

CS-25 AMENDMENT 4 - CHANGE INFORMATION

Certification Specifications (CS) are used for establishing the certification basis for applications made after the date of entry into force of a CS including any amendments. Since the complete text of a CS, including any amendments to it, is relevant for establishing the certification basis, the Agency has decided to enact and publish all amendments to CS's as consolidated documents instead of enacting and publishing only the amended text.

Consequently, except for a note "Amdt. 25/4" under the amended paragraph, the consolidated text of CS-25 does not allow readers to see the detailed changes introduced by the new amendment. To allow readers to also see these detailed changes this document has been created. The same format as for publication of Notices of Proposed Amendments has been used to show the changes:

1. text not affected by the new amendment remains the same: unchanged
2. deleted text is shown with a strike through: ~~deleted~~
3. new text is highlighted with grey shading: **new**
4.
Indicates that remaining text is unchanged in front of or following the reflected amendment.
....

CS-25 BOOK 1 – AIRWORTHINESS CODE

1. Add reference to AMC in CS 25.729 and delete references to obsolete AMCs so that the text reads:

CS 25.729 Retracting mechanism
(See AMC 25.729)

- (e) Position indicator and warning device. ~~(See AMC 25.729 (e).)~~ If a retractable landing gear is used ...
- ...
- (f) Protection of equipment ... be protected from the damaging effects of –
- (1) A bursting tyre, ~~(see AMC 25.729 (f))~~;
 - (2) A loose tyre tread unless it is shown that a loose tyre tread cannot cause damage; and
 - (3) Possible wheel brake temperatures ~~(see AMC 25.729 (f))~~.

2. Add reference to AMC in CS 25.773 and amend CS 25.773(b) to read:

CS 25.773 Pilot compartment view
(See AMC 25.773)

....

(b) *Precipitation conditions.* For precipitation conditions, the following apply:

- (1) ...
 - (i) ...
 - (ii) The icing conditions specified in CS 25.1419 if certification with ice protection provisions is requested. ~~(See AMC 25.773(b)(1)(ii))~~
 - (2) ...
 - (3) The first pilot must have a window that:
 - (i) ~~a window that~~ is openable under the conditions prescribed in sub-paragraph (b)(1) of this paragraph when the cabin is not pressurised; ~~provides the view specified in that paragraph, and gives sufficient protection from the elements against impairment of the pilot's vision, or~~
 - (ii) provides the view specified in (b)(1); and
 - (iii) gives sufficient protection from the elements against impairment of the pilot's vision.
- ~~a. An alternative means to maintain a clear view under the conditions specified in sub-paragraph (b)(1) of this paragraph, considering the probable damage due to severe hail encounter.~~
- (4) ...
 - (i) Any system failure or combination of failures, which is not Extremely Improbable in accordance with CS 25.1309, under the precipitation conditions specified in sub-paragraph (b)(1) of this paragraph.
 - (ii) An encounter with severe hail, birds or insects.

....

3. Replace existing CS 25.783 with the following:

CS 25.783 Fuselage Doors

(a) *General.* This paragraph applies to fuselage doors, which includes all doors, hatches, openable windows, access panels, covers, etc., on the exterior of the fuselage that do not require the use of tools to open or close. This also applies to each door or hatch through a pressure bulkhead, including any bulkhead that is specifically designed to function as a secondary bulkhead under the prescribed failure conditions of CS-25. These doors must meet the requirements of this paragraph, taking into account both pressurised and unpressurised flight, and must be designed as follows:

(1) Each door must have means to safeguard against opening in flight as a result of mechanical failure, or failure of any single structural element.

(2) Each door that could be a hazard if it unlatches must be designed so that unlatching during pressurised and unpressurised flight from the fully closed, latched, and locked condition is extremely improbable. This must be shown by safety analysis.

(3) Each element of each door operating system must be designed or, where impracticable, distinctively and permanently marked, to minimise the probability of incorrect assembly and adjustment that could result in a malfunction.

(4) All sources of power that could initiate unlocking or unlatching of any door must be automatically isolated from the latching and locking systems prior to flight and it must not be possible to restore power to the door during flight.

(5) Each removable bolt, screw, nut, pin, or other removable fastener must meet the locking requirements of CS 25.607.

(6) Certain doors, as specified by CS 25.807(h), must also meet the applicable requirements of CS 25.809 through CS 25.812 for emergency exits.

(b) *Opening by persons.* There must be a means to safeguard each door against opening during flight due to inadvertent action by persons. In addition, for each door that could be a hazard, design precautions must be taken to minimise the possibility for a person to open the door intentionally during flight. If these precautions include the use of auxiliary devices, those devices and their controlling systems must be designed so that:

(1) no single failure will prevent more than one exit from being opened, and

(2) failures that would prevent opening of any exit after landing must not be more probable than remote.

(c) *Pressurisation prevention means.* There must be a provision to prevent pressurisation of the aeroplane to an unsafe level if any door subject to pressurisation is not fully closed, latched, and locked.

(1) The provision must be designed to function after any single failure, or after any combination of failures not shown to be extremely improbable.

(2) Doors that meet the conditions described in sub-paragraph (h) of this paragraph are not required to have a dedicated pressurisation prevention means if, from every possible position of the door, it will remain open to the extent that it prevents pressurisation or safely close and latch as pressurisation takes place. This must also be shown with any single failure and malfunction except that:

(i) with failures or malfunctions in the latching mechanism, it need not latch after closing, and

(ii) with jamming as a result of mechanical failure or blocking debris, the door need not close and latch if it can be shown that the pressurisation loads on the jammed door or mechanism would not result in an unsafe condition.

(d) *Latching and locking.* The latching and locking mechanisms must be designed as follows:

(1) There must be a provision to latch each door.

(2) The latches and their operating mechanism must be designed so that, under all aeroplane flight and ground loading conditions, with the door latched, there is no force or torque tending to unlatch the latches. In addition, the latching system must include a means to secure the latches in the latched position. This means must be independent of the locking system.

(3) Each door subject to pressurisation, and for which the initial opening movement is not inward, must:

(i) have an individual lock for each latch;

(ii) have the lock located as close as practicable to the latch; and

(iii) be designed so that, during pressurised flight, no single failure in the locking system would prevent the locks from restraining the latches necessary to secure the door.

(4) Each door for which the initial opening movement is inward, and unlatching of the door could result in a hazard, must have a locking means to prevent the latches from becoming disengaged. The locking means must ensure sufficient latching to prevent opening of the door even with a single failure of the latching mechanism.

(5) It must not be possible to position the lock in the locked position if the latch and the latching mechanism are not in the latched position.

(6) It must not be possible to unlatch the latches with the locks in the locked position. Locks must be designed to withstand the limit loads resulting from:

(i) the maximum operator effort when the latches are operated manually;

(ii) the powered latch actuators, if installed; and

(iii) the relative motion between the latch and the structural counterpart.

(7) Each door for which unlatching would not result in a hazard is not required to have a locking mechanism meeting the requirements of sub-paragraphs (d)(3) through (d)(6) of this paragraph.

(8) A door that could result in a hazard if not closed, must have means to prevent the latches from being moved to the latched position unless it can be shown that a door that is not closed would be clearly evident before flight.

(e) *Warning, caution, and advisory indications.* Doors must be provided with the following indications:

(1) There must be a positive means to indicate at the door operator's station that all required operations to close, latch, and lock the door(s) have been completed.

(2) There must be a positive means, clearly visible from each operator station for each door that could be a hazard if unlatched, to indicate if the door is not fully closed, latched, and locked.

(3) There must be a visual means on the flight deck to signal the pilots if any door is not fully closed, latched, and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed, latched, and locked indication is remote for:

(i) each door that is subject to pressurisation and for which the initial opening

movement is not inward; or

(ii) each door that could be a hazard if unlatched.

(4) There must be an aural warning to the pilots prior to or during the initial portion of take-off roll if any door is not fully closed, latched, and locked, and its opening would prevent a safe take-off and return to landing.

(f) *Visual inspection provision.* Each door for which unlatching could be a hazard must have a provision for direct visual inspection to determine, without ambiguity, if the door is fully closed, latched, and locked. The provision must be permanent and discernible under operational lighting conditions, or by means of a flashlight or equivalent light source.

(g) *Certain maintenance doors, removable emergency exits, and access panels.* Some doors not normally opened except for maintenance purposes or emergency evacuation and some access panels need not comply with certain sub-paragraphs of this paragraph as follows:

(1) Access panels that are not subject to cabin pressurisation and would not be a hazard if open during flight need not comply with sub-paragraphs (a) through (f) of this paragraph, but must have a means to prevent inadvertent opening during flight.

(2) Inward-opening removable emergency exits that are not normally removed, except for maintenance purposes or emergency evacuation, and flight deck-openable windows need not comply with sub-paragraphs (c) and (f) of this paragraph.

(3) Maintenance doors that meet the conditions of sub-paragraph (h) of this paragraph, and for which a placard is provided limiting use to maintenance access, need not comply with sub-paragraphs (c) and (f) of this paragraph.

(h) *Doors that are not a hazard.* For the purposes of this paragraph, a door is considered not to be a hazard in the unlatched condition during flight, provided it can be shown to meet all of the following conditions:

(1) Doors in pressurised compartments would remain in the fully closed position if not restrained by the latches when subject to a pressure greater than 3.447 kPa (0.5 psi). Opening by persons, either inadvertently or intentionally, need not be considered in making this determination.

(2) The door would remain inside the aeroplane or remain attached to the aeroplane if it opens either in pressurised or unpressurised portions of the flight. This determination must include the consideration of inadvertent and intentional opening by persons during either pressurised or unpressurised portions of the flight.

(3) The disengagement of the latches during flight would not allow depressurisation of the cabin to an unsafe level. This safety assessment must include the physiological effects on the occupants.

(4) The open door during flight would not create aerodynamic interference that could preclude safe flight and landing.

(5) The aeroplane would meet the structural design requirements with the door open. This assessment must include the aeroelastic stability requirements of CS 25.629, as well as the strength requirements of Subpart C.

(6) The unlatching or opening of the door must not preclude safe flight and landing as a result of interaction with other systems or structures.

4. Amend CS 25.807 by adding new sub-paragraph (h) and (k) to read as follows:

CS 25.807 Emergency exits

....

(g) [Reserved]

(h) *Other exits.* The following exits must also meet the applicable emergency exit requirements of CS 25.809 through 25.812, and must be readily accessible:

(1) Each emergency exit in the passenger compartment in excess of the minimum number of required emergency exits

(2) Any other floor-level door or exit that is accessible from the passenger compartment and is as large or larger than a Type II exit, but less than 1.17m (46 inches) wide.

(3) Any other ventral or tail passenger cone exit.

(i) [Reserved]

(j) [Reserved]

(k) Each passenger entry door in the side of the fuselage must qualify as a Type A, Type I, or Type II passenger emergency exit.

....

5. Amend CS 25.809 by revising sub-paragraph (b), by adding a new sub-paragraph (b)(3), by revising sub-paragraphs (c) and by replacing sub-paragraph (f) to read as follows:

CS 25.809 Emergency exit arrangement

(b) readily accessible to the flight crew area. Inward opening doors may be used if there are means to prevent occupants from crowding against the door to an extent that would interfere with the opening of the door. Each emergency exit must be capable...

....

(1)

(2)

(3) Even though persons may be crowded against the door on the inside of the aeroplane.

(c) The means of opening emergency exits must be simple and obvious; ~~and~~ may not require exceptional effort; and must be arranged and marked so that it can be readily located and operated, even in darkness. Internal exit-opening means involving sequence operations (such as operation of two handles or latches or the release of safety catches) may be used for flight crew emergency exits if it can be reasonably established that these means are simple and obvious to crewmembers trained in their use.

....

(f) Each door must be located where persons using them will not be endangered by the propellers when appropriate operating procedures are used.

....

6. Amend CS 25.810 by adding a new sub-paragraph (e) to read as follows:

CS 25.810 Emergency egress assist means and escape routes

....

(e) If an integral stair is installed in a passenger entry door that is qualified as a passenger emergency exit, the stair must be designed so that, under the following conditions, the

effectiveness of passenger emergency egress will not be impaired:

(1) The door, integral stair, and operating mechanism have been subjected to the inertia forces specified in CS 25.561(b)(3), acting separately relative to the surrounding structure.

(2) The aeroplane is in the normal ground attitude and in each of the attitudes corresponding to collapse of one or more legs of the landing gear.

7. Add a new CS 25.820 to read as follows:

CS 25.820 Lavatory doors

All lavatory doors must be designed to preclude anyone from becoming trapped inside the lavatory. If a locking mechanism is installed, it must be capable of being unlocked from the outside without the aid of special tools.

8. Revise CS 25.851(b)(2) to read:

CS 25.851 Fire extinguishers

....

(b) *Built-in fire extinguishers.* If a built-in fire extinguisher is provided-

(1) ...

(2) The capacity of each required built-in fire extinguishing system must be adequate for any fire likely to occur **anywhere** in the compartment where used, considering the volume of the compartment and the ventilation rate. (see AMC 25.851(b)).

9. Delete the existing paragraph CS 25.1329 (Automatic Pilot System) in its entirety and replace with the following::

~~CS 25.1329 — Automatic pilot system~~

~~(See AMC 25.1329.)~~

~~(a) — Each automatic pilot system must be approved and must be designed so that the automatic pilot can be quickly and positively disengaged by the pilots to prevent it from interfering with their control of the aeroplane.~~

~~(b) — Unless there is automatic synchronisation, each system must have a means to readily indicate to the pilot the alignment of the actuating device in relation to the control system it operates.~~

~~(c) — Each manually operated control for the system must be readily accessible to the pilots.~~

~~(d) — Quick release (emergency) controls must be on both control wheels, on the side of each wheel opposite the throttles.~~

~~(e) — Attitude controls must operate in the plane and sense of motion specified in CS 25.777 (b) and 25.779 (a) for cockpit controls. The direction of motion must be plainly indicated on, or adjacent to, each control.~~

~~(f) — The system must be designed and adjusted so that, within the range of adjustment available to the human pilot, it cannot produce hazardous loads on the aeroplane, or create hazardous deviations in the flight path, under any condition of flight appropriate to its use, either during normal operation, or in the event of a malfunction, assuming that corrective action begins within a reasonable period of time.~~

~~(g) — If the automatic pilot integrates signals from auxiliary controls or furnishes signals for operation of other equipment, there must be positive interlocks and sequencing of engagement to prevent improper operation. Protection against adverse interaction of integrated components, resulting from a malfunction, is also required.~~

~~(h) — Means must be provided to indicate to the flight crew the current mode of operation and any modes armed by the pilot. Selector switch position is not acceptable as a means of indication.~~

~~(i) — A warning must be provided to each pilot in the event of automatic or manual disengagement of the automatic pilot. (See CS 25.1322 and AMC 25.1322.)~~

CS 25.1329 Flight Guidance System

(See AMC Nos. 1 and 2 to CS 25.1329)

- (a) Quick disengagement controls for the autopilot and autothrust functions must be provided for each pilot. The autopilot quick disengagement controls must be located on both control wheels (or equivalent). The autothrust quick disengagement controls must be located on the thrust control levers. Quick disengagement controls must be readily accessible to each pilot while operating the control wheel (or equivalent) and thrust control levers.
- (b) The effects of a failure of the system to disengage the autopilot or autothrust functions when manually commanded by the pilot must be assessed in accordance with the specifications of CS 25.1309.
- (c) Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a transient response affecting the control or flight path of the aeroplane any greater than a minor transient.
- (d) Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce a transient response affecting the control or flight path of the aeroplane any greater than a minor transient.
- (e) Under rare-normal or non-normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce a transient

response affecting the control or flight path of the aeroplane any greater than a significant transient.

- (f) The function and direction of motion of each command reference control (e.g., heading select, vertical speed) must be readily apparent or plainly indicated on, or adjacent to, each control if necessary to prevent inappropriate use or confusion.
- (g) Under any condition of flight appropriate to its use, the flight guidance system must not:
 - produce unacceptable loads on the aeroplane (in accordance with CS 25.302), or
 - create hazardous deviations in the flight path.

This applies to both fault-free operation and in the event of a malfunction, and assumes that the pilot begins corrective action within a reasonable period of time.

- (h) When the flight guidance system is in use, a means must be provided to avoid excursions beyond an acceptable margin from the speed range of the normal flight envelope. If the aircraft experiences an excursion outside this range, the flight guidance system must not provide guidance or control to an unsafe speed.
- (i) The flight guidance system functions, controls, indications, and alerts must be designed to minimise flight crew errors and confusion concerning the behaviour and operation of the flight guidance system. Means must be provided to indicate the current mode of operation, including any armed modes, transitions, and reversions. Selector switch position is not an acceptable means of indication. The controls and indications must be grouped and presented in a logical and consistent manner. The indications must be visible to each pilot under all expected lighting conditions.
- (j) Following disengagement of the autopilot, a warning (visual and aural) must be provided to each pilot and be timely and distinct from all other cockpit warnings.
- (k) Following disengagement of the autothrust function, a caution must be provided to each pilot.
- (l) The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls.
- (m) During autothrust operation, it must be possible for the flight crew to move the thrust levers without requiring excessive force. The autothrust response to flight crew override must not create an unsafe condition.

10. Delete paragraph CS 25.1335 (Flight Director Systems) in its entirety:

~~CS 25.1335 Flight director systems~~

~~Means must be provided to indicate to the flight crew the current mode of operation and any modes armed by the pilot. Selector switch position is not acceptable as a means of indication.~~

11. Revise CS 25.1439 to read:

CS 25.1439 Protective breathing equipment

(a) Fixed (stationary, or built in) protective breathing equipment must be installed for the use of the flight crew, and at least one portable protective breathing equipment shall be located at or near the flight deck for use by a flight crew member. In addition, portable protective breathing equipment must be installed for the use of appropriate crew members for fighting fires in compartments accessible in flight other than the flight deck. This includes isolated compartments and upper and lower lobe galleys, in which crew member occupancy is permitted during flight. Equipment must be installed for the maximum number of crew members expected to be in the area during any operation. ~~Protective breathing equipment must be installed for use of appropriate crewmembers. Such equipment must be located so as to be available for use in compartments accessible in flight.~~

(b) For protective breathing equipment required by sub-paragraph (a) of this paragraph ~~CS 25.1439(a)~~ or by the applicable Operating Regulations, the following apply:

(1) ...

...

(3) Equipment, including portable equipment, ~~while in use~~ must allow communication with other crew members while in use. Equipment available at flight crew assigned duty stations must also enable the flight crew to use radio equipment.

(4) The part of the equipment protecting the eyes ~~may~~ must not cause any appreciable adverse effect on vision and must allow corrective glasses to be worn.

(5) ~~Each dispensing~~ The equipment must supply protective oxygen of 15 minutes duration per crew member at a pressure altitude of 2438m (8000ft) with a respiratory minute volume of 30 litres per minute BTPD. The equipment and system must be designed to prevent any inward leakage to the inside of the mask device and prevent any outward leakage causing significant increase in the oxygen content of the local ambient atmosphere. If a demand oxygen system is used, a supply of 300 litres of free oxygen at 21°C (70°F) and 760 mm Hg pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. If a continuous flow open circuit protective breathing system is used a flow rate of 60 litres per minute at 2438 m (8 000 ft) (45 litres per minute at sea level) and a supply of 600 litres of free oxygen at 21°C (70°F) and 204 kPa (760 mm Hg) pressure is considered to be of 15-minute duration at the prescribed altitude and minute volume. Continuous flow systems must not increase the ambient oxygen content of the local atmosphere above that of demand systems. BTPD refers to body temperature conditions, that is 37°C (99°F), at ambient pressure, dry. (See AMC 25.1439(b)(5))

(6) The equipment must meet the requirements of CS 25.1441.

12. Revise CS 25.1453 to read:

**CS 25.1453 Protection of oxygen equipment from rupture
(~~See AMC 25.1453~~)**

(a) Each element of the system, excluding chemical oxygen generators, must have sufficient strength to withstand the maximum working pressures and temperatures in combination with any externally applied load, arising from consideration of limit structural loads that may be acting on that part of the system in service.

(1) The maximum working pressure must include the maximum normal operating pressure, the transient and surge pressures, tolerances of any pressure limiting means and possible pressure variations in the normal operating modes. Transient or surge pressures need not be considered except where these exceed the maximum normal operating pressure multiplied by 1.10.

(2) Account must be taken of the effects of temperature up to the maximum anticipated temperature to which the system may be subjected.

(3) Strength demonstration using proof pressure and burst pressure coefficients specified in Table 1 is acceptable, unless higher stresses result when elements are subjected to combined pressure, temperature and structural loads.

(i) The proof and burst factors in Table 1 must be applied to maximum working pressure obtained from sub-paragraph (a)(1) with consideration given to the temperature of sub-paragraph (a)(2).

(ii) Proof pressure must be held for a minimum of 2 minutes and must not cause any leakage or permanent distortion.

(iii) Burst pressure must be held for a minimum of 1 minute and must not cause rupture but some distortion is allowed.

TABLE 1

Systems Element	Proof Factor	Burst Factor
Cylinders (i.e. pressure vessels)	1.5	2.0
Flexible hoses	2.0	4.0
Pipes and couplings	1.5	3.0
Other components	1.5	2.0

(b) Oxygen pressure sources and tubing pipe lines between the sources and shut-off means must be:

(1) Protected from unsafe temperatures, and

(2) Located where the probability and hazard of rupture in a crash landing are minimised.

- (c) Parts of the system subjected to high oxygen pressure must be kept to a minimum and must be remote from occupied compartments to the extent practicable. Where such parts are installed within occupied compartments they must be protected from accidental damage.
- (d) Each pressure source (e.g. tanks or cylinders) must be provided with a protective device (e.g. rupture disc). Such devices must prevent the pressure from exceeding the maximum working pressure multiplied by 1.5.
- (e) Pressure limiting devices (e.g. relief valves), provided to protect parts of the system from excessive pressure, must prevent the pressures from exceeding the applicable maximum working pressure multiplied by 1.33 in the event of malfunction of the normal pressure controlling means (e.g. pressure reducing valve).
- (f) The discharge from each protective device and pressure limiting device must be vented overboard in such a manner as to preclude blockage by ice or contamination, unless it can be shown that no hazard exists by its discharge within the compartment in which it is installed. In assessing whether such hazard exists consideration must be given to the quantity and discharge rate of the oxygen released, the volume of the compartment into which it is discharging, the rate of ventilation within the compartment and the fire risk due to the installation of any potentially flammable fluid systems within the compartment.

13. Make a correction in Appendix F, Part II, sub-paragraph (f)(4) as follows:

- (4) Turn on the burner and ensure that the thermocouples are reading $1038 \pm 38.56^{\circ}\text{C}$ ($1900 \pm 100^{\circ}\text{F}$) to ensure steady state conditions have been achieved.

CS-25 BOOK 2 - ACCEPTABLE MEANS OF COMPLIANCE (AMC)

14. Delete existing AMCs 25.729(e) & 25.729(f).

AMC 25.729(e)

~~Retracting Mechanism~~

~~1 — When light indicators are used, they should be arranged so that —~~

~~a. — A green light for each unit is illuminated only when the unit is secured in the correct landing position.~~

~~b. — A warning light consistent with CS 25.1322 is illuminated at all times except when the landing gear and its doors are secured in the landing or retracted position.~~

~~2 — The warning required by CS 25.729(e)(2) should preferably operate whatever the position of wing leading or trailing edge devices or the number of engines operating.~~

~~3 The design should be such that nuisance activation of the warning is minimised, for example—~~

~~a. When the landing gear is retracted after a take-off following an engine failure, or during a take-off when a common flap setting is used for take-off and landing;—~~

~~b. When the throttles are closed in a normal descent; or~~

~~c. When flying at low altitude in clean or low speed configuration (special operation).~~

~~4 Inhibition of the warning above a safe altitude out of final approach phase either automatically or by some other means to prevent these situations is acceptable, but it should automatically reset for a further approach.~~

~~5 Means to de-activate the warning required by CS 25.729(e) may be installed for use in abnormal or emergency conditions provided that it is not readily available to the flight crew, i.e. the control device is protected against inadvertent actuation by the flight crew and its de-activated state is obvious to the flight crew.~~

~~AMC 25.729(f)~~

~~Protection of Equipment on Landing Gear and in Wheel Wells~~

~~The use of fusible plugs in the wheels is not a complete safeguard against damage due to tyre explosion.~~

~~Where brake overheating could be damaging to the structure of, or equipment in, the wheel wells, an indication of brake temperature should be provided to warn the pilot.~~

15. Introduce a new AMC 25.729 to read:

AMC 25.729

Retracting Mechanism

1. PURPOSE. This Acceptable Means of Compliance (AMC) provides guidance material for use as an acceptable means of demonstrating compliance with the landing gear retracting mechanism requirements of the Certification Specification (CS) for large aeroplanes.

2. RELATED DOCUMENTS.

a. *Related Certification Specifications.* CS 25.729 and other paragraphs relating to landing gear retracting mechanism installations together with their applicable AMCs, if any. Paragraphs which prescribe requirements for the design, substantiation, and certification of landing gear retracting mechanisms include:

CS 25.111	Take-off path
CS 25.301	Loads
CS25.303	Factor of safety

CS 25.305	Strength and deformation
CS 25.307	Proof of structure
CS 25.333	Flight envelope
CS 25.471	General [Ground loads]
CS 25.561	General [Emergency Landing Conditions]
CS 25.601	General [Design and Construction]
CS 25.603	Materials
CS 25.605	Fabrication methods
CS 25.607	Fasteners
CS 25.609	Protection of structure
CS 25.613	Material strength properties
CS 25.619	Special factors
CS 25.621	Casting factors
CS 25.623	Bearing factors
CS 25.625	Fitting factors
CS 25.729	Retracting mechanism
CS 25.777	Cockpit controls
CS 25.779	Motion and effect of cockpit controls
CS 25.781	Cockpit control knob shape
CS 25.863	Flammable fluid fire protection
CS 25.869	Fire protection: systems
CS 25.899	Electrical bonding, etc.
CS 25.1301	Function and installation
CS 25.1309	Equipment, systems and installations
CS 25.1315	Negative acceleration
CS 25.1316	System lightning protection
CS 25.1322	Warning, caution and advisory lights
CS 25.1353	Electrical equipment and installations
CS 25.1357	Circuit protective devices
CS 25.1360	Precautions against injury
CS 25.1435	Hydraulic systems
CS 25.1515	Landing gear speeds
CS 25.1555	Control markings
CS 25.1583	Operating limitations
CS 25.1585	Operating procedures

b. *FAA Advisory Circulars (AC's).*

AC 20-34D	Prevention of Retractable Landing Gear Failures
AC 23-17B	Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships
AC 25.1309-1A	System Design and Analysis
AC 25-7A	Flight Test Guide for Certification of Transport Category Airplanes
AC 25-22	Certification of Transport Airplane Mechanical Systems
AC 43.13-1B	Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair.

c. *Federal Aviation Administration Orders.*

Order 8110.4C Type Certification Process

Advisory Circulars and FAA Orders can be obtained from the U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

d. *Society of Automotive Engineers (SAE) Documents.*

SAE AIR-4566	Crashworthiness Landing Gear Design
SAE ARP-1311A	Landing Gear - Aircraft
ISO 7137	Environmental Conditions and Test Procedures for Airborne Equipment (not an SAE document but is available from the SAE)

These documents can be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.

e. *Industry Documents.*

(1) EUROCAE ED-14D/RTCA, Inc., Document No. DO-160D,
Environmental Conditions and Test Procedures for Airborne Equipment.

