals from internal and external sources is not unlikely.

The perturbations are described as signals that result from any condition that is able to modify the command signal from its intended characteristics. They can be classified in two categories:

(1) Internal causes that could modify the command and control signals include, but are not limited to:

— loss of data bits, frozen or erroneous values;

— unwanted transients;

— computer capacity saturation;

— processing of signals by asynchronous microprocessors;

— adverse effects caused by transport lag;

— poor resolution of digital signals;

— sensor noise;

— corrupted sensor signals;

— aliasing effects;

— inappropriate sensor monitoring thresholds;

— structural interactions (such as control surface compliance or coupling of structural modes with control modes) that may adversely affect the system operation.

(2) External causes that could modify the command and control signals include but are not limited to:

— high-intensity radiated fields (HIRF);

— lightning;

— electromagnetic interference (EMI) effects (e.g. motor interference, aeroplane's own electrical power and power switching transients, smaller signals if they can affect flight control, transients due to electrical failures.)

Spurious signals and/or false data that are a consequence of perturbations in either of the two above categories may result in malfunctions that produce unacceptable system responses equivalent to those of conventional systems such as limit cycle/oscillatory failures, runaway/hardover conditions, disconnection, lockups and false indication/warning that consequently present a flight hazard. It is imperative that the command signals remain continuous and free from internal and external perturbations and common-cause failures. Therefore, special design measures should be employed to maintain system integrity at a level of safety at least equivalent to that which is achieved with traditional hydromechanical designs. These special design measures can be monitored through the system safety assessment (SSA) process, provided specific care is directed to development methods and on quantitative and qualitative demonstrations of compliance.

The following should be considered when evaluating compliance with CS 25.671(c)(2):

(1) The flight control system should continue to provide its intended function, regardless of any malfunction from sources in the integrated systems environment of the aeroplane.

(2) Any malfunctioning system in the aerodynamic loop should not produce an unsafe level of uncommanded motion and should automatically recover its ability to perform critical functions upon removal of the effects of that malfunction.

(3) Systems in the aerodynamic loop should not be adversely affected during and/or after exposure to any sources of a malfunction.

(4) Any disruption to an individual unit or component as a consequence of a malfunction, and which requires annunciation and flight crew action, should be identified to and agreed by EASA to assure that:

a) the failure can be recognised by the flight crew, and

b) the flight crew action can be expected to result in continued safe flight and landing.

(5) An automatic change from a normal to a degraded mode that is caused by spurious signal(s) or malfunction(s) should meet the probability guidelines associated with the hazard assessment established in AMC 25.1309, e.g. for a condition assessed as 'major', the probability of occurrence should be no more than 'remote' (Pc < 10^{-5} per flight hour).

(6) Exposure to a spurious signal or malfunction should not result in a hazard with a probability greater than that allowed by the criteria of AMC 25.1309. The impact on handling qualities should be evaluated.

The complexity and criticality of the fly-by-wire flight control system necessitates the additional laboratory testing beyond that required as part of individual equipment validation and software verification.

It should be shown that either the fly-by-wire flight control system signals cannot be altered unintentionally, or that altered signal characteristics would meet the following criteria:

(1) Stable gain and phase margins are maintained for all control surface closed-loop systems. Pilot control inputs (pilot in the loop) are excluded from this requirement;

(2) Sufficient pitch, roll, and yaw control power is available to provide control for continued safe flight and landing, considering all the fly-by-wire flight control system signal malfunctions that are not extremely improbable; and

(3) The effect of spurious signals on the systems that are included in the aerodynamic loop should not result in unacceptable transients or degradation of the performance of the aeroplane. Specifically, in case of signals that would cause a significant uncommanded motion of a control surface actuator, either the signal should be readily detected and deactivated or the surface motion should be arrested by other means in a satisfactory manner. Small amplitude residual system oscillations may be acceptable.

It should be demonstrated that the output from the control surface closed-loop system does not result in uncommanded, sustained oscillations of flight control surfaces. The effects of minor instabilities may be acceptable, provided that they are thoroughly investigated, documented, and understood. An example of an acceptable condition would be one where a computer input is perturbed by spurious signals, but the output signal remains within the design tolerances, and the system is able to continue to operate in its selected mode of operation and is not affected by this perturbation.