(2) EUROCAE ED-12B/RTCA, Inc., Document No. DO-178B,
Software Considerations in Airborne Systems and Equipment Certification.

These documents can be obtained from EUROCAE, 17 rue Hamelin, 75783 Paris Cedex 15, France

f. *Military Documents.*

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

This document can be obtained from the Department of Defence, DODSSP, Standardisation Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

4. DISCUSSION.

a. *Intent of rule.* (Reference CS 25.729 Retracting mechanism)

This rule provides minimum design and certification requirements for landing gear actuation systems to address:

- (1) Structural integrity for the nose and main landing gear, retracting mechanism(s), doors, gear supporting structure for loads imposed during flight;
- (2) Positive locking of the kinematic mechanisms;
- (3) Redundant means of extending the landing gear;
- (4) Demonstration of proper operation by test;
- (5) Gear up-and-locked and down-and-locked position indications and aural warning;
- (6) Equipment damage from tyre burst, loose tread, and wheel brake temperatures.

b. *Demonstration of retracting mechanism proper functioning.* (Reference CS 25.729(d) Operation test)

Guidance addressing flight testing used to demonstrate compliance with this paragraph may be found in EASA AMC equivalent to FAA Advisory Circular (AC) 25-7A, Flight Test Guide for Transport Category Aeroplanes, chapter 4, section 4, paragraph 52, issued June 3, 1999.

c. *Retracting mechanism Indication.* (Reference CS 25.729(e) Position indicator and warning device)

- (1) When light indicators are used, they should be arranged so that-
 - (i) A green light for each unit is illuminated only when the unit is secured in the correct landing position.
 - (ii) A warning light consistent with CS 25.1322 is illuminated at all times except when the landing gear and its doors are secured in the landing or retracted position.
- (2) The warning required by CS 25.729(e)(2) should preferably operate whatever the position of wing leading- or trailing-edge devices or the number of engines operating.
- (3) The design should be such that nuisance activation of the warning is minimised, for example-
 - (i) When the landing gear is retracted after a take-off following an engine failure, or during a take-off when a common flap setting is used for take-off and landing;
 - (ii) When the throttles are closed in a normal descent; or
 - (iii) When flying at low altitude in clean or low speed configuration (special operation).
- (4) Inhibition of the warning above a safe altitude out of final approach phase either automatically or by some other means to prevent these situations is acceptable, but it should automatically reset for a further approach.
- (5) Means to de-activate the warning required by CS 25.729(e) may be installed for use in abnormal or emergency conditions provided that it is not readily available to the flight crew, i.e. the control device is protected against inadvertent actuation by the flight crew and its de-activated state is obvious to the flight crew.

d. *Protection of equipment on landing gear and in wheel wells.* (Reference CS 25.729(f) Protection of equipment on landing gear and in wheel wells)

The use of fusible plugs in the wheels is not a complete safeguard against damage due to tyre explosion.

Where brake overheating could be damaging to the structure of, or equipment in, the wheel wells, an indication of brake temperature should be provided to warn the pilot.

e. *Definitions.* For definitions of V_{SR} and V_C , see CS-Definitions 2, titled Abbreviations and symbols.

16. Delete existing AMC 25.773(b)(1)(ii) and introduce a new AMC 25.773 to read:

AMC 25.773(b)(1)(ii)

Pilot Compartment View

~~For windshields protected by the application of electrical heat, a nominal heating capacity of 70 W/dm² would be adequate.~~

AMC 25.773

Pilot compartment view

The FAA Advisory Circular AC 25.773-1 : Pilot Compartment View Design Considerations (January 8, 1993), is accepted by the EASA as providing acceptable means of compliance with CS 25.773.

17. Introduce a new Acceptable Means Of Compliance (AMC 25.783) as follows:

AMC 25.783

Fuselage Doors

PURPOSE

This Acceptable Means Of Compliance, which is similar to the FAA Advisory Circular AC 25.783-1A describes an acceptable means for showing compliance with the requirements of CS-25 dealing with the certification of fuselage external doors and hatches.

The means of compliance described in this document is intended to provide guidance to supplement the engineering and operational judgement that must form the basis of any compliance findings relative to the structural and functional safety standards for doors and their operating systems

This document describes an acceptable means, but not the only means, for demonstrating compliance with the requirements. Terms such as “shall” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described in this document is used.

2. RELATED CS PARAGRAPHS The contents of this AMC are considered by the EASA in determining compliance of doors with the safety requirements of CS 25.783. Other related paragraphs are:

CS 25.571, “Damage-tolerance and fatigue evaluation of structure”

CS 25.607, “Fasteners”

CS 25.703, “Take-off warning system”

CS 25.809, “Emergency exit arrangement”

3. DEFINITIONS OF TERMS

Inconsistent or inaccurate use of terms may lead to the installation of doors and hatches that do not fully meet the safety objectives of the regulations. To ensure that such installations fully comply with the regulations, the following definitions should be used when showing compliance with CS 25.783:

a. “*Closed*” means that the door has been placed within the door frame in such a position that the latches can be operated to the “latched” condition. “*Fully closed*” means that the

door is placed within the door frame in the position it will occupy when the latches are in the latched condition.

- b. “Door” includes all doors, hatches, openable windows, access panels, covers, etc. on the exterior of the fuselage which do not require the use of tools to open or close. This also includes each door or hatch through a pressure bulkhead including any bulkhead that is specifically designed to function as a secondary bulkhead under the prescribed failure conditions of CS-25.
- c. “Door operator’s station” means the location(s) where the door closing, latching and locking operations are performed.
- d. “Emergency exit” is an exit designated for use in an emergency evacuation.
- e. “Exit” is a door designed to allow egress from the aeroplane.
- f. “Flight” refers to that period of time from start of the take-off roll until the aeroplane comes to rest after landing.
- g. “Inadvertent action by persons” means an act committed without forethought, consideration or consultation.
- h. “Initial inward opening movement”. *In order for a door design to be classified as having inward initial opening movement the design of its stops, guides and rollers and associated mechanism, should be such that positive pressurisation of the fuselage acting on the mean pressure plane of the fully closed door must always ensure a positive door closure force. (See AMC 25.783 Paragraph 5, (d) (4)).*
- i. “Initial opening movement,” refers to that door movement caused by operation of a handle or other door control mechanism, which is required to place the door in a position free of structure that would interfere with continued opening of the door.
- j. “Inward” means having a directional component of movement that is inward with respect to the mean (pressure) plane of the body cut-out.
- k. “Latched” means the latches are engaged with their structural counterparts and held in position by the latch operating mechanism.
- l. “Latches” are movable mechanical elements that, when engaged, prevent the door from opening.
- m. “Latching system” means the latch operating system and the latches.
- n. “Locked” means the locks are engaged and held in position by the lock operating mechanism.
- o. “Locking system” means the lock operating system and the locks.
- p. “Locks” are mechanical elements in addition to the latch operating mechanism that monitor the latch positions, and when engaged, prevent latches from becoming disengaged.
- q. “Stops” are fixed structural elements on the door and door frame that, when in contact with each other, limit the directions in which the door is free to move.

4. BACKGROUND

4.1 History of incidents and accidents

There is a history of incidents and accidents in which doors, fitted in pressurised aeroplanes, have opened during pressurised and unpressurised flight. Some of these inadvertent openings have resulted in fatal crashes. After one fatal accident that occurred in 1974, the FAA and industry representatives formed a design review team to examine the current regulatory requirements for doors to determine if those regulations were adequate to ensure safety. The team's review and eventual recommendations led to the FAA issuing Amendment 25-54 to 14 CFR part 25 in 1980, that was adopted by the JAA in JAR-25 Change 10 in 1983, which significantly improved the safety standards for doors installed on large aeroplanes. Included as part of JAR-25 Change 10 (Amendment 25-54) was JAR 25.783, "Doors," which provides the airworthiness standards for doors installed on large aeroplanes.

Although there have been additional minor revisions to JAR 25.783 subsequent to the issuance of Change 10 (Amendment 25-54), the safety standards for doors have remained essentially the same since 1980.

4.2 Continuing safety problems

In spite of the improved standards brought about in 1980, there have continued to be safety problems, especially with regard to cargo doors. Cargo doors are often operated by persons having little formal instruction in their operation. Sometimes the operator is required to carry out several actions in sequence to complete the door opening and closing operations. Failure to complete all sequences during closure can have serious consequences. Service history shows that several incidents of doors opening during flight have been attributed to the failure of the operator to complete the door closure and locking sequence. Other incidents have been attributable to incorrect adjustment of the door mechanism, or failure of a vital part.

4.3 Indication to the flight crew

Experience also has shown that, in some cases, the flight deck indication system has not been reliable. In other instances, the door indication system was verified to be indicating correctly, but the flight crew, for unknown reasons, was not alerted to the unsafe condition. A reliable indication of door status on the flight deck is particularly important on aeroplanes used in operations where the flight crew does not have an independent means readily available to verify that the doors are properly secured.

4.4 Large cargo doors as basic airframe structure.

On some aeroplanes, large cargo doors form part of the basic fuselage structure, so that, unless the door is properly closed and latched, the basic airframe structure is unable to carry the design aerodynamic and inertial loads. Large cargo doors also have the potential for creating control problems when an open door acts as an aerodynamic surface. In such cases, failure to secure the door properly could have catastrophic results, even when the aeroplane is unpressurised.

4.5 NTSB (USA) recommendations.

After two accidents occurred in 1989 due to the failure of cargo doors on transport category aeroplanes, the FAA chartered the Air Transport Association (ATA) of America to study the door design and operational issues again for the purpose of recommending improvements. The ATA concluded its study in 1991 and made recommendations to the FAA for improving the design standards of doors. Those recommendations together with additional recommendations

from the National Transportation Safety Board (NTSB) were considered in the development of improved standards for doors adopted by Amendment 25-114.

5. DISCUSSION OF THE CURRENT REQUIREMENTS

Service history has shown that to prevent doors from becoming a hazard by opening in flight, it is necessary to provide multiple layers of protection against failures, malfunctions, and human error. Paragraph 25.783 addresses these multiple layers of protection by requiring:

- a latching system;
- a locking system;
- indication systems;
- a pressure prevention means.

These features provide a high degree of tolerance to failures, malfunctions, and human error. Paragraph CS 25.783 intends that the latching system be designed so that it is inherently or specifically restrained from being back-driven from the latches; but even so, the latches are designed to eliminate, as much as possible, all forces from the latch side that would tend to unlatch the latches. In addition to these features that prevent the latches from inadvertently opening, a separate locking system is required for doors that could be a hazard if they become unlatched. Notwithstanding these safety features, it could still be possible for the door operator to make errors in closing the door, or for mechanical failures to occur during or after closing; therefore, an indicating system is required that will signal to the flight crew if the door is not fully closed, latched, and locked. However, since it is still possible for the indication to be missed or unheeded, a separate system is required that prevents pressurisation of the aeroplane to an unsafe level if the door is not fully closed, latched, and locked.

The following material restates the requirements of CS 25.783 *in italicised text* and, immediately following, provides a discussion of acceptable compliance criteria.

CS 25.783(a) General Design Considerations

This paragraph applies to fuselage doors, which includes all doors, hatches, openable windows, access panels, covers, etc., on the exterior of the fuselage that do not require the use of tools to open or close. This also applies to each door or hatch through a pressure bulkhead, including any bulkhead that is specifically designed to function as a secondary bulkhead under the prescribed failure conditions of CS-25. These doors must meet the requirements of this paragraph, taking into account both pressurised and unpressurised flight, and must be designed as follows:

(a)(1) Each door must have means to safeguard against opening in flight as a result of mechanical failure, or failure of any single structural element.

Failures that should be considered when safeguarding the door against opening as a result of mechanical failure or failure of any single structural element include those caused by:

- wear;
- excessive backlash;

- excessive friction;
- jamming;
- incorrect assembly;
- incorrect adjustment;
- parts becoming loose, disconnected, or unfastened;
- parts breaking, fracturing, bending or flexing beyond the extent intended.

(a)(2) Each door that could be a hazard if it unlatches must be designed so that unlatching during pressurised and unpressurised flight from the fully closed, latched, and locked condition is extremely improbable. This must be shown by safety analysis .

All doors should incorporate features in the latching mechanism that provide a positive means to prevent the door from opening as a result of such things as:

- vibrations;
- structural loads and deflections;
- positive and negative pressure loads, positive and negative ‘g’ loads;
- aerodynamic loads etc.

The means should be effective throughout the approved operating envelope of the aeroplane including the unpressurised portions of flight.

The safety assessment required by this regulation may be a qualitative or quantitative analysis, or a combination as appropriate to the design. In evaluating a failure condition that results in total failure or inadvertent opening of the door, all contributing events should be considered, including:

- failure of the door and door supporting structure;
- flexibility in structures and linkages;
- failure of the operating system;
- erroneous signals from the door indication systems;
- likely errors in operating and maintaining the door.

(a)(3) Each element of each door operating system must be designed or, where impracticable, distinctively and permanently marked, to minimise the probability of incorrect assembly and adjustment that could result in a malfunction.

Experience has shown that the level of protection against mechanical failure can be significantly improved by careful attention to detail design. The following points should therefore be taken into account:

- (a) To minimise the risk of incorrect assembly and adjustment, parts should be designed to prevent incorrect assembly if, as a result of such incorrect assembly, door functioning would be adversely affected. “Adverse effects” could be such things as preventing or impeding the opening of the door during an emergency, or reducing the capability of the

door to remain closed. If such designs are impracticable and marking is used instead, the marking should remain clearly identifiable during service. In this respect, markings could be made using material such as permanent ink, provided it is resistant to typical solvents, lubricants, and other materials used in normal maintenance operations.

- (b) To minimise the risk of the door operating mechanism being incorrectly adjusted in service, adjustment points that are intended for “in-service” use only should be clearly identified, and limited to a minimum number consistent with adequate adjustment capability. Any points provided solely to facilitate adjustment at the initial build and not intended for subsequent use, should be made non-adjustable after initial build, or should be highlighted in the maintenance manual as a part of the door mechanism that is not intended to be adjusted.

(a)(4) All sources of power that could initiate unlocking or unlatching of each door must be automatically isolated from the latching and locking systems prior to flight and it must not be possible to restore power to them during flight.

For doors that use electrical, hydraulic, or pneumatic power to initiate unlocking or unlatching, those power sources must be automatically isolated from the latching and locking systems before flight, and it should not be possible to restore power to them during flight. It is particularly important for doors with powered latches or locks to have all power removed that could power these systems or that could energise control circuits to these systems in the event of electrical short circuits. This does not include power to the door indicating system, auxiliary securing devices if installed, or other systems not related to door operation. Power to those systems should not be sufficient to cause unlocking or unlatching unless each failure condition that could result in energising the latching and locking systems is extremely improbable.

(a)(5) Each removable bolt, screw, nut, pin, or other removable fastener must meet the locking requirements of CS 25.607. [Fasteners]

Refer to AMC 25.607 for guidance on complying with CS 25.607.

(a)(6) Certain fuselage doors, as specified by 25.807(h), must also meet the applicable requirements of CS 25.809 through 25.812 for emergency exits.

CS 25.783(b) Opening by persons

There must be means to safeguard each door against opening during flight due to inadvertent action by persons.

The door should have inherent design features that achieve this objective. It is not considered acceptable to rely solely on cabin pressure to prevent inadvertent opening of doors during flight, because there have been instances where doors have opened during unpressurised flight, such as during landing. Therefore all doors should incorporate features to prevent the door from being opened inadvertently by persons on board.

In addition, design precautions must be taken to minimise the possibility for a person to open a door intentionally during flight. If these precautions include the use of auxiliary devices, those devices and their controlling systems must be designed so that:

- (i) no single failure will prevent more than one exit from being opened, and*

(ii) failures that would prevent opening of any exit after landing are improbable.

The intentional opening of a door by persons on board while the aeroplane is in flight should be considered. This rule is intended to protect the aircraft and passengers but not necessarily the person who intentionally tries to open the door. Suitable design precautions should therefore be taken; however, the precautions should not compromise the ability to open an emergency exit in an emergency evacuation. The following precautions should be considered:

- (a) For doors in pressurised compartments: it should not normally be possible to open the door when the compartment differential pressure is above 13.8 kPa (2 psi). The ability to open the door will depend on the door operating mechanism and the handle design, location and operating force. Operating forces in excess of 136 kg (300 pounds) should be considered sufficient to prevent the door from being opened. During approach, take-off and landing when the compartment differential pressure is lower, it is recognised that intentional opening may be possible; however, these phases are brief and all passengers are expected to be seated with seat belts fastened. Nevertheless flight experience has shown that cabin staff may cycle door handles during take-off in an attempt to ensure that the door is closed, resulting in door openings in flight. For hazardous doors CS 25.783(e)(2) intends to provide a positive means to indicate to the door operator after closure of the door on the ground, that the door is not properly closed, latched and locked. CS 25.783(e)(2) will minimise, but can not prevent the deliberate cycling of the door handle by the cabin staff during take-off.
- (b) For doors that cannot meet the guidance of (a) above, and for doors in non-pressurised aeroplanes: The use of auxiliary devices (for example, a speed-activated or barometrically-activated means) to safeguard the door from opening in flight should be considered. The need for such auxiliary devices should depend upon the consequences to the aeroplane and other occupants if the door is opened in flight.
- (c) Auxiliary devices installed on emergency exits: The failure of an auxiliary device should normally result in an unsecured position of the device. Failures of an auxiliary device that would prevent opening of the exit after landing should not be more probable than Remote (1×10^{-5} /flight hour). Where auxiliary devices are controlled by a central system or other more complex systems, a single failure criterion for opening may not be sufficient. The criteria for failure of the auxiliary device to open after landing should include consideration of single failures and all failure conditions that are more probable than remote. In the assessment of single failures, no credit should be given to dormant functions.

The opening of exits on the ground should also be considered in the design, relative to the effects of differential pressure. While it is desirable and required to be able to open exits under normal residual differential pressure, opening of the exit with significant differential pressure can be a hazard to the person opening the exit. Clearly, emergency conditions may dictate that the exit be opened regardless of the differential pressure. Devices that restrict opening of the door, or affect the pressurization system, can have failure modes that create other safety concerns. However, the manufacturer should consider this issue in the design of the door and provide warnings where necessary, if it is possible to open a door under differential pressure that may be hazardous to the exit operator.

CS 25.783(c) Pressurisation prevention means

There must be a provision to prevent pressurisation of the aeroplane to an unsafe level if any door subject to pressurisation is not fully closed, latched, and locked.

(c)(1) The provision must be designed to function after any single failure, or after any combination of failures not shown to be extremely improbable.

- (a) The provisions for preventing pressurisation must monitor the closed, latched and locked condition of the door. If more than one lock system is used, each lock system must be monitored. Examples of such provisions are vent panels and pressurisation inhibiting circuits. Pressurisation to an unsafe level is considered to be prevented when the pressure is kept below 3.447 kPa (1/2 psi). These systems are not intended to function to depressurise the aeroplane once the fully closed latched and locked condition is established and pressurisation is initiated.
- (b) If a vent panel is used, it should be designed so that, in normal operation or with a single failure in the operating linkage, the vent panel cannot be closed until the door is latched and locked. The vent panel linkage should monitor the locked condition of each door lock system.
- (c) If automatic control of the cabin pressurisation system is used as a means to prevent pressurisation, the control system should monitor each lock. Because inadvertent depressurisation at altitude can be hazardous to the occupants, this control system should be considered in showing compliance with the applicable pressurisation system reliability requirements. Normally, such systems should be automatically disconnected from the aeroplane's pressurisation system after the aeroplane is airborne, provided no prior unsafe condition was detected.
- (d) It should not be possible to override the pressurisation prevention system unless a procedure is defined in the Master Minimum Equipment List (MMEL) that confirms a fully closed, latched and locked condition. In order to prevent the override procedure from becoming routine, the override condition should not be achievable by actions solely on the flight deck and should be automatically reset at each door operational cycle.

(c)(2) Doors that meet the conditions described in sub-paragraph (h) of this paragraph are not required to have a dedicated pressurisation prevention means if, from every possible position of the door, it will remain open to the extent that it prevents pressurisation or safely close and latch as pressurisation takes place. This must also be shown with any single failure and malfunction except that:

- (i) with failures or malfunctions in the latching mechanism, it need not latch after closing, and*
- (ii) with jamming as a result of mechanical failure or blocking debris, the door need not close and latch if it can be shown that the pressurisation loads on the jammed door or mechanism would not result in an unsafe condition.*

As specified in CS 25.783(d)(7), each door for which unlatching would not result in a hazard is not required to have a locking mechanism; those doors also may not be required to have a dedicated pressurisation prevention means. However, this should be determined by demonstrating that an unsafe level of pressurisation cannot be achieved for each position that the door may take during closure, including those positions that may result from single failures or jams.

- Excluding jamming and excluding failures and malfunctions in the latching system, for every possible position of the door, it must either remain open to the extent that it prevents pressurisation, or safely close and latch as pressurisation takes place;
- With single failures of the latching system or malfunctions in the latching system the door may not necessarily be capable of latching, but it should either remain open to the extent that it prevents pressurisation, or safely move to the closed position as pressurisation takes place; and
- With jamming as a result of mechanical failure in the latching system or blocking debris, the pressurisation loads on the jammed door or mechanism may not result in damage to the door or airframe that could be detrimental to safe flight (both the immediate flight or future flights). In this regard, consideration should be given to jams or non-frangible debris that could hold the door open just enough to still allow pressurisation, and then break loose in flight after full pressurisation is reached.

CS 25.783(d) Latching and locking

The latching and locking mechanisms must be designed as follows:

(d)(1) There must be a provision to latch each door.

- (a) The definitions of latches and locks are redefined in Chapter 3 [Definitions of Terms], particularly in regard to mechanical and structural elements of inward-opening plug doors. In this regard, fixed stops are not considered latches. The movable elements that hold the door in position relative to the fixed stops are considered latches. These movable elements prevent the door from opening and will support some loads in certain flight conditions, particularly when the aeroplane is unpressurised.
- (b) For all doors, sub-paragraph 25.783(d)(2) requires that the latching system employ a securing means other than the locking system. The separate locking system may not be necessary for certain doors with an initial inward movement (see CS 25.783(d)(4)).

(d)(2) The latches and their operating mechanism must be designed so that, under all aeroplane flight and ground loading conditions, with the door latched, there is no force or torque tending to unlatch the latches. In addition, the latching system must include a means to secure the latches in the latched position. This means must be independent of the locking system.

The latches of doors for which the initial opening movement is outward are typically subject to vibrations; structural loads and deflections; positive and negative pressure loads; positive and negative 'g' loads; aerodynamic loads; etc. The latches of doors for which the initial opening movement is inward typically share some of these same types of loads with fixed stops. Doors for which the initial opening movement is inward tend to be resistant to opening when the aircraft is pressurised since a component of the pressure load tends to hold the door closed.

- (a) Latch design. The design of the latch should be such that with the latch disconnected from its operating mechanism, the net reaction forces on the latch should not tend to unlatch the latch during both pressurised and unpressurised flight throughout the approved flight envelope. The effects of possible friction in resisting the forces on the latch should be ignored when considering reaction forces tending to unlatch the door. The effects of distortion of the latch and corresponding structural attachments should be

taken into account in this determination. Any latch element for which 'g' loads could result in an unlatching force should be designed to minimise such forces.

- (b) Latch securing means. Even though the principal back-driving forces should be eliminated by design, it is recognised that there may still be ratcheting forces that could progressively move the latches to the unlatched position. Therefore, each latch should be positively secured in the latched position by its operating mechanism, which should be effective throughout the approved flight envelope. The location of the operating system securing means will depend on the rigidity of the system and the tendency for any forces (such as ratcheting, etc.) at one latch to unlatch other latches.
- (c) Over-centre features in the latching mechanism are considered to be an acceptable securing means, provided that an effective retaining feature that functions automatically to prevent back-driving is incorporated. If the design of the latch is such that it could be subject to ratcheting loads which might tend to unlatch it, the securing means should be adequate to resist such loads.
- (d) Back-driving effect of switches. In those designs that use the latch to operate an electrical switch, any back-driving effect of the switch on the latch is permissible, provided that the extent of any possible movement of the switch

- is insufficient to unlatch it; and
- will not result in the latch being subjected to any other force or torque tending to unlatch it.

- (e) The latch securing means must be independent of the locking means. However, the latching and locking functions may be fulfilled by a single operating means, provided that it is not possible to back-drive the locks via the latch mechanism when the door locks are engaged with the latch mechanism.

(d)(3) Each door subject to pressurisation, and for which the initial opening movement is not inward must:

- (i) have an individual lock for each latch;*
- (ii) have the lock located as close as practicable to the latch; and*
- (iii) be designed so that during pressurised flight, no single failure in the locking system would prevent the locks from restraining the latches necessary to secure the door.*

- (a) To safeguard doors subject to pressurisation and for which the initial opening movement is not inward, each latch must have an individual lock. The lock should directly lock the latch. In this regard, the lock should be located directly at the latch to ensure that, in the event of a single failure in the latch operating mechanism, the lock would continue to restrain the latch in the latched position. Even in those cases where the lock cannot be located directly at the latch, the same objective should be achieved. In some cases, a pair of integrally-connected latches may be treated as a single latch with respect to the requirement for a lock provided that:

- 1) the lock reliably monitors the position of at least one of the load carrying elements of the latch, and
- 2) with any one latch element missing, the aeroplane can meet the full requirements of CS-25 as they apply to the unfailed aeroplane, and

3) with the pair disengaged, the aeroplane can achieve safe flight and landing, and meet the damage tolerance requirements of CS 25.571[Damage-tolerance and fatigue evaluation of structure].

- (b) In some designs more latches are provided than necessary to meet the minimum design requirements. The single failure requirement for the locking system is intended to ensure that the number and combination of latches necessary to secure the door will remain restrained by the locking mechanism. Only those latches needed to meet the minimum design requirements need to remain restrained after the single failure.
- (c) In meeting this requirement, the indirect locking provided through the latch system by the locks at other latches may be considered. In this case, the locking system and the latching system between the locked latch and the unlocked latch should be designed to withstand the maximum design loads discussed in sub-paragraph d.(6) of this AMC, below, as appropriate to pressurised flight.

(d)(4) Each door for which the initial opening movement is inward, and unlatching of the door could result in a hazard, must have a locking means to prevent the latches from becoming disengaged. The locking means must ensure sufficient latching to prevent opening of the door even with a single failure of the latching mechanism.

For a door to be classified as having Initial Inward Opening Movement before opening outwards, and thus be eligible for some relief regarding the locks compared with other outward opening doors, the following conditions should be fulfilled:

- a) Loads on the door resulting from positive pressure differential of the fuselage should be reacted by fixed (non moveable) structural stops on the door and fuselage doorframe.
- b) The stops must be designed so that, under all 1g aeroplane level flight conditions, the door to fuselage stop interfaces produce no net force tending to move the door in the opening direction.
- c) If the stops are used to provide the initial inward opening movement, the stops should be designed such that they cause the door to move inwards, typically at a minimum angle of 3° relative to the mean pressure plane, opposing any positive fuselage pressure differential:
 - 1) until the door is in a position where it is clear of the fixed stops and is free to open, or
 - 2) until the loads required to overcome friction between the door and fuselage stops are sufficient to prevent the door moving in an opening direction when the door is subjected to loads of +/- 0.5g; or
 - (3) if neither of the above options are appropriate, based on justified engineering judgement and agreed with the Agency.
- d) If guides or other mechanisms are used to position the door such that it can move clear of the fixed stops in an opening direction, the means used should, be designed such that it causes the door to move inwards, typically at a minimum angle of 3° relative to the mean

pressure plane, opposing any positive fuselage pressure differential and be sufficiently robust to function without significant loss of effectiveness when the door is subject to a differential pressure of 13.8 kPa (2 psi):

- 1) until the door is in a position where it is clear of the fixed stops and is free to open, or
- 2) until the loads required to overcome friction are sufficient to prevent the door moving in an opening direction when the door is subjected to loads of +/- 0.5g; or
- (3) if neither of the above options are appropriate, based on justified engineering judgement and agreed with the Agency.

On these doors, the locking means should monitor the latch securing means, but need not directly monitor and lock each latch. Additionally, the locking means could be located such that all latches are locked by locking the latching mechanism. With any single failure in the latching mechanism, the means must still lock a sufficient number of latches to ensure that the door remains safely latched.

(d)(5) It must not be possible to position the lock in the locked position if the latch and the latching mechanism are not in the latched position.

The lock should be an effective monitor of the position of the latch such that, if any latch is unlatched, the complete locking system cannot be moved to the locked position. Although an over-centre feature may be an adequate means of securing the latching mechanism, it is not considered to be the locking means for the latches.

(d)(6) It must not be possible to unlatch the latches with the locks in the locked position. Locks must be designed to withstand the limit loads resulting from:

- (i) the maximum operator effort when the latches are operated manually;*
- (ii) the powered latch actuators, if installed; and*
- (iii) the relative motion between the latch and the structural counterpart.*

Although the locks are not the primary means of keeping the latches engaged, they must have sufficient strength to withstand any loads likely to be imposed during all approved modes of door operation. The operating handle loads on manually-operated doors should be based on a rational human factors evaluation. However, the application of forces on the handle in excess of 136 kg (300 pounds) need not be considered. The loads imposed by the normal powered latch actuators are generally predictable; however, loads imposed by alternate drive systems are not. For this reason the locks should have sufficient strength to react the stall forces of the latch drive system. Load-limiting devices should be installed in any alternate drive system for the latches in order to protect the latches and the locks from overload conditions. If the design of the latch is such that it could be subject to ratcheting loads which might tend to unlatch it, the locks should be adequate to resist such loads with the latch operating system disconnected from the latch.

(d)(7) Each door for which unlatching would not result in a hazard is not required to have a locking mechanism meeting the requirements of sub-paragraph (d)(3) through (d)(6) of this

paragraph.

See sub-paragraph CS 25.783(h) of this AMC, below, for a description of doors for which unlatching is considered not to result in a safety hazard.

(d)(8) A door that could result in a hazard if not closed, must have means to prevent the latches from being moved to the latched position unless it can be shown that a door that is not closed would be clearly evident before flight.

For door security, it is good basic design philosophy to provide independent integrity in the closing, latching, locking and indication functions. The integrity of the closing function in particular is vulnerable to human factors and experience has shown that human error can occur resulting in an unsafe condition.

Door designs should incorporate a feature that prevents the latches from moving to the latched position if the door is not closed. The importance of such a feature is that it prevents the latched and locked functions from being completed when the door is not closed.

If the feature is provided by electronic means, the probability of failure to prevent the initiation of the latching sequence should be no greater than remote (1×10^{-5} /flight hour).

To avoid the potential for an unsafe condition, the means provided to indicate the closed position of the door under sub-paragraph (e) should be totally independent of the feature preventing initiation of the latching sequence.

As an alternative to providing the feature described above, reliance can be placed on trained cabin attendants or flight crew members to determine that certain doors are not fully closed. This alternative is applicable only to doors that are normally operated by these crew members, and where it is visually clearly evident from within the aircraft without detailed inspection under all operational lighting conditions that the door is not fully closed.

CS25.783(e) *Warning, caution and advisory indications*

Doors must be provided with the following indications:

(e)(1) There must be a positive means to indicate at each door operator's station that all required operations to close, latch, and lock the door(s) have been completed.

In order to minimise the probability of incomplete door operations, it should be possible to perform all operations for each door at one station. If there is more than one operator's station for a single door, appropriate indications should be provided at each station. The positive means to indicate at the door operator's station that all required operations have been completed are such things as final handle positions or indicating lights. This requirement is not intended to preclude or require a single station for multiple doors.

(e)(2) There must be a positive means, clearly visible from each operator station for each door that could be a hazard if unlatched, to indicate if the door is not fully closed, latched, and locked.

A single indication that directly monitors the door in the closed, latched and locked conditions should be provided unless the door operator has a visual indication that the door is fully closed

latched and locked. This indication should be obvious to the door operator. For example, a vent door or indicator light that monitors the door locks and is located at the operator's station may be sufficient. In case of an indicator light, it should not be less reliable than the visual means in the cockpit as required per CS 25.783(e)(3). The same sensors could be used for both indications in order to prevent any discrepancy between the indications.

(e)(3) There must be a visual means on the flight deck to signal the pilots if any door is not fully closed, latched, and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed, latched, and locked indication is remote for:

- (i) each door that is subject to pressurisation and for which the initial opening movement is not inward, or*
- (ii) each door that could be a hazard if unlatched.*

The visual means may be a simple amber light or it may need to be a red warning light tied to the master warning system depending on the criticality of the door. The door closed, latched and locked functions must be monitored, but only one indicator is needed to signal that the door is in the closed, latched and locked condition. Indications should be reliable to ensure they remain credible. The probability of erroneous closed, latched, and locked indication should be no greater than remote (1×10^{-5} /flight hour) for:

- each door subject to pressurisation and for which the initial opening movement is not inward; and for
- each door that could be a hazard if unlatched.

(e)(4) There must be an aural warning to the pilots prior to or during the initial portion of take-off roll if any door is not fully closed, latched, and locked and its opening would prevent a safe take-off and return to landing.

Where an unlatched door could open and prevent a safe take-off and return to landing, a more conspicuous aural warning is needed. It is intended that this system should function in a manner similar to the take-off configuration warning systems of CS 25.703 [Take-off Warning system]. The visual display for these doors may be either a red light or a display on the master warning system. Examples of doors requiring these aural warnings are:

- doors for which the structural integrity of the fuselage would be compromised if the door is not fully closed, latched and locked, or
- doors that, if open, would prevent rotation or interfere with controllability to an unacceptable level.

CS 25.783(f) Visual inspection provision

Each door for which unlatching could be a hazard, must have provisions for direct visual inspection to determine, without ambiguity, if the door is fully closed, latched, and locked. The provision must be permanent and discernible under operational lighting conditions or by means of a flashlight or equivalent light source.

A provision is necessary for direct visual inspection of the closed position of the door and the

status of each of the latches and locks, because dispatch of an aeroplane may be permitted in some circumstances when a flight deck or other remote indication of an unsafe door remains after all door closing, latching and locking operations have been completed. Because the visual indication is used in these circumstances to determine whether to permit flight with a remote indication of an unsafe door, the visual indication should have a higher level of integrity than, and be independent of, the remote indication.

(a) The provisions should:

- 1) allow direct viewing of the position of the locking mechanism to show, without ambiguity, whether or not each latch is latched and each lock is locked. For doors which do not have a lock for each latch, direct viewing of the position of the latches and restraining mechanism may be necessary for determining that all the latches are latched. Indirect viewing, such as by optical devices or indicator flags, may be acceptable provided that there is no failure mode that could allow a false latched or locked indication.
- 2) preclude false indication of the status of the latches and locks as a result of changes in the viewing angle. The status should be obvious without the need for any deductive processes by the person making the assessment.
- 3) be of a robust design so that, following correct rigging, no unscheduled adjustment is required. Furthermore, the design should be resistant to unauthorised adjustment.
- 4) preclude mis-assembly that could result in a false latched and locked indication.

(b) If markings are used to assist the identification of the status of the latches and locks, such markings must include permanent physical features to ensure that the markings will remain accurately positioned.

(c) Although the visual means should be unambiguous in itself, placards and instructions may be necessary to interpret the status of the latches and locks.

(d) If optical devices or windows are used to view the latches and locks, it should be demonstrated that they provide a clear view and are not subject to fogging, obstruction from dislodged material or giving a false indication of the position of each latch and lock. Such optical devices and window materials should be resistant to scratching, crazing and any other damage from all materials and fluids commonly used in the operation and cleaning of aeroplanes.

CS 25.783(g) Certain maintenance doors, removable emergency exits, and access panels

Some doors not normally opened except for maintenance purposes or emergency evacuation and some access panels need not comply with certain sub-paragraphs of this paragraph as follows:

- (1) Access panels that are not subject to cabin pressurisation and would not be a hazard if open during flight need not comply with sub-paragraphs (a) through (f) of this paragraph, but must have a means to prevent inadvertent opening during flight.*
- (2) Inward-opening removable emergency exits that are not normally removed, except for maintenance purposes or emergency evacuation, and flight deck-openable windows need not comply with sub-paragraphs (c) and (f) of this paragraph.*
- (3) Maintenance doors that meet the conditions of sub-paragraph (h) of this paragraph, and for which a placard is provided limiting use to maintenance access, need not*

comply with sub-paragraphs (c) and (f) of this paragraph.

Some doors not normally opened except for maintenance purposes or emergency evacuation and some access panels are not required to comply with certain sub-paragraphs of CS 25.783 as described in CS 25.783(g). This generally pertains to access panels outside pressurised compartments whose opening is of little or no consequence to safety and doors that are not used in normal operation and so are less subject to human errors or operational damage.

CS 25.783(h) Doors that are not a hazard

For the purpose of this paragraph, a door is considered not to be a hazard in the unlatched condition during flight, provided it can be shown to meet all of the conditions as mentioned in CS 25.783(h).

CS 25.783 recognises four categories of doors:

- Doors for which the initial opening is not inward, and are presumed to be hazardous if they become unlatched.
- Doors for which the initial opening is inward, and could be a hazard if they become unlatched.
- Doors for which the initial opening is inward, and would not be a hazard if they become unlatched.
- Small access panels outside pressurised compartments for which opening is of little or no consequence to safety.

CS 25.783(h) describes those attributes that are essential before a door in the normal (unfailed) condition can be considered not to be a hazard during flight.

6. STRUCTURAL REQUIREMENTS

In accordance with CS 25.571, the door structure, including its mechanical features (such as hinges, stops, and latches), that can be subjected to airframe loading conditions, should be designed to be damage tolerant. In assessing the extent of damage under CS 25.571 and CS 25.783 consideration should be given to single element failures in the primary door structure, such as frames, stringers, intercostals, latches, hinges, stops and stop supports.

The skin panels on doors should be designed to be damage tolerant with a high probability of detecting any crack before the crack causes door failure or cabin decompression.

Note: This paragraph applies only to aircraft with a certification basis including CS 25.571 or equivalent requirements for damage tolerance.

18. Introduce a new AMC 25.851(b) to read:

AMC 25.851(b)
Built-in Fire Extinguishers

1. PURPOSE.

This AMC sets forth acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the built-in fire suppression systems when required for cargo compartments of large aeroplanes. The guidance provided within this AMC has been found acceptable for showing compliance with the provisions of CS 25.855 and 25.857 for built-in fire extinguishing systems. As with all AMC material, it is not mandatory and does not constitute a regulation. For application to the product, alternate methods may be elected to be followed, provided that these methods are also found by the EASA to be an acceptable means of complying with the requirements of CS-25.

2. RELATED CS PARAGRAPHS.

CS 25.851 "Fire extinguishers"

CS 25.855 "Cargo or baggage compartments"

CS 25.857 "Cargo compartment classification"

CS 25.858 "Cargo compartment fire detection systems"

3. RESERVED.

4. BACKGROUND.

Minimal written guidance is available for use in certifying cargo compartment fire extinguishing or suppression systems. Testing at the FAA Technical Center and other data from standardised fire extinguishing evaluation tests indicates that the use of averaging techniques may not substantiate that there are adequate concentration levels of fire extinguishing agent throughout the compartment to effectively suppress a cargo fire.

Cargo fire extinguishing systems installed in aeroplanes today primarily use Halon 1301 as the fire suppression agent. One widely used method to certify Halon 1301 cargo fire suppression systems requires an initial concentration of five percent by volume in order to knock down a cargo fire. Subsequent concentration levels should not drop below three percent by volume for the remainder of the flight in order to suppress a cargo fire until it can be completely extinguished by ground personnel following a safe landing.

Since Halon 1301 is approximately five times heavier than air, it tends to stratify and settle after it is released into the cargo compartment. Also, due to temperature differences and ventilation patterns, in a ventilated compartment, Halon 1301 will start to stratify shortly after discharge and the concentration level will decay faster in the upper locations of the compartment than in the lower locations. Halon 1301 will also have a tendency to move aft due to any upward pitch or forward in any downward pitch of the aeroplane in flight. For some products the concentration levels of Halon 1301 have been measured at various locations throughout the cargo compartment and used an arithmetic average of the individual sampling locations to determine an overall concentration level for the cargo compartment. This averaging technique may allow the concentration level to drop below three percent by volume at individual sampling locations near the top of the cargo compartment.

Testing at the FAA Technical Center and other data from standardised fire extinguishing evaluation tests indicates that the use of averaging techniques may not substantiate that there are adequate concentration levels of fire extinguishing agent throughout the compartment to effectively suppress a cargo fire. If a cargo fire occurred, and was subsequently suppressed by Halon 1301, the core of the fire could remain hot for a period of time. If the local concentration of Halon 1301 in the vicinity of the fire core dropped below three percent by volume and sufficient oxygen is available, re-ignition could occur. The FAA tests have shown that when the Halon 1301 concentration level drops below three percent by volume and the cargo fire re-ignites, the convective stirring caused by the heat of the fire may be insufficient to raise the local concentration of Halon in the vicinity of the fire. Therefore, compliance testing will require the use of point-concentration data from each sensor and that the probes closest to the cargo compartment ceiling must be at least at the highest level that cargo and baggage can be loaded as specified by the manufacturer and certified by the appropriate airworthiness authority. In addition, certification test data acquisition must include analysis and/or data taken after landing at a time increment which represents the completion of an evacuation.

5. COMPARTMENT CLASSIFICATION.

All cargo compartments must be properly classified in accordance with CS 25.857 and meet the requirements of CS 25.857 pertaining to the particular class involved. In order to establish appropriate requirements for fire protection, a system for classification of cargo or baggage compartments was developed and adopted for large aeroplanes. Classes A, B, and C were initially established; Classes D and E were added later.

a. A Class A compartment is one that is located so close to the station of a crewmember that the crewmember would discover the presence of a fire *immediately*. In addition, each part of the compartment is easily accessible so that the crewmember could quickly extinguish a fire with a portable fire extinguisher. A Class A compartment is not required to have a liner.

(1) Typically, a Class A compartment is a small open compartment in the cockpit area used for storage of crew luggage. A Class A compartment is not, however, limited to such use; it may be located in the passenger cabin and used for other purposes provided it is located adjacent to a crewmember's station and crewmember remains present during all times when it is used for storage.

(2) Because a Class A compartment does not have a liner, it is *absolutely essential* that the compartment be small and located close enough to a crewmember that any fire that might occur could be discovered and extinguished immediately. Without a liner to contain it, an undetected or uncontrolled fire could quickly become catastrophic by burning out of the compartment and spreading throughout the aeroplane. All portions of the compartment must be within arms length of the crewmember in order for any fire to be detected immediately and extinguished in a timely manner. Although there may be some exceptions, such as a 'U-Shaped' compartment for example, a Class A compartment greater than 1.42 (50 cubic feet) in volume would not typically have the accessibility required by CS 25.857(a)(2) for fighting a fire.

b. A Class B compartment is one that is more remote than a Class A compartment and must, therefore, incorporate a fire or smoke detection system to give warning at the pilot or flight engineer station. Because a fire could not be detected and extinguished as quickly, a Class B compartment must have a liner in accordance with CS 25.855. A Class B cargo or baggage compartment has sufficient access in flight to enable a crewmember to reach all parts of the compartment with the contents of a hand fire extinguisher. There are means to ensure that, while the access provisions are being used, no hazardous quantity of smoke, flames, or extinguishing agent will enter areas occupied by the crew or passengers.

c. A Class C compartment differs from a Class B compartment in that it is not required to be accessible in flight and must, therefore, have a built-in fire extinguishing system to suppress or control any fire occurring therein. A Class C compartment must have a liner and a fire or smoke detection system in accordance with CS 25.855 and 25.857. There must also be a means to control ventilation and drafts within the compartment and a means to exclude hazardous quantities of smoke, flames, or extinguishing agent from occupied areas.

d. FAR Amendment 25-93 removed the Class D cargo compartment classification for new aeroplanes effective March 19, 1998.

e. A Class E compartment is particular to an all-cargo aeroplane. Typically, a Class E compartment is the entire cabin of an all-cargo aeroplane; however, other compartments of such aeroplanes may be classified as Class E compartments. A fire in a Class E compartment is controlled by shutting off the ventilating airflow to or within the compartment. Additionally, most cargo aeroplanes have smoke/fire procedures that recommend that the crew turn off the ventilating air, don their oxygen equipment, and gradually raise the cabin altitude, between 6096 m (20,000 feet) and 7620 m (25,000 feet), to limit the oxygen supply and help control a fire until the aeroplane can descend to land. A Class E compartment must have a liner and a fire or smoke detection system installed in accordance with CS 25.855; however, it is not required to have a built-in fire suppression system.

6. FIRE EXTINGUISHING OR SUPPRESSION SYSTEMS.

The terms “extinguishing system” and “suppression system” will be used interchangeably in this AMC. The system is not required to extinguish a fire in its entirety. The system is intended, instead, to suppress a fire until it can be completely extinguished by ground personnel following a safe landing.

7. TESTING VOLUMETRIC CONCENTRATION LEVELS.

For the product it should be demonstrated that the cargo fire extinguishing system provides adequate concentration levels of extinguishing agent to combat a fire anywhere where baggage and cargo is placed within the cargo compartment for the time duration required to land and evacuate the aeroplane. A combination of flight-testing and analysis may be used to comply with this requirement. If Halon 1301 is used, an initial minimum concentration of five percent by volume is required to knock down a cargo fire. Subsequent gaseous extinguishing agent should, if required for the duration of the flight, be introduced via a metering or other appropriate system to ensure that point concentration levels do not drop below three percent

by volume for the remainder of the flight. The duration of agent application should be determined from route analysis (i.e. the time to travel from the farthest distance expected in route to the nearest adequate airport for landing per applicable operational rules. For Extended Operation with Two-Engine Aeroplanes (ETOPS) AMC 20-6 specify that an analysis or tests should be conducted to show, considering approved maximum diversion in still air (including an allowance for 15-minute holding and/or approach and land), that the ability of the system to suppress or extinguish fires is adequate to ensure safe flight and landing at a suitable airport. The minimum extinguishing agent concentration levels are to be maintained for the required duration throughout the cargo compartment where cargo will be carried, including side to side, end to end, and top to bottom. However, flight test measurements do not have to be made in compartment areas that are designated empty and will not contain cargo.

The fire extinguishing agent concentration levels should be measured at sufficient vertical, horizontal, and longitudinal locations to ensure that sufficient resolution exists to define the variations in fire extinguishing agent concentration levels throughout the cargo compartment in these planes. No averaging techniques are permitted in compliance demonstrations for CS 25.851(b)(2). The only exception to this will be in the event of a sensor failure where interpolation of sensor data from other nearby probes to yield an estimate of missing agent concentration data may be allowed by the Agency. In the event such interpolation is necessary, then a linear interpolation of the data will provide an acceptable means of approximating the missing data.

Sampling locations should also be placed as close as practical to potential leakage or ventilation flow areas (e.g., door seals, vents, etc.) which can disrupt the local concentration levels.

The concentration levels should not be less than the minimum established for that fire extinguishing agent at any point within the compartment. Arithmetic averaging of individual sampling locations to determine the concentration levels is not acceptable. The use of averaged concentration data will no longer be accepted, except in well-defined cases (i.e., during certification tests) where a sensor probe failure occurs and the use of interpolation from adjacent sensor probes is warranted. Compliance with CS 25.851(b) will require the use of point-concentration data from each sensor and that the probes closest to the cargo compartment ceiling must be at least at the highest level that cargo and baggage can be loaded as specified by the manufacturer and certified by the Agency. Other placement of concentration sensor probes within the cargo compartment should be sufficient to substantiate that there are adequate concentration levels of fire extinguishing agent throughout the compartment to effectively control a cargo compartment fire. The sampling rate should be sufficient to establish a concentration level versus time decay curve. In the event that a single sensor displays a suspect time history, the use of an interpolated time averaged value may be acceptable to the Agency. If fire extinguishing agent concentration levels at a probe drop below the minimum requirement, it should be a temporary anomaly of short duration and not observed in adjacent probes. If it could be demonstrated that the temporary anomaly is associated with aeroplane manoeuvres, then the data may be acceptable to the Agency.

Typically there are two type of extinguishing agent dispensing systems, a flood or dump (high rate discharge) system and a metered system. The flood or dump system dispenses the agent with the activation of the system and a selected amount of agent is injected into the

compartment to suppress the fire. Once the agent concentration level approaches the minimum sustaining level, i.e., 3%, a second and subsequent discharge of agent takes place to assure the 3% concentration level is maintained for the time necessary to divert to a safe landing. The metered systems usually discharge agent into the compartment for fire suppression (5%) and then adds agent in a prescribed amount to the compartment to maintain the 3% concentration level.

Certification flight test demonstration is required for a “dump” system for the duration of the intended diversion profile. If a metering system is proposed, the system’s acceptability may be demonstrated through a limited flight test, in which a portion of the system is actually tested, and the full capability of the system is demonstrated via analysis. It is recognised that issues such as what compartment size should be tested (smallest or largest), the test duration in flight, and whether reliable analytical methods are available to predict concentration levels for various locations and heights in a given cargo compartment will have an impact on certification tests. EASA concurrence must be obtained for this type of testing and analysis of the product. A sufficient portion of the metering system capability should be demonstrated to provide enough data to establish fire extinguishing agent concentration and behaviour for the remaining flight. It is recognised that aeroplane climb flight phase and the descent flight phase represent dynamic environments and no data need be acquired during these transient flight phases were cabin altitude changes would preclude accurate data acquisition. However, certification data must include analysis and/or data taken after landing at a time increment representative of the completion of an evacuation of all occupants.

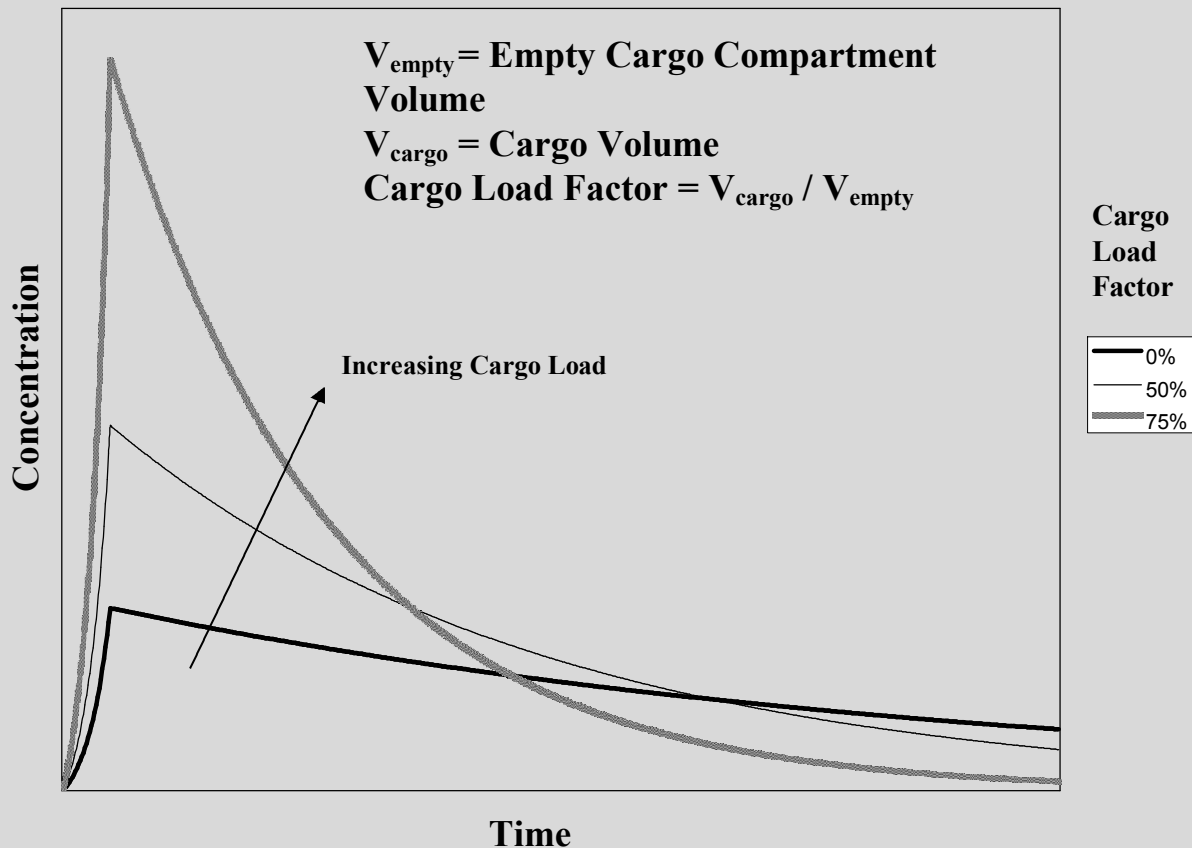
If it is proposed for a product to use a fire extinguishing agent other than Halon 1301, the Agency should be contacted. The EASA will initiate a Certification Review Item addressing the use of an alternate fire extinguishing agent.

8. AEROPLANE TEST CONDITIONS.

Flight tests are required to demonstrate function and dissipation of the fire extinguishing agent or simulant in a cargo compartment. For certification tests, the aeroplane and relevant systems should be in the type design configuration.

The cargo compartment should be empty for the above test. However, as shown in Figure 8-1, a compartment with cargo may be more time critical than an empty compartment for minimum fire extinguishing agent concentration levels. The time critical nature depends on several factors. Even with a pure “dump” system, having cargo does not necessarily mean a marginally performing system during an empty cargo compartment test will result in a “bad” system with cargo. Also, metering systems, if designed properly, are relatively insensitive to the cargo load factor.