When demonstrating compliance with CS 25.671(c), these system characteristics should be demonstrated using the following means:

(1) Systematic laboratory validation that includes a realistic representation of all relevant interfacing systems, and associated software, including the control system components that are part of the pitch, roll, and yaw axis control. Closed-loop aeroplane simulation/testing is necessary in this laboratory validation;

(2) Laboratory or aeroplane testing to demonstrate unwanted coupling of electronic command signals and their effects on the mechanical actuators and interfacing structure over the spectrum of operating frequencies; and

(3) Analysis or inspection to substantiate that physical or mechanical separation and segregation of equipment or components are utilised to minimise any potential hazards.

A successful demonstration of signal integrity should include all the elements that contribute to the command and control signals to the 'aerodynamic closed loop' that actuates the aerodynamic control surfaces (e.g. rudder, elevator, stabiliser, flaps, and spoilers). The 'aerodynamic closed loop' should be evaluated for the normal and degraded modes. Elements of the integrated 'aerodynamic closed loop' may include, for example: digital or analogue flight control computers, power control units, control feedback, major data busses, and the sensor signals including: air data, acceleration, rate gyros, commands to the surface position, and respective power supply sources. Autopilot systems (including feedback functions) should be included in this demonstration if they are integrated with the fly-by-wire flight control system.

b. Formalisation of Compliance Demonstration for Electronic Flight Control Laws.

On fly-by-wire aeroplanes, flight controls are typically implemented according to complex control laws and logics.

The handling qualities certification tests, usually performed on conventional aeroplanes to demonstrate compliance with CS-25 Subpart B specifications, are not considered to be sufficient to demonstrate the behaviour of the flight control laws in all foreseeable situations that may be encountered in service.

In order to demonstrate compliance with an adequate level of formalisation, the following should be performed and captured within certification documents:

— Determination of the flight control characteristics that require detailed and specific test strategy; and

— Substantiation of the proposed validation strategy (flight tests, simulator tests, analyses, etc.) covering the characteristics and features determined above.

In particular, the following characteristics of flight control laws should be covered:

— discontinuities;

— robustness versus piloted manoeuvres and/or adverse weather conditions;

— protection priorities (entry/exit logic conditions not symmetrical);

— control law mode changes with and without failures; and

— determination of critical scenarios for multiple failures.

The validation strategy should include, but should not be limited to, operational scenarios. The determination that an adequate level of formalisation of validation strategy has been achieved should be based on engineering judgement.

[Amdt No: 25/24]
[Amdt No: 25/27]

CS 25.672 Stability augmentation and automatic and power-operated systems

ED Decision 2020/001/R

If the functioning of stability augmentation or other automatic or power-operated systems is necessary to show compliance with the flight characteristics requirements of this CS-25, such systems must comply with CS 25.671 and the following:

(a) A warning, which is clearly distinguishable to the pilot under expected flight conditions without requiring his attention, must be provided for any failure in the stability augmentation system or in any other automatic or power-operated system, which could result in an unsafe condition if the pilot were not aware of the failure. Warning systems must not activate the control systems.

(b) The design of the stability augmentation system or of any other automatic or power-operated system must permit initial counteraction of failures of the type specified in CS 25.671(c) without requiring exceptional pilot skill or strength, by either the deactivation of the system, or a failed portion thereof, or by overriding the failure by movement of the flight controls in the normal sense.

(c) It must be shown that after any single failure of the stability augmentation system or any other automatic or power-operated system:

(1) The aeroplane is safely controllable when the failure or malfunction occurs at any speed or altitude within the approved operating limitations that is critical for the type of failure being considered.

(2) The controllability and manoeuvrability requirements of this CS-25 are met within a practical operational flight envelope (for example, speed, altitude, normal acceleration, and aeroplane configurations) which is described in the Aeroplane Flight Manual; and

(3) The trim, stability, and stall characteristics are not impaired below a level needed to permit continued safe flight and landing.

[Amdt 25/18]
[Amdt 25/24]

CS 25.675 Stops

ED Decision 2003/2/RM

(a) Each control system must have stops that positively limit the range of motion of each movable aerodynamic surface controlled by the system.

(b) Each stop must be located so that wear, slackness, or take-up adjustments will not adversely affect the control characteristics of the aeroplane because of a change in the range of surface travel.