Figure 8-1. Effect of Cargo Load on Halon 1301 Concentration Levels



A specific example of the effect of cargo compartment loading is shown in Figure 8-2, using the Appendix 1 simulation. If the volume of the compartment is decreased to represent increasing cargo load percentages and the leakage rate and initial Halon quantity are kept constant, then the initial Halon concentrations increase and the concentration decay rates also increase. Using this approach, the concentration in an empty compartment will decay to 3% faster than a loaded compartment up to a load percentage of about 65.6%. With compartments loaded to a higher percentage than 65.6%, the concentration will fall below 3% faster than an empty compartment.

This simulation of cargo loading assumes that the Halon concentration is homogeneous throughout the compartment and that the volume taken up by the loaded cargo is uniformly distributed throughout the compartment. Note: Both of these assumptions are not true in an actual loaded compartment so caution should be exercised to relate the measurements taken in an actual loaded compartment in flight.



Theoretical Halon Decay

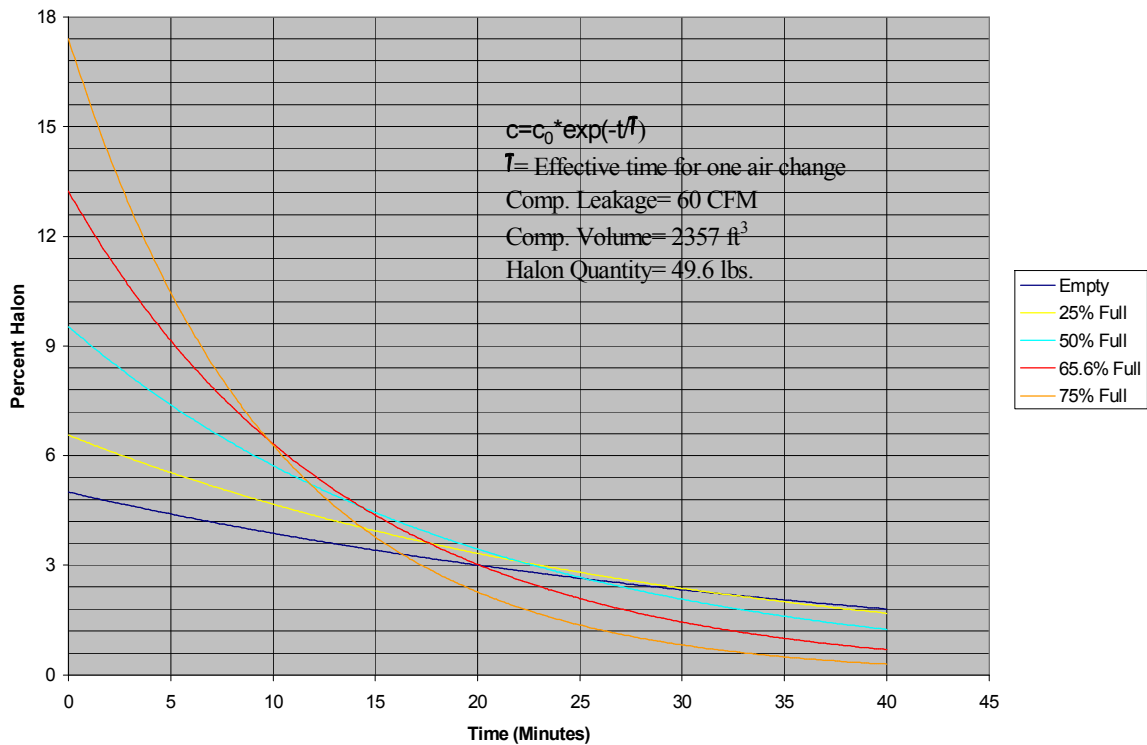


Figure 8-2

Analysis should be provided to ensure that the suppression agent concentration levels will not fall below the minimum requirement with a cargo load factor as follows:

- a. For cargo compartments using only standard cargo containers, the maximum possible volume occupied by containerised cargo should be determined for the product and this value be used as the cargo load factor. This maximum volume becomes an aeroplane limitation.
- b. For all other configurations, a minimum cargo load factor of 75% by volume should be used for the product.”

Appendix 1 to this AMC provides guidance on analysing Halon 1301 concentration levels.

The suppression system certification test should be conducted, as a minimum, during steady-state cruise with a maximum cabin-to-ambient pressure differential. The ventilation system should be configured per the aeroplane flight manual (AFM) procedures for a cargo compartment fire. The system should also be demonstrated acceptable for unpressurised flight conditions unless there is a restriction on unpressurised flight for the aeroplane.

It should be noted that cargo compartment leakage rates would vary between aeroplanes. This is especially significant for changes introduced by supplemental type certificate (STC) modifying aeroplanes that have been in service. Some preliminary testing should be done to determine the maximum leakage rates seen/expected in service. For new type designs the issue

of wear and tear on the compartment should also be addressed when establishing the decay rate in a brand new aircraft at the factory.

9. EVALUATION OF ALTERNATE GASEOUS EXTINGUISHING/SUPPRESSION SYSTEMS AND ALTERNATE AGENTS

The Montreal Protocol, in existence since 1987, is an international agreement to phase out production of ozone-depleting substances, including halogenated hydrocarbons also known as Halon. The Montreal Protocol prohibits the manufacture or import of new Halon in all developed countries as of January 1, 1994, and will extend this prohibition to developing countries in the future. The US Environmental Protection Agency (EPA) has subsequently released a regulation banning the intentional release of Halons during repair, testing, and disposal of equipment containing Halons and during technician training. However, the EPA has provided the aviation industry an exemption from their ban on the intentional release of Halons in determining compliance with airworthiness standards. A European Regulation¹ governing substances that deplete the ozone layer has also been published and contains provisions that allow exemptions for critical uses of Halon, including fire extinguishing in aviation. It should be noted that the EPA/EU exemption is predicated on the basis that there is currently no suitable alternate agent or system available for use on commercial transport category aeroplanes. It is the understanding of the EASA that once a suitable replacement extinguishing agent or system has been found then the EPA/EU will remove the exemption.

To date, FAA Technical Center testing of alternate gaseous extinguishing/suppression agents has not yielded any acceptable alternate Halon replacement agents for use in cargo compartments. For example, testing at the Technical Center utilising HFC-125 demonstrated the need for large concentrations of this agent that would carry weight penalty and toxicity concerns. The Technical Center will continue to pursue this line of research to identify alternate gaseous and liquid and other fire extinguishing / suppression agent systems. Acceptable means of compliance for these immature systems are beyond the scope of this AMC. Future revisions to this AMC will be accomplished as soon as suitable standards are developed for these systems.

Should the EASA be approached with the intent of utilising for the product an alternate agent or alternate gaseous fire extinguishing system in lieu of a Halon 1301 system, then the recommended approach would be to perform testing on the product which meets the Minimum Performance Standards for that application as developed by the International Halon Replacement Working Group. The International Halon Replacement Working Group was established in October 1993. This group was tasked to work towards the development of minimum performance standards and test methodologies for non-Halon aircraft fire suppression agents/systems in cargo compartments, engine nacelles, hand held extinguishers, and lavatory trash receptacles. The International Halon Replacement Working Group has been

¹ REGULATION (EC) No 2037/2000 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 June 2000 on substances that deplete the ozone layer

expanded to include all system fire protection R&D for aircraft and now carries the name, International Aircraft Systems Fire Protection Working Group.

To ensure acceptable means of compliance, the following must be provided :

- a. The test data and gaseous agent distribution profiles which meet the certification criteria as expressed below and in the Minimum Performance Standards as developed by FAA Technical Center as part of the International Halon Replacement program. (See paragraph 15 for the listing of the references.)
- b. A system description document that includes a description of the distribution of the gaseous agent under the test conditions in the cargo compartment.
- c. A detailed test plan.
- d. Chemical data which describes the agent and any toxicity data.

9.1 Pre-Test Considerations:

- a. An EASA accepted analyser (for example, Statham-derivative analyser) capable of measuring the agent distribution profile in the form of volumetric concentration is required.
- b. An EASA accepted analyser (for example, Statham-derivative analyser) and associated hardware are configured for the particular application.
- c. The fire suppression system should be completely conformed prior to the test.
- d. The fire extinguisher bottle(s) should be serviced and prepared for the prescribed test(s).

9.2 Test Procedures:

- a. Perform the prescribed distribution test in accordance with the test plan approved by the Agency. See Paragraph 7 for guidance on probe placement.
- b. An EASA accepted analyser (for example, Statham-derivative analyser) should record the distribution profile as volumetric concentration for the agent.

9.3 Test Result Evaluation:

- a. Produce the data from the EASA accepted analyser (for example, Statham-derivative analyser) in graphical format. This format should be the volumetric concentration of the agent versus time. A specific percent volumetric initial concentration and a specific percent volumetric metered concentration for the length of the test duration as determined by previous testing conducted per the established minimum performance standards is required for airworthiness approval of cargo compartment systems.
- b. Using the appropriate MPS evaluation criteria, evaluate the distribution profile of the agent for acceptable performance. The acceptability of the test data would be dependent upon

the distribution profile and duration exhibited by each probe per (1) above and Paragraph 7 for cargo compartment fire extinguishing systems

10. EVALUATION OF ALTERNATE LIQUID AGENT AND FIRE EXTINGUISHING/SUPPRESSION SYSTEMS

The FAA Technical Center has released a Technical Note that represents the latest Minimum Performance Standards (MPS) for a water spray system. However, as mentioned within the body of the report, additional developmental testing would be needed for the product and the FAA to be approached regarding certification of such a system. Additional testing would be required to demonstrate compliance with an Aerosol spray can fire threat. The Technical Center continues to perform research towards identifying alternate liquid and other fire extinguishing / suppression systems. Acceptable means of compliance for these immature systems are beyond the scope of this AMC. Future revisions to this AMC will be accomplished as soon as suitable standards are developed for these systems.

If for the product it is proposed to use a liquid fire extinguishing agent or system, the EASA should be contacted. The EASA will initiate a Certification Review Item addressing the use of an alternate fire extinguishing agent or system.

11. USE OF SIMULANTS FOR CERTIFICATION TESTING

The aviation industry may continue to use Halon in cargo fire suppression applications as long as acceptable alternatives have not been identified and shown to provide an equivalent level of safety. The EPA/EU is allowing the aviation industry to use Halon to demonstrate system functionality as long as a simulant or alternate extinguishing agent or alternate fire extinguishing system cannot be used in place of the Halon during system or equipment testing for technical reasons. It should be noted, however, that certain states continue to ban the release of Halon for testing. The FAA Technical Center and the International Aircraft Systems Fire Protection Working Group are concentrating efforts on evaluating alternative fire extinguishing agents and the use of simulants during certification testing. The EASA plans to approve a simulant which can be used in place of Halon 1301 during certification tests of aircraft fire extinguishing systems to predict actual Halon 1301 volumetric concentration levels. When approved, use of a simulant will be the preferred method for demonstrating compliance.

As of the date of this AMC, no suitable simulant for cargo compartment gaseous fire extinguishing systems has been identified. However, should the EASA being approached with the intent of utilising for the product a simulant in lieu of a Halon 1301 system or other gaseous fire extinguishing system then the recommended approach would be to perform testing which meets the Minimum Performance Standards for that application as developed by the International Aircraft Systems Fire Protection Working Group. To ensure acceptable successful means of compliance the same information as outlined above in paragraph 7 should be provided.

A simulant is defined in this AMC as a chemical agent that adequately imitates the discharge and distribution characteristics of a given extinguishing agent. It need not be an actual fire

suppressant. For certain cases due to cost of the extinguishing agent, problems with supply of the extinguishing agent, etc; it may be more appropriate for the application to utilise a simulant. The Agency would require adequate analysis and testing be accomplished to establish the validity of the simulant. As a minimum, corroborating information would need to be provided as to the detailed chemical analysis of the simulant and evaluation testing of the fire extinguishing system operated with the simulant which demonstrates the equivalent behaviour. To ensure acceptable means of compliance, the following must be provided:

- (1) The test data and distribution profiles using the simulant which meet the certification criteria as expressed below and in the Minimum Performance Standards as developed by FAA Technical Center as part of the International Aircraft Systems Fire Protection Working Group. (See Paragraph 15 for the listing of the references.)
- (2) A system description document that includes a description of the distribution of the simulant under the test conditions in the cargo compartment.
- (3) A detailed test plan.
- (4) Chemical data which describes the simulant and any toxicity data.

For the application the distribution of the simulant must be described as compared with Halon 1301 under the following conditions:

- a. Given the same filling conditions, the simulant is loaded into the fire extinguisher bottle based on an equivalent liquid fraction to the Halon 1301 charge weight required. This is an equivalent statement to the mass of the simulant being a specific percentage of the Halon 1301 charge weight required.
- b. The fire extinguisher bottle containing the simulant is pressurised with nitrogen in an identical manner required by the Halon 1301 charge weight.
- c. The simulant is discharged into the test environment, i.e. cargo compartment.

11.1 Pre-Test Considerations:

- a. An EASA accepted analyser (for example, Statham-derivative analyser) capable of measuring the simulant distribution profile in the form of volumetric concentration is required.
- b. An EASA accepted analyser (for example, Statham-derivative analyser) and associated hardware are configured for the particular application.
- c. The fire suppression system should be completely conformed for Halon 1301.
- d. The fire extinguisher bottle(s) should be serviced and prepared for the prescribed test(s).

11.2 Test Procedures:

- a. Perform the prescribed distribution test in accordance with the EASA approved test plan. See Paragraph 7 for guidance on probe placement.
- b. An EASA accepted analyser (for example, Statham-derivative analyser) should record the distribution profile as volumetric concentration for the simulant.

11.3 Test Result Evaluation:

- a. Produce the data from the EASA accepted analyser (for example, Statham-derivative analyser) in graphical format. This format should be the volumetric concentration of the simulant versus time. A specific percent volumetric initial concentration and a specific percent volumetric metered concentration for the length of the test duration as determined by previous testing conducted per the established minimum performance standards is required for airworthiness approval of cargo compartment systems.
- b. Using the Halon 1301 certification criteria, evaluate the distribution profile of the simulant for acceptable performance. The acceptability of the test data would be dependent upon the distribution profile and duration exhibited by each probe (See above and Paragraph 7 for cargo compartment fire extinguishing systems).

12. ESTABLISHING DURATION FOR THE SUPPRESSION SYSTEM.

The adequacy of the capacity of the “built-in system” is understood to mean, that there is sufficient quantity of agent to combat the fire anywhere where baggage and cargo is placed within the cargo compartment for the time duration required to land and evacuate the aeroplane. Current built-in cargo fire extinguishing systems utilise Halon 1301 as the fire extinguishing agent. Protection is afforded as long as the minimum concentration levels in the cargo compartment do not drop below three percent by volume. The time for which a suppression system will maintain the minimum required concentration levels should be identified as a certificate limitation.

The designer of the product should work with the aircraft owner and the civil aviation authority providing operational approval to ensure that the cargo fire extinguishing system provides the required protection time (i.e., proper sizing of the cargo fire extinguishing system) for the specific route structure. The civil aviation authority may insist on some holding time to allow for weather and other possible delays, and may specify the speeds and altitudes used to calculate aeroplane diversion times based on one-engine-out considerations.

The civil aviation authority providing operational approval for the aeroplane determines the maximum allowable time, following the discovery of a fire or other emergency situation, required to divert the aeroplane to an alternate landing site. In the past, for some cases, the maximum allowable time was calculated by adding a 15 minute allowance for holding and/or approach and landing to the actual time required to reach the alternate landing site under specific operating conditions. With the issuance of this AMC, an allowance of 15 minute for approach and landing must be considered and certification data must include analysis and/or data taken after landing at a time increment which represents the completion of an evacuation of all occupants.

AMC 20-6 “Extended Range Operation with Two-Engine Aeroplanes (ETOPS),” provides acceptable means for obtaining approval under applicable operational rules for two-engine aeroplanes operating over a route that contains a point farther than one hour’s flying time at the normal one-engine inoperative cruise speed (in still air) from an adequate airport. It includes specific criteria for deviations of 75 minutes, 120 minutes, and 180 minutes from an adequate airport plus an allowance for 15-minute holding and/or approach and land.

Certification flight tests, supplemented by analysis for cargo load factors and additional metering system bottles as applicable, determines the maximum protection time provided by the cargo fire extinguishing system. This maximum protection time may not be the same as the maximum allowable time required to divert the aeroplane. The certificate limitation for total time, including the 15 minute allowance for holding and/or approach and landing as applicable, should never be greater than the maximum protection time provided by the cargo fire extinguishing system.

The following examples illustrate these issues:

Example 1

Maximum protection time provided
By cargo fire extinguishing system = 127 minutes
Maximum diversion time = 112 minutes + 15 minutes

(Note - in this example, the civil aviation authority required an allowance of 15 minutes for holding and/or approach and landing)

Certificate limitation for total time = 127 minutes

Example 2

Maximum protection time provided
By cargo fire extinguishing system = 68 minutes
Maximum diversion time = 60 minutes

(Note - in this example, the civil aviation authority did not require the 15 minutes allowance for holding and/or approach and landing. With the issuance of this AMC, the approach indicated in example 2 above is no longer considered an acceptable means of compliance.)

Certificate limitation for total time = 60 minutes”

13. MANUAL CONSIDERATIONS.

To ensure fire protection/fire suppression system effectiveness and safe continuation of flight and landing, the applicable aeroplane manuals should contain appropriate directives, for example:

- a. Any procedures related to fighting a cargo compartment fire should be clearly defined in the Aeroplane Flight Manual (AFM).

- b. Aeroplane Flight Manuals should contain instructions to land at the nearest adequate airport (or suitable airport for ETOPS) following detection of a cargo fire.
- c. Cargo loading restrictions (certified type of loading per compartment, limits for loading heights and width, etc.) should be clearly described in the Weight & Balance Manual or any other appropriate aeroplane manual.
- d. Where the use of aeroplane manuals is considered to be impractical during cargo loading activities, all necessary information may be introduced into crew operating manuals or part of dedicated instructions for cargo loading personnel.

14. PLACARDS AND MARKINGS IN CARGO COMPARTMENTS

Experience has shown that under certain circumstances and despite clear instructions in the applicable aircraft documentation, cargo loading personnel may not obey loading restrictions. Especially pallets may be loaded higher than certified or bulk cargo may be stowed up to the ceiling, adversely affecting smoke detection and fire protection/fire suppression system effectiveness.

To visually indicate the applicable loading restrictions to each person being responsible for cargo loading activities in a compartment, placards and markings for certified type of cargo, maximum loading height and widths may need to be installed in that compartment.

For the design of these indications (i.e., for shape, size, colour and brightness), illumination conditions in the compartment should be considered. Markings and placards should not be easily erased, disfigured or obscured. Further guidance may be derived from compliance demonstrations for CS paragraphs regulating other internal markings and placards, for example in the cockpit or passenger compartment.

15. REFERENCES.

- a. Report No. FAA-RD-71-68, Fire Extinguishing Methods for New Passenger Cargo Aircraft, dated November 1971.
- b. Report No. DOT/FAA/AR-96/5, Evaluation of Large Class B Cargo Compartment's Fire Protection, dated June 1996.
- c. Civil Aviation Authority (CAA) Paper 91003, Cargo Bay Fire Suppression, dated March 1991.
- d. Report No. DOT/FAA/AR-00-28, Development of a Minimum Performance Standard for Aircraft Cargo Compartment Gaseous Fire Suppression Systems, dated September 2000.
- e. Report No. DOT/FAA/AR-TN01/1, Water Spray as a Fire Suppression Agent for Aircraft Cargo Compartment Fires, dated March 2001.

APPENDIX 1: ANALYTICAL METHODS FOR DETERMINING HALON 1301 CONCENTRATION LEVELS

1. PURPOSE. This appendix contains analytical methods for determining Halon 1301 fire extinguishing agent concentration levels in empty or loaded cargo compartments as a function of time.

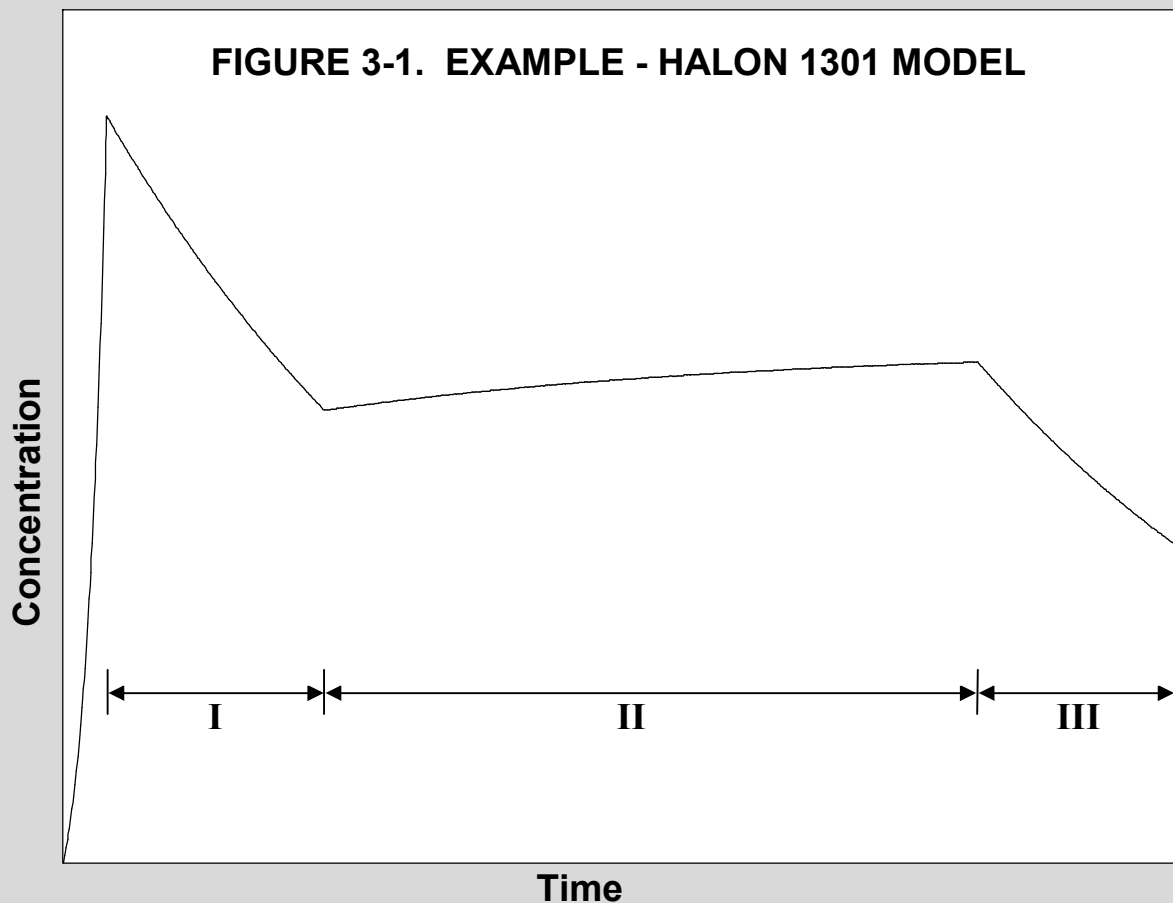
2. EXPLANATION OF TERMS AND SYMBOLS.

TABLE 2-1. TERMS AND SYMBOLS

SYMBOL	DESCRIPTION	UNITS CONSISTENT WITH EQUATIONS
C(t)	Halon 1301 concentration by volume at time "t." $= V_{\text{Halon 1301}} / V$	Dimensionless
$V_{\text{Halon 1301}}$	Volume of Halon 1301 in cargo compartment.	Cubic metre - m ³ (Cubic feet - ft ³)
V	Cargo compartment free volume (i.e., volume not occupied by cargo). $= 1 - (V_{\text{cargo}} / V_{\text{empty}})$	Cubic metre - m ³ (Cubic feet - ft ³)
V_{cargo}	Cargo volume.	Cubic metre - m ³ (Cubic feet - ft ³)
V_{empty}	Empty cargo compartment volume.	Cubic metre - m ³ (Cubic feet - ft ³)
T	Time.	Minutes – Min
E	Cargo compartment leakage rate.	Cubic metre per minute - m ³ /min (Cubic feet per minute - ft ³ /min)
S	Specific volume of Halon 1301.	Cubic metre per kilogram m ³ /kg (cubic feet per pounds(mass) ft ³ /lbm)
R	Halon 1301 flow rate.	Kilogram per minute kg/min (pounds(mass) per minute lbm/min)

3. HALON 1301 CONCENTRATION LEVEL MODEL.

Cargo compartment fire extinguishing systems generally use a combination of one or two types of Halon 1301 discharge methods. One type rapidly releases all of the fire extinguishing agent from one or more pressurised bottles into the cargo compartment. This type of discharge method is commonly known as a high rate discharge or 'dump' system.



The second type of Halon 1301 discharge method slowly releases the fire extinguishing agent from one or more pressurised bottles into the cargo compartment. This type of discharge method is commonly known as a metering system.

The following list provides some examples, not all-inclusive, of different combinations of these Halon 1301 discharge methods.

- a. One high rate discharge.
- b. One high rate discharge followed by a second high rate discharge at a specified later time.
- c. One high rate discharge followed by a metered discharge at a specified later time.
- d. Simultaneous high rate and metered discharges.

The Halon 1301 fire extinguishing system described in paragraph 3.c. above utilizes both types of discharge methods and is illustrated in Figure 3-1.

Prior to Phase I - Initial High Rate Discharge of Halon 1301

This portion of the extinguishing process illustrates the high rate discharge method of releasing all of the fire extinguishing agent from one or more pressurised bottles into the cargo compartment.

Phase I - Exponential “Decay” of Halon 1301

The beginning of Phase I represents the initial concentration of Halon 1301 used to knock down a cargo fire. Since no more Halon 1301 is introduced into the cargo compartment during Phase I, the concentration of Halon 1301 undergoes an exponential “decay” versus time.

The governing equation for exponential “decay” during Phase I is the following:

$$C(t) = C(0) e^{-E t/V}$$

NOTE - **C(0)** is the initial concentration of Halon 1301 used to knock down a cargo fire at the beginning of Phase I and **t** is the time elapsed since the beginning of Phase I.

Phase II - Metered Discharge of Halon 1301

The metered discharge of Halon 1301 starts at the beginning of Phase II. The example in Figure 3-1 shows that the metering rate is set to release Halon 1301 into the cargo compartment at a rate which is slightly greater than the rate Halon 1301 is lost through cargo compartment leakage.

The governing equation for metering during Phase II is the following:

$$C(t) = [C(0) - \{ R S / E \}] e^{-E t/V} + \{ R S / E \}$$

NOTE - **C(0)** is the concentration of Halon 1301 at the end of Phase I and **t** is the time elapsed since the end of Phase I.

Phase III - Exponential “Decay” of Halon 1301

The beginning of Phase III marks the end of Halon 1301 metering. As in Phase I, since no more Halon 1301 is introduced into the cargo compartment, the concentration of Halon 1301 undergoes an exponential “decay” versus time.

The governing equation for exponential “decay” during Phase III is the same as during Phase I with one exception; **C(0)** is the concentration of Halon 1301 at the end of Phase II and **t** is the time since the end of Phase II.”

19. Make corrections in AMC 25.1309, paragraphs b, c and d of Section 4 as follows :

b. Certain single failures or jams covered by CS 25.671(c)(1) and CS 25.671(c)(3) are ~~accepted~~ **excepted** from the requirements of CS 25.1309(b)(1)(ii). FAR 25.671(c)(1) requires the consideration of single failures, regardless of the probability of the failure. CS 25.671(c)(1) does not consider the effects of single failures if their probability is shown to be extremely improbable and the failures also meet the requirements of CS 25.571(a) and (b).

c. Certain single failures covered by CS 25.735(b)(1) are ~~accepted~~ **excepted** from the requirements of CS 25.1309(b). The reason concerns the brake system requirement that limits the effect of a single failure to doubling the brake roll stopping distance. This requirement has been shown to provide a satisfactory level of safety without the need to analyse the particular circumstances and conditions under which the single failure occurs.

d. The failure effects covered by CS 25.810(a)(1)(v) and CS 25.812 are ~~excepted~~—~~accepted~~ from the requirements of CS 25.1309(b). ...

20. Delete existing AMC 25.1329 (Automatic Pilot) and replace with revised and expanded AMC 25.1329 material comprising AMC Nos. 1 and. 2 to CS 25.1329 as follows:

~~AMC 25.1329~~
~~Automatic Pilot~~

~~INTRODUCTION~~

~~CS 25.1329 and this AMC apply to basic automatic pilot certification. For automatic pilots, which are capable of automatic landing or are to be used in precision approaches with a decision height below 60 m (200 ft), supplementary airworthiness requirements apply (see CS AWO).~~

~~1—General~~

~~1.1—For the purpose of this AMC the term ‘automatic pilot’ includes the sensors, computers, power supplies, servo motors/actuators and associated wiring, necessary for its function. It includes any indications and controllers necessary for the pilot to manage and supervise the system.~~

~~1.2—Any part of the automatic pilot, which remains connected to the primary flight controls when the automatic pilot is not in use, is regarded as a part of the primary flight controls and the provisions for such systems are applicable.~~

~~1.3—In showing compliance with CS 25.395(b), servo motors, their mountings and their connection to the flight control system should have limit and ultimate factors of safety of not less than 1.0 and 1.5 respectively, with the maximum loads which can be imposed by the automatic pilot, or by the flight control system (up to its design load).~~

~~1.4 — Adequate precautions should be taken in the design process and adequate procedures should be specified in the maintenance manual to prevent the incorrect installation, connection or adjustment of parts of the automatic pilot if such errors would hazard the aeroplane (e.g. torque clutches or limit switches with a range of adjustment such that maladjustment could be hazardous).~~

~~1.5 — The response of the automatic pilot should be considered in showing compliance with the structural requirements of CS 25 Subparts C and D.~~

~~1.6 — The automatic pilot should be so designed and installed that the tolerances demonstrated during certification tests can be maintained in service.~~

~~1.7 — The automatic pilot should not cause sustained nuisance oscillations, undue control activity or sudden large attitude changes, especially when configuration or power changes are taking place.~~

~~1.8 — When automatic functions are provided which may be used with the automatic pilot (e.g. automatic throttle control or yaw damper, etc.) and use of the automatic pilot is permitted with any of these functions inoperative, it should comply with the provisions of this AMC with these functions operative and inoperative.~~

~~1.9 — Operating procedures for use with the automatic pilot should be established. (See CS 25.1585(a) and (b).)~~

~~1.10 — In addition to the quick release controls of CS 25.1329(d), in order to show compliance with CS 25.1309 an alternative means of disengagement, readily accessible in flight, should be provided.~~

~~1.11 — It should be possible to disengage the automatic pilot at any time without unacceptable out-of-trim forces.~~

~~2 — *Performance of Function*~~

~~2.1 — The automatic pilot should be demonstrated to perform its intended function in all configurations in which it may be used throughout all appropriate manoeuvres and environmental conditions, including turbulence, unless an appropriate operating limitation or statement is included in the aeroplane Flight Manual. All manoeuvres should be accomplished smoothly, accurately and without sustained nuisance oscillation. This demonstration should be conducted with system tolerances at the lower limits of automatic pilot authority.~~

~~NOTE: The acceptability of the performance may be based on subjective judgement taking into account the experience acquired from similar equipment and the general behaviour of the aeroplane. The acceptable performance may vary according to aeroplane type and model.~~

~~2.2 — If the automatic pilot is to be approved for ILS or MLS approaches, a series of approaches should be made in the normal approach configuration(s) to the Minimum Use Height (MUH) (see paragraph 5.3.4). These approaches should be made in conditions chosen to show that the performance is satisfactory within permitted extremes such as weight, centre of gravity position, wind speed, capture angle and range. Unless otherwise justified, performance should be demonstrated on at least two facilities of each type of approach system, which is to be certificated for use with the automatic pilot. To cover this range of conditions, it can be expected that in the order of 15 approaches will be needed. In the event that the performance is not satisfactory down to the MUH established in accordance with paragraph 5.3.4, then the Flight Manual should specify an MUH at which the performance is satisfactory.~~

~~(An approach is considered to be satisfactory if it is stable without large deviations from the intended path or speed during the approach and, at the MUH, the position and velocities of the aeroplane are such that a safe landing can readily be made.)~~

~~2.3 If approval is sought for ILS or MLS approaches initiated with one engine inoperative and the aeroplane trimmed at glide path intercept, the automatic pilot should be capable of conducting the approach without further manual trimming.~~

~~3 Controls, Indicators and Warnings~~

~~3.1 The controls, indicators and warnings should be so designed as to minimise crew errors. Mode and malfunction indications should be presented in a manner compatible with the procedures and assigned tasks of the flight crew. The indications should be grouped in a logical and consistent manner and be visible from each pilot's station under all expected lighting conditions.~~

~~3.2 The means provided to comply with CS 25.1329(h) should also give an appropriate indication when there is—~~

- ~~a. Failure to achieve the selected mode; and~~
- ~~b. Inadvertent change or disengagement of a mode.~~

~~4 Characteristics of Some Specific Modes~~

~~4.1 Automatic Acquisition of Altitude Hold Mode. Where the automatic pilot has the ability to acquire and maintain a pre-selected altitude it should be shown in particular that—~~

~~a. If the pilot fails to advance the throttles following an altitude acquisition from a descent, the aeroplane exhibits no hazardous characteristics if recovery action is taken within a reasonable period after the onset of stall warning, or other appropriate warning;~~

~~NOTE: Compliance with this provision need not be demonstrated if adequate means are provided to prevent such an error.~~

~~b. Resetting the datum pressure or the selected altitude at any time during altitude acquisition does not result in a hazardous manoeuvre.~~

~~4.2 Go-around Mode. Where the automatic pilot has the ability to carry out an automatic go-around—~~

~~a. The speed should be compatible with that used for a manually controlled go-around; it should not be less than the higher of 1.13 V_{SR} or the appropriate minimum control speed (see CS 25.149);~~

~~b. The control actions and flight path during the initial rotation should not be significantly different from those of a manually controlled go-around;~~

~~c. Flight path control following an engine failure during go-around should not require exceptional piloting skill or alertness; and~~

~~d. Any failure condition that causes the automatic pilot to fail to initiate the go-around without a warning appropriate to the approved use of the system, should be assessed as Extremely Remote.~~

~~4.3 Control Wheel Steering Mode (CWS). Where the pilot has the ability to make inputs to the automatic pilot by movement of the normal control wheel (control wheel steering)—~~

~~a. — It should be possible for the pilot to overpower the automatic pilot and to achieve the maximum available control surface deflection without using forces so high that the controllability requirements of CS 25.143(d) are not met;~~

~~b. — The maximum bank and pitch attitudes, which can be achieved without overpowering the automatic pilot, should be limited to those necessary for the normal operation of the aeroplane;~~

~~NOTE: Typically $\pm 35^\circ$ in roll $+20^\circ$ to -10° in pitch.~~

~~c. — It should be possible to perform all normal manoeuvres smoothly and accurately without nuisance oscillation. It should be possible also to counter all normal changes of trim due to change of configuration or power, within the range of flight conditions in which control wheel steering may be used, without encountering excessive discontinuities in control force which might adversely affect the flight path;~~

~~d. — The stall and stall recovery characteristics of the aeroplane should remain acceptable. It should be assumed that recovery is made with CWS in use unless automatic disengagement of the automatic pilot is provided;~~

~~e. — In showing compliance with CS 25.143(g) account should be taken of such adjustments to trim as may be carried out by the automatic pilot in the course of manoeuvres, which can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged manoeuvres provided the reduced control forces would not be hazardous;~~

~~f. — If the use of this mode for take off and landing is to be permitted it should be shown that —~~

~~i. — Sufficient control, both in amplitude and rate is available without encountering force discontinuities;~~

~~ii. — Reasonable mishandling is not hazardous (e.g. engaging the automatic pilot while the elevators or ailerons are held in an out-of-trim position); and~~

~~iii. — Runaway rates and control forces are such that the pilot can readily overpower the automatic pilot with no significant deviation in flight path;~~

~~iv. — Any lag in aircraft response induced by the CWS mode is acceptable for the intended manoeuvre.~~

~~g. — It should not be possible to revert to the CWS mode by applying a force to the control column or wheel unless the autopilot is in a capture mode (e.g. altitude capture, localizer capture). When the force is released the autopilot should return to the previously engaged capture mode or to the track mode.~~

~~5 — Failure Conditions~~

~~5.1 — Analysis~~

~~5.1.1 — An analysis should be carried out to define the Failure Conditions and their Effects and to show that the probability of each Failure Condition is such that the provisions of paragraph 5.2 are achieved. The depth of the analysis may be significantly reduced and numerical probability analysis may not be required in the case of a single-channel automatic pilot if worst-case failures can be easily identified and used as the basis of a ground and flight test demonstration programme (e.g. where the effect of a failure is limited by an independent device whose serviceability is frequently checked).~~

~~5.1.2 When the failure of a device can remain undetected in normal operation, the frequency with which the device is checked will directly influence the probability that such a failure is present on any particular occasion. This should be taken into account when assessing the probabilities of any Failure Conditions, which include dormant failures in the monitoring devices or in other unchecked parts of the system (see paragraph 5.1.6).~~

~~5.1.3 When the failure of a component or equipment can be expected to result in other failures, then these further failures should be taken into account in the analysis. In assessing which further failures may occur, consideration should be given to any change in the equipment operating conditions for other components or equipment resulting from the first failure.~~

~~5.1.4 In considering damage from external sources, account should be taken of the location of the equipment in the aeroplane and other features of the installation.~~

~~5.1.5 Attention should be given in the analysis to common mode failures (i.e. multiple failures arising from a single cause). The following are examples:~~

- ~~a. A local fire causing multiple fractures;~~
- ~~b. Electromagnetic interference or electrical transients causing multiple malfunctions;~~
- ~~c. Mechanical vibration causing multiple failures or malfunctions;~~
- ~~d. Leakage of water or other liquids (e.g. from galley, lavatories or cargo) causing multiple electrical failures;~~
- ~~e. The failure of a cooling system or the leakage of hot air causing multiple failures in other systems;~~
- ~~f. Lightning strike; and~~
- ~~g. Engine failure.~~

~~5.1.6 When exposure times relevant to failure probability calculations are dependent on flight crew and maintenance checks (i.e. pre-flight, first flight of the day, pre-land etc.) and/or inspection intervals for dormant (latent) failures, these tasks, time intervals and the recommended component monitoring programme should be clearly specified in the certification documentation, and made available for the purposes of scheduling flight crew and maintenance procedures.~~

~~5.2 Acceptability of Failure Conditions~~

~~5.2.1 Any Failure Condition occurring within the normal flight envelope should be assessed as Extremely Improbable if its effect is one of the following:~~

- ~~a. A load on any part of the primary structure sufficient to cause a catastrophic structural failure;~~
- ~~b. Catastrophic loss of flight path control;~~
- ~~c. Exceedance of V_{DE}/M_{DE} ; or~~
- ~~d. Catastrophic flutter or vibration.~~

~~5.2.2 Any Failure Condition occurring within the normal flight envelope should be assessed as Extremely Remote if its effect is one of the following:~~

- ~~a. A load on any part of the structure greater than its limit load;~~

- ~~b. Exceedance of airspeed halfway between V_{MO} and V_{DF} or a Mach number halfway between M_{MO} and M_{DF} ;~~
- ~~c. A stall;~~
- ~~d. A normal acceleration less than a value of 0 g;~~
- ~~e. Bank angles of more than 60° en route or more than 30° below a height of 305 m (1000 ft). If the MUH is below 30m (100 ft), the bank angle exceedance limit should be reduced to a value, which takes account of the size of the aeroplane and its handling characteristics;~~
- ~~f. Hazardous degradation of the flying qualities of the aeroplane;~~
- ~~g. Hazardous height loss in relation to minimum permitted height for automatic pilot use (see paragraph 5.3); or~~
- ~~h. Engagement or disengagement of a mode leading to hazardous consequences.~~

~~5.2.3 Any Failure Condition for which the probability of occurrence is assessed as Remote should have an appropriately less severe effect than those listed in paragraph 5.2.2.~~

~~5.2.4 Compliance with the requirements of paragraphs 5.2.1, 5.2.2 and 5.2.3 should be shown by ground simulation, flight tests or suitable analysis. Where appropriate, account should be taken of pilot recognition of the Failure Condition, and any subsequent recovery action taken. The limiting values given in paragraph 5.2.2 should not be exceeded either during any manoeuvre caused by the failure or during the recovery by the pilot. The minimum heights at which the automatic pilot may be used should be determined.~~

~~5.2.5 The most critical of the Failure Conditions which are not assessed as Extremely Remote or Extremely Improbable should be demonstrated in flight test (see paragraph 5.3). Failure Conditions, which are assessed as Extremely Remote, may be demonstrated by a ground simulation or analysis, which has been suitably validated, using the same procedures as are specified in paragraph 5.3 for flight test.~~

~~5.3 *Flight Demonstrations.* When demonstrating compliance with paragraph 5.2 by means of flight test, the following procedures should be used:~~

~~5.3.1 *General*~~

- ~~a. Failure Conditions of the automatic pilot including, where appropriate, multi-axis failures and automatic trim failures, should be simulated in such a manner as to represent the overall effect of each Failure Condition about all axes.~~
- ~~b. Following recognition of the Failure Condition by the pilot, a delay, as specified in paragraphs 5.3.2, 5.3.3, 5.3.4 and 5.3.5 should be applied before the commencement of recovery action. Following such delay the pilot should be able to return the aeroplane to its normal flight attitude under full manual control without engaging in any dangerous manoeuvres during recovery and without control forces exceeding the values given in CS 25.143(d). During the recovery the pilot may overpower the automatic pilot or disengage it. For the purpose of determining the minimum height at which the autopilot may be used during an approach, a normal acceleration of the order of 1.5 g should be applied. Such an acceleration should not lead to an unsafe speed excursion during the manoeuvre to resume a normal flight path.~~

~~e. — System authority should be set at the most adverse tolerance limits unless an analysis shows that they have no significant effect and the flight conditions should be the most critical which is appropriate (centre of gravity, weight, flap setting, altitude, speed, power or thrust).~~

~~d. — In malfunction tests described in paragraphs 5.3.2, 5.3.3, 5.3.4 and 5.3.5 the recognition point should be that at which a pilot in service operation in non-visual conditions may be expected to recognise the need to take action and not that at which the test pilot engaged in the flight trials does so. Recognition of the malfunction may be through the behaviour of the aeroplane or an appropriate failure warning system and the recognition point should be identified. Control column or wheel movements alone should not be used for recognition. The recognition time should not normally be less than 1 second. If a recognition time of less than 1 second is claimed, specific justification will be required (e.g. additional tests to ensure that the time is representative in the light of the cues available to the pilot).~~

~~e. — If any auto throttle system is installed, the tests should be performed with the auto throttle system engaged or disengaged whichever is the more adverse case.~~

~~f. — For control wheel steering, in those phases of flight where the pilot is exercising manual control (e.g. take-off, landing) the delay times specified in paragraphs 5.3.2, 5.3.3, and 5.3.5 need not be applied. The pilot may commence recovery action at the recognition point. (See also paragraph 4.3 f.)~~

~~g. — The aeroplane should be so instrumented that the parameters appropriate to the test are recorded (e.g. normal acceleration, airspeed, height, pitch and roll angles, automatic pilot engagement state). The fitment of the instrumentation should not affect the behaviour of the automatic pilot or any other system.~~

~~5.3.2 *Climb, Cruise, Descent and Holding*~~

~~a. — Recovery action should not be initiated until three seconds after the recognition point.~~

~~b. — The MUH for the automatic pilot in climb, cruise, descent or holding should not be less _____ than 305 m (1000 ft), unless the height loss is determined under the conditions for which use of the automatic pilot is requested. In that case the MUH should not be less than twice the height loss. The height loss is measured as the difference between the height at the time the malfunction is induced to the lowest height in the recovery manoeuvre.~~

~~5.3.3 *Manoeuvring Flight*~~

~~a. — Recovery action should not be initiated until one second after the recognition point.~~

~~b. — Malfunctions should be induced in turns at the maximum bank angles for normal operation.~~

~~5.3.4 *Approach Coupled to an ILS or MLS vertical guidance*~~

~~a. — The aircraft should be flown down the glide path in the configuration and at the approach speed specified. Simulated automatic pilot malfunctions should be induced at critical points during the approach, taking into consideration all possible design variations in automatic pilot system sensitivity and authority. In general, malfunction demonstrations~~

may be restricted to hard-overs (and possibly automatic trim failures) unless an MUH below 30m (100 ft) is requested, when runaways at lower rates should also be investigated

~~b. — A 3° glide path should be used.~~

~~e. — The aeroplane should be so instrumented that the following information is recorded:~~

~~i. — The path of the aeroplane with respect to the normal glide path;~~

~~ii. — The point along the glide path when the simulated malfunction is induced;~~

~~iii. — The point where the pilot indicates recognition of the malfunction; and~~

~~iv. — The point along the path of the aeroplane where the recovery action is initiated.~~

~~d. — Recoveries from malfunction should simulate non-visual conditions with a one-second time delay between recognition point and initiation of recovery.~~

~~e. — The MUH should be determined as the height of the aeroplane wheels at the point where recovery from the failure is initiated when the path of the aeroplane wheels during the recovery manoeuvre is tangent to the runway or to a 1:29 slope line drawn from a point 4.6 m (15 ft) above the runway threshold (See Figure 1). If there is no automatic landing capability, the MUH should not be less than 15m (50 ft).~~

~~f. — An engine failure should not cause a heading change at a rate greater than three degrees per second averaged over a five second period, or produce hazardous attitudes (see also paragraph 5.2.2 e.). In showing compliance with this, manual retrimming of the aeroplane is not permitted.~~

~~5.3.5 Approach not coupled to ILS or MLS vertical guidance~~

~~a. — The procedure described in paragraphs 5.3.4 a. to f. should be applied.~~

~~b. — A descent path of three degrees should be used unless the automatic pilot is to be approved for significantly steeper descents.~~

~~c. — The MUH for the automatic pilot should not be less than twice the height loss, where the height loss is measured as described in paragraph 5.3.2 b.~~

~~5.3.6 Failure to disengage. Unless failure of the automatic pilot to disengage during the approach when the pilot operates the quick release control on the control wheel is assessed as Extremely Remote it should be demonstrated that the pilot could control the aeroplane manually without operating any of the other disengagement controls.~~

~~5.3.7 Automatic Pilot Engagement below 305 m (1000 ft) after Take-Off~~

~~a. — The minimum altitude at which the automatic pilot may be engaged should be the greatest of the following:~~

~~i. — The altitude at which, in an all-engines take-off at the WAT limit using the AFM procedures, the aeroplane response and recovery manoeuvre resulting from the worst case nose-down hardover does not penetrate the net flight path as defined in CS 25.115.~~

~~ii. — The altitude at which, in an all-engines take-off at the WAT limit using the AFM procedures, the aeroplane has reached an airspeed so that the manoeuvre resulting from the worst case nose-up hardover does not result in an unsafe speed in the whole manoeuvre including the pilot recovery.~~

~~iii. — The altitude at which the stall identification system (e.g. stick pusher) is armed (if installed).~~

~~iv. — The altitude at which the practicability of crew procedures to engage the autopilot has been demonstrated.~~

~~b. — The automatic pilot should not command, in response to the loss of an engine, a manoeuvre resulting in an unsafe attitude such that the pilot, without using exceptional skill or strength, cannot safely take over control of the aeroplane.~~

~~e. — Roll hardovers should be shown to comply with paragraph 5.2.2 e.~~

~~d. — It is assumed that the pilot will be attentive to aeroplane manoeuvres at low altitudes before flap retraction. A delay time of one second after recognition of the malfunction should be used prior to the pilot taking corrective action.~~

~~5.4 — Oscillatory tests~~

~~5.4.1 — An investigation should be made to determine the effects of an oscillatory signal of sufficient amplitude to saturate the servo amplifier of each device that can move a control surface unless such a malfunction is assessed as Extremely Improbable. The investigation should cover the range of frequencies, which can be induced by a malfunction of the automatic pilot and systems functionally connected to it, including an open circuit in a feed-back loop. The investigated frequency range should include the highest frequency, which results in apparent movement of the system driving the control surface to the lowest elastic or rigid body response frequency of the aeroplane. Frequencies less than 0.2 Hz may, however, be excluded from consideration. The investigation should also cover the normal speed and configuration ranges of the aeroplane. The results of this investigation should show that the peak loads imposed on the parts of the aeroplane by the application of the oscillatory signal are within the limit loads for these parts.~~

~~5.4.2 — The investigation may be accomplished largely through analysis with sufficient flight data to verify the analytical studies or largely through flight tests with analytical studies extending the flight data to the conditions, which impose the highest percentage of limit, load to the parts.~~

~~5.4.3 — When flight tests are conducted in which the signal frequency is continuously swept through a range, the rate of frequency change should be slow enough to permit determining the amplitude of response of any part under steady frequency oscillation at any critical frequency within the test range.~~

~~{Amdt. No.:25/3}~~

1 PURPOSE

This AMC provides interpretative material and acceptable means of compliance with the specifications of CS 25.1329 for Flight Guidance Systems. These means are intended to provide guidance to supplement the engineering and operational judgment that must form the basis of any compliance demonstration.

2 RELATED CERTIFICATION SPECIFICATIONS

CSs

The following are related CS standards:

25.115	Take-off flight path
25.302	Interaction of systems and structures
25.671	Control systems, General
25.672	Stability augmentation and automatic and power-operated systems
25.677	Trim systems
25.777	Cockpit controls
25.779	Motion and effect of cockpit controls
25.781	Cockpit control knob shape
25.901	Powerplant, General, Installation–
25.903	Powerplant, General, Engines
25.1301	Equipment, General, Function and installation–
25.1309	Equipment, systems, and installations
25.1322	Warning, caution, and advisory lights
25.1581	Aeroplane Flight Manual, General
CS-AWO	All Weather Operations

3 RELATED ADVISORY MATERIAL

EASA Acceptable Means of Compliance (AMC) and FAA Advisory Circulars (FAA AC).

The following guidance and advisory materials are related to this AMC:

AMC 20-115B	Recognition of EUROCAE ED-12B / RTCA DO-178B
AMC 25.1309	System Design and Analysis
AMC 25.1322	Alerting Systems
AMC 25.1581	Aeroplane Flight Manual
AMC 25-11	Electronic Display Systems
FAA AC 20-129	Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. National Airspace System (NAS) and Alaska
FAA AC 25-7A	Flight Test Guide for Certification of Transport Category Airplanes
FAA AC 25-12	Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category Airplanes
FAA AC 120-28D	Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout
FAA AC 120-29A	Criteria for Approval of Category I and Category II Weather Minima for Approach
FAA AC 120-41	Criteria for Operational Approval of Airborne Wind Shear Alerting and Flight Guidance Systems

4 RELATED DOCUMENTS

JAA documents:

JAR-OPS 1	Commercial Air Transportation (Aeroplanes)
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Industry documents.

The following are related Industry Standards that may be useful in the design process:

SAE ARP5366	Autopilot, Flight Director and Autothrust Systems
SAE ARP4754	Certification Considerations for Highly Integrated or Complex Aircraft Systems
SAE ARP4100	Flight Deck and Handling Qualities Standards for Transport Aircraft
SAE ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

RTCA DO-178B/ EUROCAE ED-12B	Software Considerations in Airborne Systems and Equipment
RTCA DO-160D/ EUROCAE ED-14D	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA DO-254/ EUROCAE ED-80	Design Assurance Guidance for Airborne Electronic Hardware
DOT/FAA/CT-96/1	Human Factors Design Guide for Acquisition of Commercial-Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems.

5 DEFINITIONS AND ACRONYMS

The following definitions apply to the specifications of CS 25.1329 and the guidance material provided in this AMC. They should not be assumed to apply to the same or similar terms used in other regulations or AMC material. Terms for which standard dictionary definitions apply are not defined in this AMC.

5.1 Definitions

Abnormal Condition	See Non-normal
Advisory	EASA: Crew awareness is required and subsequent crew action may be required. (AMC 25.1322)
Alert	<p>A generic term used to describe a flight deck indication meant to attract the attention of the flight crew to a non-normal operational or aeroplane system condition without implying the degree or level of urgency for recognition and corrective action by the crew. Warnings, Cautions and Advisories are considered to be Alerts.</p> <p>EASA definition: A signal to the crew intended to draw their attention to the existence of an abnormality, system fault or aircraft condition and to identify it. (AMC 25.1322)</p>
Analysis	The terms “analysis” and “assessment” are used throughout. Each has a broad definition and the two terms are to some extent interchangeable. However, the term analysis generally implies a more specific, more detailed evaluation, while the term assessment may be a more general or broader evaluation but may include one or more types of analysis (AMC 25.1309).

Arm	A condition where the intent to transition to a new mode or state has been established but the criteria necessary to make that transition has not been satisfied.
Assessment	See the definition of analysis above (AMC 25.1309).
Autopilot	The autopilot function provides automatic control of the aeroplane, typically in pitch, roll, and yaw. The term includes the sensors, computers, power supplies, servo-motors/actuators and associated wiring, necessary for its function. It includes any indications and controllers necessary for the pilot to manage and supervise the system. Any part of the autopilot that remains connected to the primary flight controls when the autopilot is not in use is regarded as a part of the primary flight controls.
Autothrust	The autothrust function provides automatic control of the thrust of the aeroplane. The term includes the sensors, computers, power supplies, servo-motors/actuators and associated wiring, necessary for its function. It includes any indications and controllers necessary for the pilot to manage and supervise the system. Any part of the autothrust that remains connected to the engine controls when the autothrust is not in use is regarded as a part of the engine control system.
Caution	A flight deck indication that alerts the flight crew to a non-normal operational or aeroplane system condition that requires immediate crew awareness. Subsequent pilot corrective compensatory action will be required.
Cognitive Task Analysis	An analysis that focuses on the mental processes, skills, strategies, and use of information required for task performance.
Complex	A system is Complex when its operation, failure modes, or failure effects are difficult to comprehend without the aid of analytical methods (AMC 25.1309).
Conformal	Positioned and scaled with respect to the outside view
Control Wheel Steering (CWS)	A Flight Guidance System (FGS) function which, when engaged, enables the pilot/first officer to manually fly the aeroplane by positioning the flight control surfaces using the autopilot servos. The positions of the flight deck controls (e.g., control column, control wheel) are determined by the FGS, which converts them into autopilot servo commands. The autopilot servos, in turn, drive the appropriate flight control surfaces.