(c) Each stop must be able to withstand any loads corresponding to the design conditions for the control system.

CS 25.677 Trim systems

ED Decision 2003/2/RM

(a) Trim controls must be designed to prevent inadvertent or abrupt operation and to operate in the plane, and the sense of motion, of the aeroplane.

(b) There must be means adjacent to the trim control to indicate the direction of the control movement relative to the aeroplane motion. In addition, there must be clearly visible means to indicate the position of the trim device with respect to the range of adjustment. The indicator must be clearly marked with the range within which it has been demonstrated that take-off is safe for all centre of gravity positions approved for take-off.

(c) Trim control systems must be designed to prevent creeping in flight. Trim tab controls must be irreversible unless the tab is appropriately balanced and shown to be free from flutter.

(d) If an irreversible tab control system is used, the part from the tab to the attachment of the irreversible unit to the aeroplane structure must consist of a rigid connection.

CS 25.679 Control system gust locks

ED Decision 2016/010/R

(See AMC 25.679)

(a) There must be a device to prevent damage to the control surfaces (including tabs), and to the control system, from gusts striking the aeroplane while it is on the ground. If the device, when engaged, prevents normal operation of the control surfaces by the pilot, it must –

(1) Automatically disengage when the pilot operates the primary flight controls in a normal manner; or

(2) Limit the operation of the aeroplane so that the pilot receives unmistakable warning at the start of take-off. (See AMC 25.679(a)(2).)

(b) The device must have means to preclude the possibility of it becoming inadvertently engaged in flight. (See AMC 25.679(b).)

[Amdt 25/18]

AMC 25.679(a)(2) Control system gust locks

ED Decision 2003/2/RM

If the device required by CS 25.679(a) limits the operation of the aeroplane by restricting the movement of a control that must be set before take-off (e.g. throttle control levers), this device should be such that it will perform the function for which it is designed even when subject to likely maladjustment or wear, so that –

a. The movement of that control is restricted as long as the device is engaged; and

b. The movement of that control is unrestricted when the device is disengaged.

AMC 25.679(b) Control system gust locks

ED Decision 2003/2/RM

For the purposes of meeting the design intent of this paragraph, flight means the time from the moment the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest after landing.

CS 25.681 Limit load static tests

ED Decision 2003/2/RM

(a) Compliance with the limit load requirements of this CS-25 must be shown by tests in which –

(1) The direction of the test loads produces the most severe loading in the control system; and

(2) Each fitting, pulley, and bracket used in attaching the system to the main structure is included.

(b) Compliance must be shown (by analyses or individual load tests) with the special factor requirements for control system joints subject to angular motion.

CS 25.683 Operation tests

ED Decision 2003/2/RM

(a) It must be shown by operation tests that when portions of the control system subject to pilot effort loads are loaded to 80% of the limit load specified for the system and the powered portions of the control system are loaded to the maximum load expected in normal operation, the system is free from –

(1) Jamming;

(2) Excessive friction; and

(3) Excessive deflection.

(b) It must be shown by analysis and, where necessary, by tests that in the presence of deflections of the aeroplane structure due to the separate application of pitch, roll and yaw limit manoeuvre loads, the control system, when loaded to obtain these limit loads and operated within its operational range of deflections can be exercised about all control axes and remain free from-

(1) Jamming;

(2) Excessive friction;

(3) Disconnection, and

(4) Any form of permanent damage.

(c) It must be shown that under vibration loads in the normal flight and ground operating conditions, no hazard can result from interference or contact with adjacent elements.

CS 25.685 Control system details

ED Decision 2016/010/R

(See AMC 25.685)

(a) Each detail of each control system must be designed and installed to prevent jamming, chafing, and interference from cargo, passengers, loose objects or the freezing of moisture. (See AMC 25.685(a).)

(b) There must be means in the cockpit to prevent the entry of foreign objects into places where they would jam the system.

(c) There must be means to prevent the slapping of cables or tubes against other parts.

(d) CS 25.689 and CS 25.693 apply to cable systems and joints.