Conventional	A system is considered to be Conventional if its functionality, the technological means used to implement its functionality, and its intended usage are all the same as, or closely similar to, that of previously approved systems that are commonly-used (AMC 25.1309).
Engage	A steady state that exists when a flight crew request for mode or system functionality has been satisfied.
Error	An omission or incorrect action by a crewmember or maintenance personnel, or a mistake in requirements, design, or implementation (AMC 25.1309).
Failure	An occurrence that affects the operation of a component, part, or element such that it can no longer function as intended (this includes both loss of function and malfunction). <u>NOTE</u> : Errors may cause failures, but are not considered to be failures (AMC 25.1309).
Failure Condition	A condition having an effect on the aeroplane and/or its occupants, either direct or consequential, which is caused or contributed to by one or more failures or errors, considering flight phase and relevant adverse operational or environmental conditions, or external events (AMC 25.1309)
Fail Operational System	A system capable of completing an operation, following the failure of any single element or component of that system, without pilot action.
Fail Passive System	A system which, in the event of a failure, results in: <ul style="list-style-type: none"> (a) no significant deviation in the aircraft flight path or attitude and (b) no out-of-trim condition at disengagement that is not easily controlled by the pilot.
Flight Director	A visual cue or set of cues that are used during manual control of the aeroplane as command information to direct the pilot how to manoeuvre the aeroplane, usually in pitch, roll and/or yaw, to track a desired flight path. The flight director, displayed on the pilot's primary head down attitude indicator (ADI) or head up display (HUD), is a component of the flight guidance system and is integrated with airborne attitude, air data and navigation systems.

Flight Guidance System	<p>A system consisting of one or more of the following elements:</p> <ul style="list-style-type: none"> (a) autopilot, (b) flight director, (c) automatic thrust control, <p>and any interactions with stability augmentation and trim systems.</p>
Flight Management System	<p>An aircraft area navigation system and associated displays and I/O device(s) having complex multi-waypoint lateral (LNAV) and vertical (VNAV) navigation capability (or equivalent), data entry capability, data base memory to store route and instrument flight procedure information, and display readout of navigation parameters. The Flight Management System provides guidance commands to the FGS for the purpose of automatic navigation and speed control when the FGS is engaged in an appropriate mode or modes (e.g., VNAV, LVAV, RNAV).</p>
Head-Up Display (HUD)	<p>A transparent optical display system located level with and between the pilot and the forward windscreen. The HUD displays a combination of control, performance, navigation, and command information superimposed on the external field of view. It includes the display element, sensors, computers and power supplies, indications and controls. It is integrated with airborne attitude, air data and navigation systems, and as a display of command information is considered a component of the flight guidance system.</p>
Inadvertent	<p>A condition or action that was not planned or intended.</p>
Latent Failure	<p>A failure is latent until it is made known to the flight crew or maintenance personnel. A significant latent failure is one, which would in combination with one or more specific failures, or events result in a Hazardous or Catastrophic Failure Condition (AMC 25.1309).</p>
Limit Flight Envelope	<p>This envelope is the most outside flight envelope, generally associated with aeroplane design limits</p>
Mode	<p>A mode is system configuration that corresponds to a single (or set of) FGS behaviour(s).</p>
Non-normal Condition	<p>A condition or configuration of the aeroplane that would not normally be experienced during routine flight operations - usually due to failures or non-routine operating conditions (e.g., excessive out-of-trim due to fuel imbalance or under certain ferry conditions).</p>

Normal Condition	Any fault free condition typically experienced in normal flight operations. Operations typically well within the aircraft flight envelope, and with routine atmospheric and environmental conditions.
Normal Flight Envelope	The range of altitude and operating speeds that are defined by the aeroplane manufacturer as consistent with conducting flight operations for which the aeroplane is designed. This envelope is generally associated with practical, routine operation and/or prescribed conditions, whether all-engine or engine inoperative.
Override	An action taken by the flight crew intended to prevent, oppose or alter an operation being conducted by a flight guidance function, without first disengaging that function.
Rare Normal Condition	A fault-free condition that is experienced infrequently by the aeroplane due to significant environmental conditions (e.g., significant wind, turbulence, or icing, etc.)
Redundancy	The presence of more than one independent means for accomplishing a given function or flight operation (AC/AMC 25.1309).
Select	The flight crew action of requesting functionality or an end state condition.
Significant transient	See “transient.”
Stability Augmentation System	Automatic systems, which provide or enhance stability for specific aerodynamic characteristics of an aeroplane (e.g., Yaw Damper, Longitudinal Stability Augmentation System, Mach Trim).
System	A combination of components, parts, and elements that are inter-connected to perform one or more specific functions (AMC 25.1309).
Transient	<p>A disturbance in the control or flight path of the aeroplane that is not consistent with response to flight crew inputs or current environmental conditions.</p> <ol style="list-style-type: none"> a. Minor transient: A transient that would not significantly reduce safety margins, and which involves flight crew actions that are well within their capabilities involving a slight increase in flight crew workload or some physical discomfort to passengers or cabin crew. b. Significant transient: A transient that would lead to a significant reduction in safety margins, a significant increase in flight crew workload, discomfort to the flight

	<p>crew, or physical distress to passengers or cabin crew, possibly including non-fatal injuries.</p> <p>NOTE: The flight crew should be able to respond to any significant transient without:</p> <ul style="list-style-type: none"> • exceptional piloting skill, alertness, or strength, • forces greater than those given in CS 25.143(ed), and • accelerations or attitudes in the aeroplane that might result in further hazard to secured or non-secured occupants.
Warning	A flight deck indication that alerts the flight crew to a non-normal operational or aeroplane system requiring immediate recognition. Immediate corrective or compensatory action by the flight crew is required.

5.2 Acronyms

AC	Advisory Circular (FAA)
ACAS	Airborne Collision Avoidance System
AMC	Acceptable Means of Compliance
AFM	Aeroplane Flight Manual
AGL	Above Ground Level
AIM	Airman’s Information Manual
ARP	Accepted and Recommended Practice
ATC	Air Traffic Control
AWO	All Weather Operations
CG	Centre of Gravity
CDI	Course Deviation Indicator
CWS	Control Wheel Steering
DA	Decision Altitude
DA(H)	Decision Altitude (Height)
DME	Distance Measuring Equipment
EFIS	Electronic Flight Instrument System
EVS	Enhanced Vision System
FAA	Federal Aviation Administration

FCOM	Flight Crew Operations Manual
F/D	Flight Director
FGS	Flight Guidance System
FLCH	Flight Level Change
FMA	Flight Mode Annunciator
FMS	Flight Management System
GA	Go-around
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GPWS	Ground Proximity Warning System
HDD	Head Down Display
HUD	Head-Up Display
IAS	Indicated Air Speed
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMA	Integrated Modular Avionics
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities
LNAV	Lateral Navigation
LOC	Localizer
MDA(H)	Minimum Descent Altitude (Height)
MLS	Microwave Landing System
MSL	Mean Sea Level
MSP	Mode Select Panel
MUH	Minimum Use Height
NAV	Navigation
ND	Navigation Display
NDB	Non Directional Beacon
NPA	Notice of Proposed Amendment
NPRM	Notice of Proposed Rulemaking

PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying
RNAV	Area Navigation
RNP	Required Navigation Performance
RTO	Rejected Takeoff
RVSM	Reduced Vertical Separation Margin
SAE	Society of Automotive Engineering
SVS	Synthetic Vision System
TCAS	Traffic Collision Alert System
TCS	Touch Control Steering
TO	Takeoff
TOGA	Takeoff or Go-around
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOR	VHF Omni Range
WAT	Weight Altitude Temperature

6 BACKGROUND

This advisory material replaces material previously provided in AMC 25.1329 for Automatic Pilots. The automatic control and guidance systems in current aircraft have evolved to a level that dictates a revision to current advisory material.

There have been dramatic changes in technology and system design, which have resulted in much higher levels of integration, automation, and complexity. These changes have also redefined the allocation of functions and interfaces between systems. Relatively simple, dedicated systems have been replaced with digital multi-function systems with more modes, and automatic changes in modes of operation. The introduction of fly-by-wire flight control systems has created new interface considerations for the FGS elements. These new systems are capable of providing better performance, increased safety and decreased workload. But if designed without consideration for the criteria in this AMC, these systems could also be confusing and not immediately intuitive for the flight crew. Significant operational experience has been gained on new generation systems and guidance material is provided herein based on that experience.

This advisory material is provided for Flight Guidance Systems, which include any autopilot

functions, flight director functions, automatic thrust control functions and any interactions with stability augmentation and trim functions.

7 GENERAL

The FGS is primarily intended to assist the flight crew in the basic control and tactical guidance of the aeroplane. The system may also provide workload relief to the pilots and may provide a means to fly a flight path more accurately to support specific operational requirements (e.g. RVSM, RNP, etc.).

The applicant should establish, document and follow a design philosophy that supports the intended operational use regarding the FGS behaviour; modes of operation; pilot interface with controls, indications, and alerts; and mode functionality.

Description of the FGS behaviour and operation should be addressed from flight crew and maintenance perspectives in appropriate documentation and training material.

Subsequent sections of this advisory material provide interpretative material and acceptable means of compliance with CS 25.1329 and the applicability of other CS-25 rules to FGS (e.g., CS 25.1301, CS 25.1309). The demonstrated means of compliance may include a combination of analysis, laboratory testing, flight-testing, and simulator testing. The applicant should coordinate with the authorities early in the certification programme, via a certification plan, to reach agreement on the methods to be used to demonstrate compliance.

7.1 Flight Guidance System Functions

The following functions, when considered separately and together, are considered elements of a Flight Guidance System:

- Flight guidance and control (e.g., autopilot, flight director displayed head-down or head-up);
- Autothrottle/autothrust systems;
- Interactions with stability augmentation and trim systems; and
- Alerting, status, mode annunciation, and situation information associated with flight guidance and control functions.

The FGS includes those functions necessary to provide guidance and control in conjunction with an approach and landing system, such as:

- the Instrument Landing System (ILS),
- the Microwave Landing System (MLS) or
- the Global Navigation Satellite System (GNSS) Landing System (GLS).

The FGS also includes those functions necessary to provide guidance and control in conjunction with a Flight Management System (FMS). The FGS does **not** include the flight planning and the generation of flight path and speed profiles tied to waypoints and other flight planning aspects of the Flight Management System (FMS). However, it does include the interface between the FMS and FGS necessary for the execution of flight path and speed

commands.

7.2 FGS Components

For the purpose of this AMC the term “FGS” includes all the equipment necessary to accomplish the FGS function, including the sensors, computers, power supplies, servomotors/actuators, and associated wiring. It includes any indications and controllers necessary for the pilot to manage and supervise the system.

Any part of the FGS that remains mechanically connected to the primary flight controls or propulsion controls when the Flight Guidance System is not in use is regarded as a part of the primary flight controls and propulsion system, and the provisions for such systems are applicable.

7.3 Compliance with CS 25.1329

Table 7.3-A lists the relevant paragraphs of CS 25.1329 and provides an indication where acceptable means of compliance with each paragraph may be found within this AMC.

TABLE 7.3-A.

Where Means of Compliance Can Be Found in this AMC

Section / Paragraph	Rule Text	Where Acceptable Means of Compliance Found in this AMC
CS 25.1329 (a)	<i>Quick disengagement controls for the autopilot and autothrust functions must be provided for each pilot. The autopilot quick disengagement controls must be located on both control wheels (or equivalent). The autothrust quick disengagement controls must be located on the thrust control levers. Quick disengagement controls must be readily accessible to each pilot while operating the control wheel (or equivalent) and thrust control levers.</i>	Section 8.1, Autopilot Engagement/Disengagement and Indications Section 8.3, Autothrust Engagement/Disengagement and Indications
CS 25.1329 (b)	<i>The effects of a failure of the system to disengage the autopilot or autothrust functions when manually commanded by the pilot must be assessed in accordance with the specifications of CS 25.1309.</i>	Section 8.1, Autopilot Engagement/Disengagement and Indications Section 8.3, Autothrust Engagement/Disengagement and Indications Section 13.6, Safety Assessment – Failure to Disengage the FGS

<p>CS 25.1329 (c)</p>	<p><i>Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a transient response affecting the control or flight path of the aeroplane any greater than a minor transient.</i></p>	<p>Section 8, FGS Engagement, Disengagement, and Override Section 13, Safety Assessment</p>
<p>CS 25.1329 (d)</p>	<p><i>Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce a transient response affecting the control or flight path of the aeroplane any greater than a minor transient.</i></p>	<p>Section 8, FGS Engagement, Disengagement, and Override Section 13, Safety Assessment</p>
<p>CS 25.1329 (e)</p>	<p><i>Under rare-normal or non-normal conditions the disengagement of any automatic control functions of a flight guidance system must not produce a transient response affecting the control or flight path of the aeroplane any greater than a significant transient.</i></p>	<p>Section 8, FGS Engagement, Disengagement, and Override Section 9.3.3, Awareness of Potential Significant Transient Condition (“Bark before Bite”)</p>
<p>CS 25.1329 (f)</p>	<p><i>The function and direction of motion of each command reference control (e.g., heading select, vertical speed) must be readily apparent or plainly indicated on, or adjacent to, each control if necessary to prevent inappropriate use or confusion.</i></p>	<p>Section 9, Controls, Indications and Alerts</p>
<p>CS 25.1329 (g)</p>	<p><i>Under any condition of flight appropriate to its use, the Flight Guidance System must not:</i></p> <ul style="list-style-type: none"> • <i>produce unacceptable loads on the aeroplane (in accordance with CS 25.302), or</i> • <i>create hazardous deviations in the flight path.</i> <p><i>This applies to both fault-free operation and in the event of a malfunction, and assumes that the pilot begins corrective action within a reasonable period of time.</i></p>	<p>Section 10, Performance of Function Section 13, Safety Assessment Section 14, Compliance Demonstration using Flight Test and Simulation</p>
<p>CS 25.1329 (h)</p>	<p><i>When the flight guidance system is in use, a means must be provided to avoid excursions beyond an acceptable margin from the speed range of the normal flight envelope. If the aircraft experiences an excursion outside this range, the flight guidance system must not provide guidance or control to an unsafe speed.</i></p>	<p>Section 10.4, Speed Protection</p>

CS 25.1329 (i)	<i>The FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behaviour and operation of the FGS. Means must be provided to indicate the current mode of operation, including any armed modes, transitions, and reversions. Selector switch position is not an acceptable means of indication. The controls and indications must be grouped and presented in a logical and consistent manner. The indications must be visible to each pilot under all expected lighting conditions.</i>	Section 9, Controls Indications and Alerts
CS 25.1329 (j)	<i>Following disengagement of the autopilot, a warning (visual and aural) must be provided to each pilot and be timely and distinct from all other cockpit warnings.</i>	Section 8.1.2.1, Autopilot Disengagement Alerts Section 13, Safety Assessment
CS 25.1329 (k)	<i>Following disengagement of the autothrust function, a caution must be provided to each pilot.</i>	Section 8.3.2, Autothrust Disengagement Section 13, Safety Assessment
CS 25.1329 (l)	<i>The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls.</i>	Section 8.4.1, Flight Crew Override of the FGS – Autopilot Section 13, Safety Assessment
CS 25.1329 (m)	<i>During autothrust operation, it must be possible for the flight crew to move the thrust levers without requiring excessive force. The autothrust response to flight crew override must not create an unsafe condition.</i>	Section 8.4.2, Flight Crew Override of the FGS - Autothrust Section 13, Safety Assessment

8 Flight Guidance System Engagement, Disengagement and Override

The characteristics of the FGS during engagement, disengagement and override have caused some concern with systems on some aeroplanes. The following criteria should be addressed in the design of a FGS.

8.1 Autopilot Engagement/Disengagement and Indications

Autopilot engagement and disengagement should be accomplished in a manner consistent with other flight crew procedures and tasks, and should not require undue attention.

8.1.1 Autopilot Engagement

Each pilot should be able to select the autopilot function of the flight guidance system with a single switch action. The single switch action should engage pitch and roll axes. The autopilot system should provide positive indication to the flight crew that the system has been engaged. The selector switch position is not acceptable as a means of indication (reference CS 25.1329(i)).

NOTE: If an operational need is identified for split-axis engagement, then annunciation or indication should be provided for each axis.

For aeroplanes with more than one autopilot installed, each autopilot may be individually selected and should be so annunciated. It should not be possible for multiple autopilots to be engaged in different modes.

The engagement of the autopilot should be free of perceptible transients. Under dynamic conditions, including manoeuvring flight, minor transients are acceptable.

Without a flight director engaged, the initial lateral and vertical modes should be consistent with minimal disturbance from the flight path. For example, the lateral mode at engagement may roll the aeroplane to wings level and then hold the aeroplane heading/track or maintain the existing bank angle (if in a normal range). A heading/track pre-select at engagement function may be provided if precautions are taken to ensure that selection reflects the current intent of the flight crew. The modes at engagement should be annunciated and any associated selected target values should be displayed.

With a flight director engaged, the autopilot should engage into a mode consistent (i.e., the same as, or if that is not possible, then compatible with) the active flight director mode of operation. Consideration should be given to the mode into which the autopilot will engage when large commands are present on either or both flight directors. For example, consideration should be given whether to retain the active flight director mode or engage the autopilot into the basic mode, and the implications for current flight path references and targets. The potential for flight crew confusion and unintended changes in flight path or modes should be considered.

Regardless of the method used, the engagement status (and changes in status) of the autopilot(s) should be clearly indicated and should not require undue attention or recall.

For modes that use multiple autopilots, the additional autopilots may engage automatically at selection of the mode or after arming the mode. A means should be provided to determine that adequate autopilot capability exists to support the intended operation (e.g., "Land 2" and "Land 3" are used in some aircraft).

NOTE: The design should consider the possibility that the pilot may attempt to engage the autopilot outside of the normal flight envelope. It is not required that the autopilot should compensate for unusual attitudes or other situations outside the normal flight envelope, unless that is part of the autopilot's intended function.

8.1.2 Autopilot Disengagement

In consequence of specifications in CS 25.1329(d), under normal conditions, automatic or manual disengagement of the autopilot must be free of significant transients or out-of-trim forces that are not consistent with the manoeuvres being conducted by the aeroplane at the time of disengagement. If multiple autopilots are engaged, any disengagement of an individual autopilot must be free of significant transients and should not adversely affect the operation of the remaining engaged autopilot(s) (CS 25.1329(d)).

Under non-normal or rare-normal conditions (see CS 25.1329(e)), disengagement of the autopilot may result in a significant transient. The flight crew should be able to respond to a significant transient without:

- exceptional piloting skill, alertness, or strength,
- forces greater than those given in CS 25.143(d), and
- accelerations or attitudes in the aeroplane that might result in a hazard to secured or non-secured occupants.

The flight crew should be made aware (via a suitable alerting or other indication) of conditions or situations (e.g., continued out-of-trim) that could result in a significant transient at disengagement. (See Section 9.3.3 on Awareness of Potential Significant Transient Condition (“Bark before Bite”).

8.1.2.1 Autopilot Disengagement Alerts (see CS 25.1329(j))

Since it is necessary for a pilot to immediately assume manual control following disengagement of the autopilot (whether manual or automatic) a visual and aural warning must be given (CS 25.1329(j)). This warning must be given without delay, and must be distinct from all other cockpit warnings (CS 25.1329(j)). The warning should continue until silenced by one of the pilots using:

- an autopilot quick disengagement control
- reengagement of the autopilot
- another acceptable means.

It should sound for a minimum period, long enough to ensure that it is heard and recognized by that pilot and by other flight crew members, but not so persistent that it adversely affects communication between crew members or is a distraction.

Disengagement of an autopilot within a multiple-autopilot system (e.g., downgraded capability), requiring immediate flight crew awareness and possible timely action, should cause a Caution level alert to be issued to the flight crew.

Disengagement of an autopilot within a multiple-autopilot system, requiring only flight crew awareness, should cause a suitable advisory to be issued to the flight crew.

8.1.2.2 Quick Disengagement Control (see CS 25.1329(a))

The purpose of the “Quick Disengagement Control” is to ensure the capability for each pilot to

manually disengage the autopilot quickly with a minimum of pilot hand/limb movement. The “Quick Disengagement Control” must be located on each control wheel or equivalent (CS 25.1329(a) and should be within easy reach of one or more fingers/thumb of the pilot’s hand when the hand is in a position for normal use on the control wheel or equivalent. The “Quick Disengagement Control” should meet the following criteria :

- (a) Be accessible and operable from a normal hands-on position without requiring a shift in hand position or grip on the control wheel or equivalent;
- (b) Be operable with one hand on the control wheel or equivalent and the other hand on the thrust levers;

NOTE: When establishing location of the quick disengagement control, consideration should be given to:

- its accessibility with large displacements of, or forces on, the control wheel (or equivalent), and
- the possible need to operate the quick disengagement control with the other hand.

- (c) Be easily located by the pilot without having to first locate the control visually;
- (d) Be designed so that any action to operate the “Quick Disengagement Control” should not cause an unintended input to the control wheel or equivalent; and
- (e) Be designed to minimize inadvertent operation and interference with other nearby control wheel (or equivalent) switches/devices (e.g., radio control, trim).

8.1.2.3 Alternative Means of Autopilot Disengagement

When a CS 25.1309 assessment shows a need for an alternative means of disengagement, the following should be addressed:

- Independence,
- The alternate means should be readily accessible to each pilot,
- Latent failure/reliability of the alternate means.

The following means of providing an alternative disengagement have been found to be acceptable:

- Selection of the engagement control to the “off” position.
- Disengage bar on mode selector panel.
- Trim switch on yoke.

NOTE: Use of circuit breakers as a means of disengagement is not considered to be acceptable.

8.1.2.5 Flight Crew Pitch Trim Input

If the autopilot is engaged and the pilot applies manual pitch trim input, either the autopilot should disengage with no more than a minor transient, or pitch trim changes should be inhibited (see CS 25.1329(l)).

8.2 Flight Director Engagement/Disengagement and Indications

Engagement and disengagement should be accomplished consistent with other flight crew procedures and tasks and should not require undue attention.

8.2.1 Flight Director Engagement

A means may be provided for each pilot to select (i.e., turn on) and deselect the flight director for display on their primary flight display (e.g., attitude display). The selection status of the flight director and the source of flight director guidance should be clear and unambiguous. Failure of a selected flight director should be clearly annunciated.

A flight director is considered “engaged” if it is selected and displaying guidance cues.

NOTE: The distinction is made between “engaged” and “selected” because the flight director might be selected, but not displaying guidance cue(s) (e.g., the cue(s) are biased out of view).

If there are multiple flight directors, and if required for crew awareness, indications should be provided to denote which flight director is engaged (e.g., FD1, FD2, HUD source). For aeroplanes with multiple flight directors installed, both flight directors should always be in the same armed and active FGS modes. The selection status of each flight director should be clear and unambiguous for each pilot. In addition, indications should be provided to denote loss of flight director independence (i.e., first officer selection of captain’s flight director).

A flight director should engage into the current modes and targets of an already engaged autopilot or flight director, if any. With no autopilot engaged, the basic modes at engagement of the flight director functions should be established consistent with typical flight operations.

NOTE: The engagement of the pitch axis in Vertical Speed or Flight Path Angle, and engagement of the lateral axis in Heading Hold, Heading Select or Bank Angle Hold have been found to be acceptable.

Since the HUD can display flight guidance, the HUD guidance mode should be indicated to both pilots and should be compatible with the active head-down flight director mode.

Engagement during manoeuvring flight should be considered.

NOTE: The design should consider the safety consequences if it is possible for the flight director to engage outside of the normal flight envelope. It is not required that the flight director should compensate for unusual attitudes or other situations outside the normal flight envelope, unless that is part of the flight director’s intended function.

8.2.1.1 Guidance Cue(s)

The flight director command guidance cue(s) will typically be displayed when the flight director is selected and valid command guidance is available or if it is automatically providing guidance as per paragraph 8.2.1.2 below. The flight director guidance cue(s) should be removed when guidance is determined to be invalid. The display of guidance cue(s) (e.g., flight director bars) is sufficient indication that the flight director is engaged.

8.2.1.2 Reactive Windshear Flight Director Engagement

For aeroplanes equipped with a flight director windshear guidance system, flight director engagement should be provided, consistent with the criteria contained in FAA AC's 25-12 and 120-41.

8.2.2 Flight Director Disengagement

There may be a means for each pilot to readily deselect his or her on-side flight director function. Flight crew awareness of disengagement and de-selection is important. Removal of guidance cue(s) alone is not sufficient indication of de-selection, because the guidance cue(s) may be removed from view for a number of reasons, including invalid guidance, autopilot engagement, etc. Therefore, the flight director function should provide clear and unambiguous indication (e.g., switch position or status) to the flight crew that the function has been deselected.

8.3 Autothrust Engagement/Disengagement and Indications

The autothrust function should be designed with engagement and disengagement characteristics that provide the flight crew positive indication that the system has been engaged or disengaged. Engagement and disengagement should be accomplished in a manner consistent with other flight crew procedures and tasks and should not require undue attention.

8.3.1 Autothrust Engagement

The autothrust engagement controls should be accessible to each pilot. The autothrust function should provide the flight crew positive indication that the system has been engaged.

The autothrust function should be designed to prevent inadvertent engagement and inadvertent application of thrust, for both on-ground and in-air operations (e.g., provide separate arm and engage functions).

The autothrust normally should be designed to preclude inadvertent engagement. However, intended modes such as a "wake up" mode to protect for unsafe speeds may be acceptable (see Section 10.4.1 on Low Speed Protection). If such automatic engagement occurs, it should be clear to the flight crew that automatic engagement has occurred, the automatic engagement should not cause any unsafe condition (e.g., unsafe pitch attitudes or unsafe pitching moments), to show compliance with CS 25.1329(c), and the reason for automatic engagement should be clear and obvious to the flight crew.

NOTE: The design should consider the possibility that the pilot may attempt to engage the autothrust function outside of the normal flight envelope or at

excessive (or too low) engine_thrust. It is not expected that the autothrust feature should compensate for situations outside the normal flight envelope or normal engine operation range, unless that is part of the intended function of the autothrust system.

8.3.2 Autothrust Disengagement

Autothrust disengagement should not cause any unsafe condition (e.g., pitch attitude, pitching moment, or significant thrust transient), to show compliance with CS 25.1329(d), and the disengagement should not preclude, inhibit, or interfere with timely thrust changes for go-around, landing, or other manoeuvres requiring manual thrust changes.

The autothrust normally should be designed to preclude inadvertent disengagement during activation of autothrust modes of operation.

Following disengagement of the autothrust function, positive indication of disengagement should include at least a visual flight crew alert and deletion of autothrust ‘engaged’ status annunciations (to show compliance with CS 25.1329(k)). For automatic disengagement, visual indications should persist until cancelled by flight crew action. For manual disengagement, if an aural is provided, visual indications should persist for some minimum period. If an aural is not provided, the visual indications should persist until cancelled by flight crew action. For aural indication, if provided, an aural alert of sufficient duration and volume should be provided to assure that the flight crew has been alerted that disengagement has occurred. An extended cycle of an aural alert is not acceptable following disengagement if such an alert can significantly interfere with flight crew coordination or radio communication. Disengagement of the autothrust function is considered a Caution alert.

8.3.2.1 Autothrust Quick Disengagement Control

Autothrust quick disengagement controls must be provided for each pilot on the respective thrust control lever as stated in CS 25.1329(a). A single-action, quick disengagement switch should be incorporated on the thrust control so that switch activation can be executed when the pilot’s other hand is on the flight controls. The disengagement control should be positioned such that inadvertent disengagement of the autothrust function is unlikely. Positioning the control on the outboard side has been shown to be acceptable for multiengine aircraft. Thrust lever knob-end-mounted disengagement controls available on both sides to facilitate use by either pilot have been shown to be preferable to those positioned to be accessible by the pilot’s palm.

8.4 Flight Crew Override of the FGS

The following sections discuss criteria related to the situation where the flight crew overrides the FGS.

8.4.1 Autopilot

- 1) The autopilot should disengage when the flight crew applies a significant override force to the controls. The applicant should interpret “significant” as a force that is consistent with an intention to overpower the autopilot by either or both pilots. The autopilot should not disengage for minor application of force to the controls (e.g., a pilot gently

bumping the control column while entering or exiting a pilot seat during cruise).

NOTE: 111 N (25 lbf) at the control column or wheel has been determined to be a significant override force level for other than approach operations on some aircraft types. To reduce nuisance disengagement, higher forces have been found acceptable for certain approach, landing, and go-around operations on some aircraft types. The force to disengage an autopilot is not necessarily the force required at the column to oppose autopilot control (e.g., cause elevator movement). The corresponding forces for a side stick or centre stick controller may be different.

Under normal conditions, a significant transient should not result from autopilot disengagement when the flight crew applies an override force to the controls (to show compliance with CS 25.1329(d)).

Sustained or incremental application of force below the disengagement threshold should not result in a hazardous condition (e.g., the automatic trim running that results in unacceptable aeroplane motion if the autopilot were to automatically disengage, or when manually disengaged).

- 2) If the autopilot is not designed to disengage in response to any override force, then the response shall be shown to be safe (CS 25.1329 (l)). Under normal conditions, a significant transient should not result from manual autopilot disengagement after the flight crew has applied an override force to the controls (CS 25.1239(d)).

NOTE: The term “override force” is intended to describe a pilot action that is intended to prevent, oppose or alter an operation being conducted by a flight guidance function, without first disengaging that function. One possible reason for this action could be an avoidance manoeuvre (such as responding to a ACAS/TCAS Resolution Advisory) that requires immediate action by the flight crew and would typically involve a rapid and forceful input from the flight crew.

Sustained application of an override force should not result in a hazardous condition. Mitigation may be accomplished through provision of an appropriate Alert and flight crew procedure.

NOTE: The term “sustained application of override force” is intended to describe a force that is applied to the controls that may be small, slow, and sustained for some period of time. This may be due to an inadvertent crew action, or may be an intentional crew action meant to “assist” the autopilot in a particular manoeuvre. See Section 14.1.5.

NOTE: For CWS – refer to Section 11.6

8.4.2 Autothrust

It should be possible for the pilot to readily override the autothrust function and set thrust by moving the thrust levers (or equivalent) with one hand. CS 25.1329(m) requires that the

autothrust response to a flight crew override must not create an unsafe condition.

Autothrust functions may be designed to safely remain engaged during pilot override. Alternatively, autothrust functions may disengage as a result of pilot override, provided that the design prevents unintentional autothrust disengagement and adequately alerts the flight crew to ensure pilot awareness.

8.5 FGS Engagement Mode Compatibility

The philosophy used for the mode at engagement of the autopilot, flight director, and autothrust functions should be provided in flight crew training material.

It should not be possible to select incompatible FGS command or guidance functions at the same time (e.g., commanding speed through elevator and autothrust at the same time).

9 Controls, Indications and Alerts

The human-machine interface with the FGS is a key to ensuring safe, effective and consistent FGS operation. The manner in which FGS information is depicted to flight crews is essential to the flight crew awareness, and therefore, the safe operation of the FGS.

The controls, indications, and alerts must be so designed as to minimize flight crew errors and confusion (CS 25.1329(i)). Indications and alerts should be presented in a manner compatible with the procedures and assigned tasks of the flight crew and provide the necessary information to perform those tasks. The indications must be grouped and presented in a logical and consistent manner and be visible from each pilot's station under all expected lighting conditions (CS 25.1329(i)). The choice of colours, fonts, font size, location, orientation, movement, graphical layout and other characteristics such as steady or flashing should all contribute to the effectiveness of the system. Controls, indications, and alerts should be implemented in a consistent manner.

It is recommended that the applicant evaluate the adequacy and effectiveness of the information provided by the FGS interface (i.e., controls, indications, alerts, and displays) to ensure flight crew awareness of FGS behaviour and operation. See Section 14, Compliance Demonstration using Flight Test and Simulation, for more discussion of appropriate analyses (which may include, for example, cognitive task analysis as a basis for evaluation).

9.1 FGS Controls

The FGS controls should be designed and located to provide convenient operation to each crewmember and to prevent crew errors, confusion and inadvertent operation (CS 25.1329(i)). To achieve this, CS 25.1329 (f) requires that command reference controls to select target values (e.g., heading select, vertical speed) should operate as specified in CS 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be readily apparent or plainly indicated on, or adjacent to, each control if needed to prevent inappropriate use or confusion (CS 25,1329(f)). CS 25.781 also provides requirements for the shapes of the knobs. The design of the FGS should address the following specific considerations:

- Differentiation of knob shape and position. (*Errors have included confusing speed and heading knobs on the mode selector panel.*)
- Design to support correct selection of target values. (*Use of a single control (e.g., concentric controls) for selecting multiple command reference targets has resulted in erroneous target value selection.*)
- Commonality of control design across different aircraft to prevent negative transfer of learning with respect to operation of the controls. (*Activation of the wrong thrust function has occurred due to variation of TOGA and autothrust disengagement function between aeroplane types- negative transfer of learning with respect to operation of the controls.*)
- Positioning of individual FGS controls, FMAs, and related primary flight display information so that, as far as reasonably practical, items of related function have similarly related positions. (*Misinterpretation and confusion have occurred due to the inconsistent arrangement of FGS controls with the annunciations on the FMA.*)
- Design to discourage or avoid inadvertent operation; e.g., engagement or disengagement (to show compliance with CS 25.777(a)).

9.2 Flight Guidance Mode Selection, Annunciation, and Indication

Engagement of the Flight Guidance System functions must be suitably annunciated to each pilot (to show compliance with CS 25.1329(i)), as described in Section 8, Flight Guidance System Engagement, Disengagement, and Override. The FGS mode annunciations must effectively and unambiguously indicate the active and armed modes of operation (CS 25.1329(i)). The mode annunciation should convey explicitly, as simply as possible, what the FGS is doing (for active modes), what it will be doing (for armed modes), and target information (such as selected speed, heading, and altitude) for satisfactory flight crew awareness.

Mode annunciation must indicate the state of the system and not just switch position or selection (CS 25.1329(i)). Mode annunciation should be presented in a manner compatible with flight crew procedures / tasks and consistent with the mode annunciation design for the specific aircraft type (i.e., compatible with other flight deck systems mode annunciations).

Operationally relevant mode changes and, in particular, mode reversions and sustained speed protection, should be clearly and positively annunciated to ensure flight crew awareness. Altitude capture is an example of an operationally relevant mode that should be annunciated because pilot actions may have different effects on the aeroplane. Annunciation of sustained speed protection should be clear and distinct to ensure flight crew awareness. It should be made clear to the pilot if a mode has failed to arm or engage (especially due to invalid sensor data). FGS sub-modes (e.g., sub-modes as the FGS transitions from localizer capture to localizer track) that are not operationally relevant need not be annunciated.

In-service experience has shown that mode annunciation alone may be insufficient (unclear or not compelling enough) to communicate mode changes to the flight crew, especially in high workload situations. Therefore, the safety consequences of the flight crew not recognizing mode changes should be considered. If necessary, an appropriate alert should be used.

Mode annunciations should be located in the forward field of view (e.g., on the primary flight

display). Mode selector switch position or status is not acceptable as the sole means of mode annunciation (CS 25.1329(i)). Modes and mode changes should be depicted in a manner that achieves flight crew attention and awareness. Aural notification of mode changes should be limited to special considerations. Colours, font type, font size, location, highlighting, and symbol flashing have historical precedent as good discriminators, when implemented appropriately. The fonts and font size should be chosen so that annunciation of FGS mode and status information is readable and understandable, without eye strain, when viewed by the pilot seated at the design eye position.

Colour should be used in a consistent manner and assure compatibility with the overall use of colour on the flight deck. Specific colours should be used such that the FGS displays are consistent with other flight deck systems, such as a Flight Management System. The use of monochrome displays is not precluded, provided that the aspects of flight crew attention and awareness are satisfied. The use of graphical or symbolic (i.e., non-textual) indications is not precluded. Implementation of such discriminators should follow accepted guidelines as described in applicable international standards (e.g., AMC 25-11) and should be evaluated for their consistency with and integration with the flight deck design. Engaged modes should be annunciated at different locations and with different colours than armed modes to assist in mode recognition. The transition from an armed mode to an engaged mode should provide an additional attention-getting feature, such as boxing and flashing on an electronic display (per AMC 25-11) for a suitable, but brief, period (e.g., ten seconds), to assist in flight crew awareness.

The failure of a mode to engage/arm when selected by the pilot should be apparent. Mode information provided to the pilot should be sufficiently detailed, so that the consequences of the interaction (e.g., ensuing mode or system configuration that has operational relevance) can be unambiguously determined. The FGS interface should provide timely and positive indication when the flight guidance system deviates from the pilot's direct commands (e.g., a target altitude, or speed setting) or from the pilot's pre-programmed set of commands (e.g., waypoint crossing). The interface should also provide clear indication when there is a difference between pilot-initiated commands (e.g., pilot engages positive vertical speed and then selects an altitude that is lower than the aircraft altitude). The default action taken by the FGS should be made apparent.

The operator should be provided with appropriate description of the FGS modes and their behaviour.

9.3 Flight Guidance Alerting (Warning, Caution, Advisory, and Status)

Alerting information should follow the provisions of CS 25.1322 and associated advisory material. Alerts for FGS engagement and disengagement are described in Section 8, Flight Guidance System Engagement, Disengagement, and Override.

There should be some method for the flight crew to determine and monitor the availability or capability of the Flight Guidance System (e.g., for dispatch), where the intended operation is predicated on the use of the FGS. The method of monitoring provided should take account of the hazard resulting from the loss of the autopilot function for the intended operation.

9.3.1 Alerting for Speed Protection

To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (see Section 10.4, Speed Protection). Low speed protection alerting should include both an aural and a visual component. High-speed protection alerts need only include a visual alert component because of existing high-speed aural alert requirements, but does not preclude giving an earlier alert.

Alerting for speed protection should be consistent with the protection provided and with the other alerts in the flight deck. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flight crew.

9.3.2 Loss of Autopilot Approach Mode

The loss of the approach mode requires immediate flight crew awareness. This may be accomplished through autopilot disengagement and related warning (as required by CS 25.1329 (j) and specified in 8.1.2.1 of this AMC). If the autopilot remains engaged and reverts to a non-approach mode, an appropriate aural warning and/or visual alert should be provided.

9.3.3 Awareness of Potential Significant Transient Condition (“Bark before Bite”)

There have been situations where an autopilot is engaged, operating normally, and controlling up to the limit of its authority for an extended period of time, and the flight crew was unaware of the situation. This service experience has shown that, without timely flight crew awareness and action, this situation can progress to a loss of control after autopilot disengagement, particularly in rare normal or non-normal conditions. However, with adequate flight crew awareness and pilot action, loss of control may be prevented.

To help ensure crew awareness and timely action, appropriate alert(s) (generally caution or warning) should be provided to the flight crew for conditions that could require exceptional piloting skill or alertness for manual control following autopilot disengagement (e.g., significantly out of trim). The number and type of alerts required would be determined by the unique situations that are being detected and by the crew procedures required to address those situations. Any alert should be clear and unambiguous, and be consistent and compatible with other flight deck alerts. Care should be taken to set appropriate thresholds for these alerts such that they are not considered a nuisance for the flight crew.

Situations that should be considered for an alert include:

Sustained Lateral Control Command: If the autopilot is holding a sustained lateral control command, it could be indicative of an unusual operating condition (e.g., asymmetric lift due to icing, fuel imbalance, asymmetric thrust) for which the autopilot is compensating. In the worst case, the autopilot may be operating at or near its full authority in one direction. If the autopilot were to disengage while holding this lateral trim, the result would be that the aeroplane would undergo a rolling moment that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement which might result from the condition.

Sustained Longitudinal Out of Trim: If the autopilot is holding sustained longitudinal trim, it

could be indicative of an unusual operating condition (e.g., an inoperative horizontal stabilizer) for which the autopilot is compensating. If the autopilot were to disengage while holding this longitudinal trim, the result would be that the aeroplane would undergo an abrupt change in pitch that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement, which might result from the condition.

Bank and Pitch Angles Beyond Those Intended for Autopilot Operations: Most autopilots are designed with operational limits in both the pitch and roll axes, such that those predetermined limits will not be purposely exceeded. If the aeroplane exceeds those limits, it could be indicative of a situation (which may not be covered by items 1. or 2.) that requires the pilot to intervene. Therefore, a timely alert should be considered to bring this condition to the attention of the flight crew to and permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement, which might result.

It is preferable that the autopilot remains engaged during out-of-trim conditions. However, if there is an automatic disengagement feature due to excessive out-of-trim, an alert should be generated and should precede any automatic disengagement with sufficient margin to permit timely flight crew recognition and manual disengagement. See also Section 8.4, Flight Crew Override of the FGS, for related material.

NOTE: This section is not intended to require alerting for all instances of automatic autopilot disengagement. It is intended only for conditions, which, if not addressed, would lead to such disengagement, which, could result in a significant transient for which the pilot may be unprepared. The intent is to provide crew awareness that would allow the flight crew to be prepared with hands on controls and take appropriate corrective action before the condition results in a potentially hazardous aeroplane configuration or state.

NOTE: This section describes alerting requirements for conditions resulting in unintended out-of-trim operation. There are FGS functions that can intentionally produce out-of-trim operation (e.g. parallel rudder operation in align or engine failure compensation modes, pitch trim operation during the approach/landing to provide trim up/flare spring bias, or pitch trim operation for certain types of Speed/Mach trim systems). It is not the intent of this section to require alerts for functions producing intentional out-of-trim conditions. Other system indications (e.g., mode and status annunciations) should be provided to make the crew aware of the operation of these functions where appropriate.

9.3.4 Failures Affecting Flight Director Guidance

Wherever practicable a failure should cause the immediate removal from view of the guidance information. If the guidance information is retained but a warning given instead, it should be such that the pilot cannot fail to observe it whilst using the guidance information.

9.4 FGS Considerations for Head-Up Displays (HUD)

Head-up displays (HUD) have unique characteristics compared to flight displays installed on the instrument panel. Most of these HUD differences are addressed during HUD certification whether or not the HUD provides flight guidance functions. The intent of this section is to

address how such HUD differences may affect FGS functions.

9.4.1 Characteristics of HUD Guidance

If the HUD is designed as a supplemental use display system, it does not replace the requirement for standard Head Down Display (HDD) of flight instrument data. The HUD is intended for use during takeoff, climb, cruise, descent, approach and landing under day, night, VMC and IMC conditions. When it can be reasonably expected that the pilot will operate primarily by reference to the HUD, it should be shown that the HUD is satisfactory for manually controlling the aeroplane and for monitoring the performance of the FGS system.

During take off and landing in certain light and visibility conditions, HUD symbology can be extremely dominant in comparison to external visual references. When visual references are relatively dim, extremely active symbology dynamics and guidance cue gains can lead the pilot to make excessively strong corrections. It should be shown that if HUD guidance cues are followed, regardless of the appearance of external visual references, they do not cause the pilot to take unsafe actions.

Generally the criteria for the mechanization of guidance displayed on the HUD would be no different than guidance displayed on the head-down display. See Section 10, Performance of Function, for flight director performance criteria.

However, unlike head-down displays, HUD's are capable of displaying certain symbology conformal to the outside scene, including guidance cues. Consequently, the range of motion of this conformal symbology, including the guidance, can present certain challenges in rapidly changing and high crosswind conditions. In certain cases, the motion of the guidance and the primary reference cue may be limited by the field of view. It should be shown that, in such cases, the guidance remains usable and that there is a positive indication that it is no longer conformal with the outside scene. It should also be shown that there is no interference between the indications of primary flight information and the flight guidance cues. In take off, approach, and landing FGS modes, the flight guidance symbology should have priority.

Additionally, HUD guidance is often used in cases, like the low visibility approach, where the pilot will need to reference both the information displayed on the HUD and outside references. Consequently, it should be shown that the location and presentation of the HUD information does not distract the pilot or obscure the pilot's outside view. For example, it would be necessary for the pilot to track the guidance to the runway without having the view of runway references or hazards along the flight path obscured by the HUD symbology.

9.4.2 HUD Flight Guidance System Display

The HUD display should present flight guidance information in a clear and unambiguous manner. Display clutter should be minimized. The HUD guidance symbology should not excessively interfere with pilots' forward view, ability to visually manoeuvre the aeroplane, acquire opposing traffic, and see the runway environment. Some flight guidance data elements are essential or critical and should not be removed by any de-clutter function.

9.4.3 Head-Up/Head-Down Display Compatibility

The HUD FGS symbology should be compatible and consistent with symbology on other FGS

displays such as head-down EFIS instruments. The FGS-related display parameters should be consistent to avoid misinterpretation of similar information, but the display presentations need not be identical. The HUD and head-down primary flight display formats and data sources need to be compatible to ensure that the same FGS-related information presented on both displays have the same intended meaning.

While not all information displayed on the HUD is directly related to the FGS, the pilot is likely to use most of the displayed information while using the HUD-displayed guidance and FGS annunciations. Therefore, when applicable, the guidelines below for the presentation of FGS-related display information should be followed as much as possible. Certain deviations from these guidelines may be appropriate due to conflict with other information display characteristics or requirements unique to head-up displays. These may include minimization of display clutter, minimization of excessive symbol flashing, and the presentation of certain information conformal to the outside scene.

- (a) Symbols should be the same format (e.g., a triangle-shaped pointer head-down appears as a triangle pointer head-up; however, some differences in HUD symbology such as the flight director “circle” versus head-down flight director “bars” or “wedge” have been found acceptable);
- (b) Information (symbols) should appear in the same general location relative to other information;
- (c) Alphanumeric readouts should have the same resolution, units, and labelling (e.g., the command reference indication for “vertical speed” should be displayed in the same foot-per-minute increments and labelled with the same characters as the head-down displays);
- (d) Analogue scales or dials should have the same range and dynamic operation (e.g., a Glideslope Deviation Scale displayed head-up should have the same displayed range as the Glideslope Deviation Scale displayed head-down, and the direction of movement should be consistent);
- (e) FGS modes (e.g. autopilot, flight director, autothrust) and status state transitions should be displayed on the HUD, and except for the use of colour, should be displayed using consistent methods (e.g., the method used head-down to indicate a flight director mode transitioning from armed to captured should also be used head-up); and
- (f) Information sources should be consistent between the HUD and the head-down displays used by the same pilot.
- (g) When FGS command information (i.e., flight director commands) are displayed on the HUD in addition to the head-down displays, the HUD depiction and guidance cue deviation “scaling” needs to be consistent with that used on the head-down displays. This is intended to provide comparable pilot performance and workload when using either head-up or head-down displays.
- (h) The same information concerning current HUD system mode, reference data, status state transitions, and alert information that is displayed to the pilot flying on the HUD, should also be displayed to the pilot not flying using consistent nomenclature to ensure unambiguous awareness of the HUD operation.

9.4.4 Alerting Issues

Although HUD's are typically not classified as integrated caution and warning systems, they may display warnings, cautions, and advisories as part of their FGS function. In this regard, HUD's should provide the equivalent alerting functionality as the head-down primary flight display(s). Warnings that require continued flight crew attention on the PFD also should be presented on the HUD (e.g., ACAS/TCAS), Windshear, and Ground Proximity Warning annunciations). If master alerting indications are not provided within the peripheral field of view of the pilot while using the HUD, the HUD should provide annunciations that inform the pilot of Caution and/or Warning conditions (ARP-5288, V12).

For monochrome HUD's, appropriate use of attention-getting properties such as flashing, outline boxes, brightness, size, and/or location are necessary to adequately compensate for the lack of colour normally assigned to distinguish and call attention to Cautions and warnings.

For multi-colour HUD's, the use of red, amber, or yellow for symbols not related to Caution and warning functions should be avoided, so that the effectiveness of distinguishing characteristics of true warnings and cautions is not reduced.

Single HUD installations rely on the fact that the non-flying pilot will monitor the head-down instruments and alerting systems, for failures of systems, modes, and functions not associated with primary flight displays.

Dual HUD installations require special consideration for alerting systems. It must be assumed that both pilots will be head-up simultaneously, full, or part-time, especially when the HUD is being used as the primary flight reference, or when the HUD is required equipment for the operation being conducted. If master alerting indications are not provided within the peripheral field of view of each pilot while using the HUD, then each HUD should provide annunciations that direct the pilot's attention to head-down alerting displays. The types of information that must trigger the HUD master alerting display are any Cautions or warnings not already duplicated on the HUD from head-down primary displays, as well as any Caution level or warning level engine indications or system alerts.

NOTE: The objective is to not redirect attention of the pilot flying to other display when an immediate manoeuvre is required (resolution advisory, windshear).

If a Ground Proximity Warning System (GPWS), wind shear detection system, a wind shear escape guidance system, or a Airborne Collision Avoidance System (ACAS) / Traffic alert and Collision Avoidance System (TCAS) is installed, then the guidance, warnings and annunciations required to be a part of these systems, and normally required to be in the pilot's primary field of view, should be displayed on the HUD.

9.4.5 Upset/Unusual Attitude Recovery Guidance

Upsets due to wake turbulence or other environmental conditions may result in near instantaneous excursions in pitch and bank angles and a subsequent unusual attitude.

If the HUD is designed to provide guidance for recovery from upsets or unusual attitudes, recovery steering guidance commands should be distinct from, and not confused with, orientation symbology such as horizon "pointers." For example, a cue for left stick input

should not be confused with a cue indicating direction to the nearest horizon. Guidance should be removed if cues become invalid at extreme attitudes, such as zenith, nadir, or inverted. For extreme attitudes it is acceptable to transition to the HDD, provided that the cues to transition from the HUD are clear and unambiguous.

If the HUD is designed to provide orientation only during upsets or unusual attitudes, cues should be designed to prevent them from being mistaken as flight control input commands.

10 PERFORMANCE OF FUNCTION

The FGS is expected to perform its intended function throughout the aeroplane's normal flight envelope. There are considerations for the FGS when operating at the limits of its performance capabilities and when operating under significant environmental conditions. The following sections provide acceptable means of compliance criteria and interpretive material for these considerations.

Where system tolerances have a significant effect on autopilot authority limits, consideration should be given to the effect on autopilot performance. Factors to be considered include but are not limited to tolerances of: servo authority, servo clutch setting, "cam-out" settings, control friction, and sensor tolerances.

10.1 Normal Performance

The FGS should provide guidance or control, as appropriate, for the intended function of the active mode(s) in a safe and predictable manner within the aeroplane's normal flight envelope.

The FGS should be designed to operate in all aeroplane configurations for its intended use within the aeroplane's normal flight envelope to provide acceptable performance for the following types of environmental conditions:

- Winds (light and moderate)
- Wind gradients (light and moderate)

NOTE: In the context of this AMC, "wind gradient" is considered a variation in wind velocity as a function of altitude, position, or time.

- Gusts (light and moderate)
- Turbulence (light and moderate)
- Icing (trace, light, moderate)

NOTE: Representative levels of the environmental effects should be established consistent with the aeroplane's intended operation.

Any performance characteristics that are operationally significant or operationally limiting should be identified with an appropriate statement or limitation in the Aeroplane Flight Manual (AFM) (Ref. CS 25.1581)..

The FGS should perform its intended function during routine aeroplane configuration or power

changes, including the operation of secondary flight controls.

Evaluation of FGS performance for compliance should be based on the minimum level of performance needed for its intended functions. Subjective judgment may be applied to account for experience acquired from similar equipment and levels that have been established as operationally acceptable by the end-user.

There are certain operations that dictate a prescribed level of performance. When the FGS is intended for operations that require specific levels of performance, the use of FGS should be shown to meet those specific levels of performance (e.g., Low Visibility Operations – Category II and III operations, Reduced Vertical Separation Minimums (RVSM), Required Navigation Performance (RNP)).

The FGS performance of intended functions should at least be equivalent to that expected of a pilot for a similar task. The AMC No.2 to CS 25.1329 provides for establishing the general behaviour of the FGS. When integrated with navigation sensors or flight management systems, the FGS should satisfy the flight technical error tolerances expected for the use of those systems in performing their intended functions.

The autopilot should provide smooth and accurate control without perceptible sustained nuisance oscillation.

The flight director, in each available display presentation (e.g., single cue, cross-pointer, flight path director) should provide smooth and accurate guidance and be appropriately damped, so as to achieve satisfactory control task performance without pilot compensation or excessive workload.

The autothrust function should provide smooth and accurate control of thrust without significant or sustained oscillatory power changes or excessive overshoot of the required power setting.

The automatic pitch trim function should operate at a rate sufficient to mitigate excessive control surface deflections or limitations of control authority without introducing adverse interactions with automatic control of the aircraft. Automatic roll and yaw trim functions, if installed, should operate without introducing adverse interactions with automatic control of the aircraft.

10.2 Performance in Rare Normal Conditions

The FGS will encounter a wide range of conditions in normal operations, some of which may be infrequent, but levy a greater than average demand on the FGS capabilities. Certain environmental conditions, as listed below, are prime examples. FGS performance during such rare normal conditions should be assessed. Such conditions may degrade FGS performance, but must be safe for FGS operation. The relative infrequency of such conditions may also be a factor in the flight crew's ability to detect and mitigate, in a timely manner, any limited capability of the FGS to cope with them. The FGS should be limited from operating in environmental conditions in which it cannot be safely operated.

This does not mean that the FGS must be disengaged when rare normal conditions, which may degrade its performance or capability, are encountered. Actually, the FGS may significantly help the flight crew during such conditions. However, the design should address the potential

for the FGS to mask a condition from the flight crew or to otherwise delay appropriate flight crew action. See Section 9.3, Flight Guidance Alerting for discussion of alerting under such conditions.