[Amdt 25/18]

AMC 25.685(a) Control system details

ED Decision 2003/2/RM

In assessing compliance with CS 25.685(a) account should be taken of the jamming of control circuits by the accumulation of water in or on any part which is likely to freeze. Particular attention should be paid to the following:

a. The points where controls emerge from pressurised compartments.

b. Components in parts of the aeroplane which could be contaminated by the water systems of the aeroplane in normal or fault conditions; if necessary such components should be shielded.

c. Components in parts of the aeroplane where rain and/or condensed water vapour can drip or accumulate.

d. Components inside which water vapour can condense and water can accumulate.

CS 25.689 Cable systems

ED Decision 2003/2/RM

(a) Each cable, cable fitting, turnbuckle, splice, and pulley must be approved. In addition –

(1) No cable smaller than 3.2 mm (0·125 inch) diameter may be used in the aileron, elevator, or rudder systems; and

(2) Each cable system must be designed so that there will be no hazardous change in cable tension throughout the range of travel under operating conditions and temperature variations.

(b) Each kind and size of pulley must correspond to the cable with which it is used. Pulleys and sprockets must have closely fitted guards to prevent the cables and chains from being displaced or fouled. Each pulley must lie in the plane passing through the cable so that the cable does not rub against the pulley flange.

(c) Fairleads must be installed so that they do not cause a change in cable direction of more than three degrees.

(d) Clevis pins subject to load or motion and retained only by cotter pins may not be used in the control system.

(e) Turnbuckles must be attached to parts having angular motion in a manner that will positively prevent binding throughout the range of travel.

(f) There must be provisions for visual inspection of fairleads, pulleys, terminals, and turnbuckles.

CS 25.693 Joints

ED Decision 2003/2/RM

Control system joints (in push-pull systems) that are subject to angular motion, except those in ball and roller bearing systems must have a special factor of safety of not less than 3·33 with respect to the ultimate bearing strength of the softest material used as a bearing. This factor may be reduced to 2·0 for joints in cable control systems. For ball or roller bearings, the approved ratings, may not be exceeded.

CS 25.697 Lift and drag devices, controls

ED Decision 2003/2/RM

(a) Each lift device control must be designed so that the pilots can place the device in any takeoff, en-route, approach, or landing position established under CS 25.101(d). Lift and drag devices must maintain the selected positions, except for movement produced by an automatic positioning or load limiting device, without further attention by the pilots.

(b) Each lift and drag device control must be designed and located to make inadvertent operation improbable. Lift and drag devices intended for ground operation only must have means to prevent the inadvertent operation of their controls in flight if that operation could be hazardous.

(c) The rate of motion of the surfaces in response to the operation of the control and the characteristics of the automatic positioning or load limiting device must give satisfactory flight and performance characteristics under steady or changing conditions of airspeed, engine power, and aeroplane attitude.

(d) The lift device control must be designed to retract the surfaces from the fully extended position, during steady flight at maximum continuous engine power at any speed below V_F + 17 km/hr (9·0 knots).

CS 25.699 Lift and drag device indicator

ED Decision 2003/2/RM

(a) There must be means to indicate to the pilots the position of each lift or drag device having a separate control in the cockpit to adjust its position. In addition, an indication of unsymmetrical operation or other malfunction in the lift or drag device systems must be provided when such indication is necessary to enable the pilots to prevent or counteract an unsafe flight or ground condition, considering the effects on flight characteristics and performance.

(b) There must be means to indicate to the pilots the take-off, en-route, approach, and landing lift device positions.

(c) If any extension of the lift and drag device beyond the landing position is possible, the control must be clearly marked to identify this range of extension.

CS 25.701 Flap and slat interconnection

ED Decision 2016/010/R

(See AMC 25.701)

(a) Unless the aeroplane has safe flight characteristics with the flaps or slats retracted on one side and extended on the other, the motion of flaps or slats on opposite sides of the plane of symmetry must be synchronised by a mechanical interconnection or approved equivalent means.

(b) If a wing-flap or slat interconnection or equivalent means is used, it must be designed to account for the applicable unsymmetrical loads, including those resulting from flight with the engines on one side of the plane of symmetry inoperative and the remaining engines at take-off power.

(c) For aeroplanes with flaps or slats that are not subjected to slipstream conditions, the structure must be designed for the loads imposed when the wing-flaps or slats on one side are carrying the most severe load occurring in the prescribed symmetrical conditions and those on the other side are carrying not more than 80% of that load.