Operations in rare normal environmental conditions may result in automatic or pilot-initiated autopilot disengagement close to the limit of autopilot authority. Autopilot disengagement in rare normal conditions should meet the safety criteria for autopilot disengagement found in Section 8.1 and the criteria for flight guidance alerting in Section 9.3.

For rare normal conditions, the FGS should provide guidance or control, as appropriate for the intended function of the active mode(s), in a safe and predictable manner, both within the normal flight envelope and for momentary excursions outside the normal flight envelope.

The following rare normal environmental conditions should be considered in the design of the FGS:

- Significant winds
- Significant wind gradients
- Windshear (e.g., microburst)

NOTE: For the purpose of this AMC, “windshear” is considered a wind gradient of such a magnitude that it may cause damage to the aircraft. The FGS may also provide suitable autopilot control during windshear. Refer to FAA Advisory Circulars AC 25-12 and AC 120-41 for windshear guidance system requirements.

- Large gusts (lateral, longitudinal, and vertical dimensions)
- Severe and greater turbulence
- Asymmetric icing

10.3 Performance in Non-Normal Conditions

The FGS will occasionally be operating when the aeroplane transitions outside of the normal flight envelope of the aeroplane, when other aeroplane systems experience failure conditions (e.g., inoperative engine, loss of hydraulics) or when the aeroplane experiences certain extraordinary conditions such as significant fuel imbalance, non-standard flap/slat or ferry configurations. Under such circumstances, the FGS characteristics and flight crew interaction with the FGS should be shown to be safe.

10.4 Speed Protection (see 25.1329 (h))

The requirement for speed protection is based on the premise that reliance on flight crew attentiveness to airspeed indications, alone, during FGS operation is not adequate to avoid unacceptable speed excursions outside the speed range of the normal flight envelope. Many existing FGS systems have no provisions to avoid speed excursions outside the normal flight envelope. Some FGS systems will remain engaged until the aircraft slows to stall conditions and also to speeds well above V_{MO}/M_{MO} .

The intent of the rule is for the FGS to provide a speed protection function for all operating modes, such that the airspeed can be safely maintained within an acceptable margin of the

speed range of the normal flight envelope.

For compliance with the intent of the rule, other systems, such as the primary Flight Control System or the FMS when in a VNAV mode, may be used to provide equivalent speed protection functionality.

If the FGS is providing speed protection function, the following are acceptable means to comply with this rule:

- The FGS may detect the speed protection condition, alert the flight crew and provide speed protection control or guidance.
- The FGS may detect the speed protection condition, alert the flight crew and then disengage the FGS.
- The FGS may detect the speed protection condition, alert the flight crew, and remain engaged in the active mode without providing speed protection control or guidance.

NOTE: If compliance with this requirement is based on use of alerting alone, the alerts should be shown to be appropriate and timely to ensure flight crew awareness and enable the pilot to keep the aeroplane within an acceptable margin from the speed range of the normal flight envelope. See Section 9.3.1 for additional discussion of speed protection alerting.

The design should consider how and when the speed protection is provided for combinations of autopilot, flight directors, and autothrust operation.

Care should be taken to set appropriate values for transitioning into and out of speed protection that the flight crew does not consider a nuisance.

The speed protection function should integrate pitch and thrust control. Consideration should be given to automatically activating the autothrust function when speed protection is invoked. If an autothrust function is either not provided or is unavailable, speed protection should be provided through pitch control alone.

The role and interaction of autothrust with elements of the FMS, the primary flight control system, and the propulsion system, as applicable, should be accounted for in the design for speed protection.

Consideration should be given to the effects of an engine inoperative condition on the performance of speed protection.

10.4.1 Low Speed Protection

When the FGS is engaged in any modes (with the possible exception of approach as discussed in Section 10.4.1.1) for which the available thrust is insufficient to maintain a safe operating speed, the low speed protection function should be invoked to avoid unsafe speed excursions.

Activation of speed protection should take into account the phase of flight, factors such as turbulence and gusty wind conditions, and be compatible with the speed schedules. The low speed protection function should activate at a suitable margin to stall warning consistent with values that will not result in nuisance alerts. Consider the operational speeds, as specified in the

Aeroplane Flight Manual (AFM), for all-engine and engine-inoperative cases during the following phases of flight:

- Takeoff.
- During departure, climb, cruise, descent and terminal area operations aeroplanes are normally operated at or above the minimum manoeuvring speed for the given flap configuration.

NOTE: For high altitude operations, it may be desirable to incorporate low speed protection at the appropriate engine out drift-down speed schedule if the FGS (or other integrated sensors/systems) can determine that the cause of the thrust deficiency is due to an engine failure.

- Approach.

NOTE: A low speed alert and a transition to the speed protection mode at approximately $1.2V_S$, or an equivalent speed defined in terms of V_{SR} , for the landing flap configuration has been found to be acceptable.

- The transition from approach to go-around and go-around climb.

10.4.1.1 Low Speed Protection during Approach Operations

Speed protection should not interfere with the landing phase of flight.

It is assumed that with autothrust operating normally, the combination of thrust control and pitch control during the approach will be sufficient to maintain speed and desired vertical flight path. In cases where it is not, an alert should be provided in time for the flight crew to take appropriate corrective action.

For approach operations with a defined vertical path (e.g., ILS, MLS, GLS, LNAV/VNAV), if the thrust is insufficient to maintain both the desired flight path and the desired approach speed, there are several ways to meet the intent of low speed protection:

- a) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed until the airspeed reaches the low speed protection value. At that time the FGS would provide guidance to maintain the low speed protection value as the aeroplane departs the defined vertical path. The FGS mode reversion and low speed alert should be activated to ensure pilot awareness.

NOTE: The pilot is expected to take corrective action to add thrust and return the aeroplane to the defined vertical path or go-around as necessary.

- b) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed to the low speed protection value. The FGS will then provide a low speed alert while remaining in the existing FGS approach mode.

NOTE: The pilot is expected to take corrective action to add thrust to cause the aeroplane to accelerate back to the desired approach speed while maintaining the defined vertical path or go-around as necessary.

- c) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed until the airspeed reaches the low speed protection value. The FGS will then provide a low speed alert and disengage.

NOTE: The pilot is expected to take corrective action when alerted to the low speed condition and the disengagement of the autopilot, to add thrust and manually return the aeroplane to the desired vertical path or go-around as necessary.

The FGS design may use any one or a combination of these ways to provide acceptable low speed protection.

If the speed protection is invoked during approach such that vertical flight path is not protected, the subsequent behaviour of the FGS after speed protection should be carefully considered. Activation of low speed protection during the approach, resuming the approach mode and reacquiring the defined vertical path, may be an acceptable response if the activation is sufficiently brief and not accompanied by large speed or path deviations.

10.4.1.2 Windshear

The interaction between low speed protection and windshear recovery guidance is a special case. Windshear recovery guidance that meets the criteria found in FAA Advisory Circulars AC 25-12 and AC 120-41 provides the necessary low speed protection when it is activated, and is considered to be acceptable for compliance with CS 25.1329(h). The autopilot should be disengaged when the windshear recovery guidance activates, unless autopilot operation has been shown to be safe in these conditions and provides effective automatic windshear recovery that meets the criteria found in the advisory circulars referenced above.

10.4.2 High Speed Protection

CS 25.1329 (h) states that the means must be provided to avoid excursions beyond an acceptable margin from the speed range of the normal flight envelope V_{MO} and M_{MO} mark the upper speed limit of the normal flight envelope. This is not intended to require, or preclude, high-speed protection based on aeroplane configurations (e.g., flaps).

The following factors should be considered in the design of high-speed protection:

1. The duration of airspeed excursions, rate of airspeed change, turbulence, and gust characteristics.
 - a) Operations at or near V_{MO}/M_{MO} in routine atmospheric conditions (e.g., light turbulence) are safe. Small, brief excursions above V_{MO}/M_{MO} , by themselves, are not unsafe.
 - b) The FGS design should strive to strike a balance between providing adequate speed protection margin and avoiding nuisance activation of high-speed protection.

NOTE: The following factors apply only to designs that provide high-speed protection through FGS control of airspeed.

2. FGS in altitude hold mode:

- a) Climbing to control airspeed is not desirable, because departing an assigned altitude can be disruptive to ATC and potentially hazardous (for example, in RVSM airspace). It is better that the FGS remain in altitude hold mode.
- b) The autothrust function, if operating normally, should effect high-speed protection by limiting its speed reference to the normal speed envelope (i.e., at or below V_{MO}/M_{MO}).
- c) The basic aeroplane high-speed alert should be sufficient for the pilot to recognize the overspeed condition and take corrective action to reduce thrust as necessary. However, if the airspeed exceeds a margin beyond V_{MO}/M_{MO} (e.g., 11 km/h (6 kt)), the FGS may transition from altitude hold to the overspeed protection mode and depart (climb above) the selected altitude.

3. During climbs and descents:

- a) When the elevator channel of the FGS is not controlling airspeed, the autothrust function (if engaged) should reduce thrust, as needed to prevent sustained airspeed excursions beyond V_{MO}/M_{MO} (e.g., 11 km/h (6 kt)), down to the minimum appropriate value.
- b) When thrust is already the minimum appropriate value, or the autothrust function is not operating, the FGS should begin using the elevator channel, as needed, for high-speed protection.
- c) If conditions are encountered that result in airspeed excursions above V_{MO}/M_{MO} , it is preferable for the FGS to smoothly and positively guide or control the aeroplane back to within the speed range of the normal flight envelope.

10.5 Icing Considerations

The FGS typically will be designed to provide acceptable performance in all standard aeroplane configurations. Operating an aeroplane in icing conditions can have significant implications on the aerodynamic characteristics of the aeroplane (e.g., ice accretion on wings, tail, and engines) and, consequently, on FGS performance. Ice accretion may be slow, rapid, symmetric, or asymmetric. During autopilot operation, the flight crew may not be aware of the gradual onset of icing conditions or the affect that the accumulation of ice is having on the handling qualities of the aeroplane.

Means should be provided to alert the flight crew as described in Section 9.3.

The implication of icing conditions on speed protection should be assessed. If the threshold of the stall warning system is adjusted due to icing conditions, appropriate adjustments should also be made to the FGS low speed protection threshold.

11 CHARACTERISTICS OF SPECIFIC MODES

There are certain operational modes of the FGS that have been implemented in different ways in different aeroplanes and systems. The following sections provide guidance and interpretative material that clarifies the operational intent for these modes and provide criteria that have been shown to be acceptable in current operations. The guidance in this section does not preclude other mode implementations.

Pilot understanding of the mode behaviour is especially important to avoid potential confusion and should be clearly annunciated as described in Section 9.2, Flight Guidance Mode Selection, Annunciation, and Indication.

11.1 Lateral Modes

This section discusses modes that are implemented in many flight guidance systems that are used primarily for lateral/directional control of the aeroplane. The criteria below identify acceptable mode operation based on past operational experience gained from the use of these modes.

11.1.1 Heading or Track Hold

In the Heading or Track Hold mode, the FGS should maintain the aeroplane heading or track. For the situation when the aeroplane is in a bank when the Heading or Track Hold mode is engaged, the FGS should roll the aeroplane to a wings-level condition and maintain the heading or track when wings-level is achieved (typically less than 5 degrees of bank angle).

11.1.2 Heading or Track Select

In the Heading or Track Select mode, the FGS should expeditiously acquire and maintain a 'selected' heading or track value consistent with occupant comfort. When the mode is initially engaged, the FGS should turn the aeroplane in a direction that is the shortest heading (or track) change to acquire the new heading (or track). Once the heading/track select mode is active, changes in the selected value should result in changes in heading/track. The FGS should always turn the aeroplane in the same direction as the sense of the selected heading change (e.g., if the pilot turns the heading select knob clockwise, the aeroplane should turn to the right), even if the shortest heading (or track) change is in the opposite direction (ref. CS 25.779(a)(1)). Target heading or track value should be presented to the flight crew.

11.1.3 Lateral Navigation Mode (LNAV)

In the LNAV mode, the FGS should acquire and maintain the lateral flight path commanded by a flight management function (that is, FMS or equivalent).

If the aeroplane is not established on the desired lateral path or within the designed path capture criteria when LNAV is selected, the FGS LNAV mode should enter an armed state. The FGS should transition from the armed state to an engaged state at a point where the lateral flight path can be smoothly acquired and tracked.

For an FGS incorporating the LNAV mode during the takeoff or go-around phase, the design should specify manoeuvring capability immediately after takeoff, and limits, should they exist. After takeoff or go-around, manoeuvring should be based upon aircraft performance with the objective to prevent excessive roll attitudes where wingtip / runway impact becomes probable, yet satisfy operational requirements where terrain and / or thrust limitations exist.

11.2 Vertical Modes

This section discusses modes that are implemented in many flight guidance systems that are

used primarily for pitch control of the aeroplane. The criteria identified reflect operational experience gained from the use of these modes.

To avoid unconstrained climbs or descents, for any altitude transitions when using applicable vertical modes, the altitude select controller should be set to a new target altitude before the vertical mode can be selected. If the design allows the vertical mode to be selected before setting the target altitude, then consideration should be given to the potential vulnerability of unconstrained climb or descent leading to an altitude violation or Controlled Flight into Terrain. Consideration should also be given to appropriate annunciation of the deviation from previously selected altitude and / or subsequent required pilot action to reset the selected altitude.

11.2.1 Vertical Speed Mode

In the Vertical Speed mode, the FGS should smoothly acquire and maintain a selected vertical speed.

Consideration should be given to:

- the situation where the selected value is outside of the performance capability of the aeroplane, or
- use of vertical speed mode without autothrust,

potentially leading to a low-speed or high-speed condition, and corresponding pilot awareness vulnerabilities. See Section 10.4, Speed Protection, for discussion of acceptable means of compliance when dealing with such situations.

11.2.2 Flight Path Angle Mode

In the Flight Path Angle mode, the FGS should smoothly acquire and maintain the selected flight path angle.

Consideration should be given to:

- the situation where the selected value is outside of the performance capability of the aeroplane, or
- use of flight path angle mode without autothrust,

potentially leading to a low-speed or high-speed condition, and corresponding pilot awareness vulnerabilities. Acceptable means of compliance have included a reversion to an envelope protection mode or a timely annunciation of the situation.

11.2.3 Airspeed (IAS)/Mach Hold (Speed on elevator)

In the Airspeed/Mach Hold mode, the FGS should maintain the airspeed or Mach at the time of engagement.

11.2.4 Airspeed (IAS)/Mach Select Mode (Speed on elevator)

In the Airspeed/Mach Select mode, the FGS should acquire and maintain a selected airspeed or Mach. The selected airspeed or Mach may be either pre-selected or synchronized to the airspeed or Mach at the time of engagement.

11.2.5 Flight Level Change (FLCH) (Speed on elevator)

In the FLCH mode, the FGS should change altitude in a coordinated way with thrust control on the aeroplane. The autopilot/flight director will typically maintain speed control through elevator. The autothrust function, if engaged, will control the thrust to the appropriate value for climb or descent.

11.2.6 Altitude Capture Mode

The Altitude Capture mode should command the FGS to transition from a vertical mode to smoothly capture and maintain the selected target altitude with consideration of the rates of climb and descent experienced in service.

In-service experience has shown that certain implementations have the potential to cause pilot confusion that may lead to altitude violations. Accordingly, the following are guidelines for the Altitude Capture mode:

- (a) The Altitude Capture mode should be automatically armed to ensure capture of the selected altitude. Note: If the altitude capture mode is armed at all times, annunciation of the armed status is not required. If the FGS is in Altitude Capture, it should be annunciated.
- (b) The Altitude Capture mode should engage from any vertical mode if the computed flight path will intercept the selected altitude and the altitude capture criteria are satisfied, except as specified during an approach (e.g., when the glidepath for approach mode is active).
- (c) Changes in the climb/descent command references, with the exception of those made by the flight crew using the altitude select controller, should not prevent capture of the target altitude.
- (d) The Altitude Capture mode should smoothly capture the selected altitude using an acceptable acceleration limit with consideration for occupant comfort.
- (e) The acceleration limit may, under certain conditions, result in an overshoot. To minimize the altitude overshoot, the normal acceleration limit may be increased, consistent with occupant safety.
- (f) During Altitude Capture, pilot selection of other vertical modes should not prevent or adversely affect the level off at the target altitude at the time of capture. One means of compliance is to inhibit transition to other pilot-selectable vertical modes (except altitude hold, go-around, and approach mode) during altitude capture, unless the target altitude is changed. If glidepath capture criteria are satisfied during altitude capture, then the FGS should transition to glidepath capture.

- (g) The FGS must be designed to minimize flight crew confusion concerning the FGS operation when the target altitude is changed during altitude capture. It must be suitably annunciated and appropriate for the phase of flight (CS 25.1329(i)).
- (h) Adjusting the datum pressure at any time during altitude capture should not result in loss of the capture mode. The transition to the pressure altitude should be accomplished smoothly.
- (i) If the autothrust function is active during altitude capture the autopilot and autothrust functions should be designed such that the FGS maintains the reference airspeed during the level-off manoeuvre. For example, if the autopilot changes from speed mode to an altitude capture or control mode, then autothrust should transition to a speed mode to maintain the reference airspeed.

11.2.7 Altitude Hold Mode

The Altitude Hold mode may be entered either by flight crew selection or by transition from another vertical mode.

When initiated by an automatic transition from altitude capture the Altitude Hold mode should provide guidance or control to the selected altitude. The automatic transition should be clearly annunciated for flight crew awareness.

When initiated by pilot action in level flight, the Altitude Hold mode should provide guidance or control to maintain altitude at the time the mode is selected.

When initiated by pilot action when the aeroplane is either climbing or descending, the FGS should immediately initiate a pitch change to arrest the climb or descent, and maintain the altitude when level flight (e.g., <1 m/s (<200 ft/min)) is reached. The intensity of the levelling manoeuvre should be consistent with occupant comfort and safety.

Automatic transition into the Altitude Hold mode from another vertical mode should be clearly annunciated for flight crew awareness.

Any aeroplane response due to an adjustment of the datum pressure should be smooth.

11.2.8 Vertical Navigation Mode (VNAV)

In the VNAV mode, the FGS should acquire and maintain the vertical commands provided by a flight management function (that is, FMS or equivalent).

If the aeroplane is not on the desired FMS path when the VNAV mode is selected, the FGS VNAV mode should go into an armed state, or provide guidance to smoothly acquire the FMS path. The flight crew should establish the aeroplane on a flight profile to intercept the desired FMS path. The FGS should transition from the armed state to an engaged state at a point where the FGS can smoothly acquire and track the FMS path.

When VNAV is selected for climb or descent, the autothrust function (if installed) should maintain the appropriate thrust setting. When levelling after a VNAV climb or descent, the autothrust function should maintain the target speed.

If the aircraft is flying a vertical path (e.g., VNAV Path) the deviation from that path should be displayed in the primary field of view (i.e., the PFD, ND, or other acceptable display).

The FGS should preclude a VNAV climb unless the Mode Selector Panel altitude window is set to an altitude above the current altitude.

Except when on a final approach segment to a runway:

- The FGS should preclude a VNAV descent unless the Mode Selector Panel altitude window is set to an altitude below the current altitude.
- The FGS should not allow the VNAV climb or descent to pass through a Mode Selector Panel altitude.

(See Section 11.5, Special Considerations for VNAV Approach Operations related to selecting a Target Altitude.)

11.3 Multi-axis Modes

This section discusses modes that are implemented in many flight guidance systems that are used in an integrated manner for pitch, lateral/directional control and thrust management of the aeroplane. The criterion identified reflects operational experience gained from the use of these modes.

11.3.1 Takeoff Mode

In the take off mode, the vertical element of the FGS should provide vertical guidance to acquire and maintain a safe climb out speed after initial rotation for takeoff. If no rotation guidance is provided, the pitch command bars may be displayed during takeoff roll but should not be considered as providing rotation guidance unless it is part of the intended function.

If rotation guidance is provided, consideration should be given to the need to show that the use of the guidance does not result in a tail strike and should be consistent with takeoff methods necessary to meet takeoff performance requirements up to 11 m (35 ft) AGL.

The Autothrust function should increase and maintain engine thrust to the selected thrust limits (e.g., full T/O, de-rate).

The FGS design should address all engine and engine-inoperative conditions consistent with the following takeoff system performance after lift-off:

- (a) Takeoff system operation should be continuous and smooth through transition from the runway portion of the takeoff to the airborne portion and reconfiguration for en route climb. The pilot should be able to continue the use of the same primary display(s) for the airborne portion as for the runway portion. Changes in guidance modes and display formats should be automatic.
- (b) The vertical axis guidance of the takeoff system during normal operation should result in the appropriate pitch attitude, and climb speed for the aeroplane considering the following factors:
 - Normal rate rotation of the aeroplane to the commanded pitch attitude, at V_R -18.5 km/h (10 kt) for all engines and V_R -9.3 km/h (5 kt) for engine out, should not result in a tail-strike.

- The system should provide commands that lead the aeroplane to smoothly acquire a pitch attitude that results in capture and tracking of the All-Engine Takeoff Climb Speed, $V_2 + X$. X is the All-Engine Speed Additive from the AFM (normally 18.5 km/h (10 kt) or higher). If pitch limited conditions are encountered a higher climb airspeed may be used to achieve the required takeoff path without exceeding the pitch limit.

(c) For engine-out operation, the system should provide commands that lead the aeroplane to smoothly acquire a pitch attitude that results in capture and tracking of the following reference speeds:

- V_2 , for engine failure at or below V_2 . This speed should be attained by the time the aeroplane has reached 11m (35 ft) altitude.
- Airspeed at engine failure, for failures between V_2 and $V_2 + X$.
- $V_2 + X$, for failures at or above $V_2 + X$. Alternatively, the airspeed at engine failure may be used, provided it has been shown that the minimum takeoff climb gradient can still be achieved at that speed.

If implemented, the lateral element of the takeoff mode should maintain runway heading/track or wings level after lift-off and a separate lateral mode annunciation should be provided.

11.3.2 Go-Around Mode

The vertical element of the FGS Go-around mode should initially rotate the aeroplane, or provide guidance to rotate the aeroplane, to arrest the rate of descent. The autothrust function, if installed, should increase thrust and either, maintain thrust to specific thrust limits, or maintain thrust for an adequate, safe climb.

The FGS should acquire and maintain a safe speed during climb out and aeroplane configuration changes. Typically, a safe speed for go-around climb is V_2 , but a different speed may be found safe for windshear recoveries (see FAA Advisory Circular AC 25-12). The lateral element of the FGS should maintain heading/track or wings level.

The autothrust function should not exceed thrust limits (e.g., full go-around thrust or de-rated go-around thrust limits) nor reduce thrust, for winds, below the minimum value required for an adequate, safe climb or reduce thrust lever position below a point that would cause a warning system to activate. The initial go-around manoeuvre may require a significant change in pitch attitude. It is acceptable to reduce thrust to lower the pitch attitude for comfort of the occupants when a safe climb gradient has been established. It should be possible for the pilot to re-select the full thrust value if needed.

The go-around mode should engage even if the MSP altitude is at or below the go-around initiation point. The aeroplane should climb until another vertical mode is selected or the MSP altitude is adjusted to an altitude above the present aircraft altitude.

The FGS design should address all engine and engine-out operation. The design should consider an engine failure resulting in a go-around, and the engine failure occurring during an all engine go-around.

Characteristics of the go-around mode and resulting flight path should be consistent with

manually flown go-around.

11.3.3 Approach Mode

In the Approach mode, the FGS should capture and track a final approach lateral and vertical path (if applicable) from a navigation or landing system (e.g., ILS, MLS, GLS, RNP).

The FGS should annunciate all operationally relevant approach mode annunciations. Modes that are armed, waiting for capture criteria to be satisfied, should be indicated - in addition to the active pre-capture mode. A positive indication of the capture of the previously armed mode should be provided.

The FGS may have sub-modes that become active without additional crew selection. An assessment of the significance of these sub-mode transitions to the flight crew should be made. If assessed to be significant (e.g., Flare), positive annunciation of the transition should be provided.

Glideslope capture mode engagement may occur prior to localizer capture. However, it is the flight crew's responsibility to ensure proper safe obstacle/terrain clearance when following vertical guidance when the aeroplane is not established on the final lateral path.

Additional guidance and criteria is contained in CS-AWO.

11.4 Autothrust Modes

This section discusses modes that are implemented in many flight guidance systems that are used primarily for controlling the engines on the aeroplane. The criterion identified reflects operational experience gained from the use of these modes.

11.4.1 Thrust Mode

In the Thrust mode, the FGS should command the autothrust function to achieve a selected target thrust value.

11.4.2 Speed Mode

In the Speed mode, the FGS should command the autothrust function to acquire and maintain the selected target speed value - assuming that the selected speed is within the speed range of the normal flight envelope. The autothrust system may fly a higher airspeed than the selected target speed during takeoff, or during approach when operating in winds or turbulent conditions.

11.4.3 Retard Mode

If such a mode is installed on a specific aircraft, it should work in a similar manner for both automatic and manual landings, when the autothrust function is engaged.

11.5 Special Considerations for VNAV Approach Operations related to selecting a Target Altitude

For approach operations, the FGS vertical modes should allow the pilot to set the target altitude to a missed approach value prior to capturing the final approach segment. This should be possible for capturing from both above and below the final approach segment.

For VNAV Path operations, it should be possible to define a descent path to the final approach fix and another path from the final approach fix to the runway with the target altitude set for the missed approach altitude. Appropriate targets and descent points should be identified by the FMS.

11.6 Control Wheel Steering (Control Steering through the Autopilot)

In the Control Wheel Steering (CWS) mode, the FGS allows the flight crew to manoeuvre the aeroplane through the autopilot. This has implications for control harmony, stability, and crew awareness that need to be thoroughly addressed.

If provided, a CWS mode should meet the following requirements:

- (a) It should be possible for the pilot to manoeuvre the aeroplane using the normal flight controls with the CWS mode engaged and to achieve the maximum available control surface deflection without using forces so high that the controllability specifications of CS 25.143 (d) are not met.
- (b) The maximum bank and pitch attitudes that can be achieved without overpowering the automatic pilot should be limited to those necessary for the normal operation of the aeroplane.

NOTE: Typically 35 degrees in roll and +20 degrees to -10 degrees in pitch

- (c) It should be possible to perform all normal manoeuvres smoothly and accurately without nuisance oscillation. It should be possible also to counter all normal changes of trim due to change of configuration or power, within the range of flight conditions in which control wheel steering may be used, without encountering excessive discontinuities in control force which might adversely affect the flight path.
- (d) The stall and stall recovery characteristics of the aeroplane should remain acceptable. It should be assumed that recovery is made with CWS in use unless automatic disengagement of the automatic pilot is provided.
- (e) In showing compliance with CS 25.143 (g), account should be taken of such adjustments to trim as may be carried out by the automatic pilot in the course of manoeuvres that can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged manoeuvres, provided that the reduced control forces would not be hazardous.
- (f) If the use of this mode for takeoff and landing is to be permitted, it should be shown that:
 - i) Sufficient control, both in amplitude and rate is available without encountering force discontinuities;

- ii) Reasonable mishandling is not hazardous (e.g., engaging the automatic pilot while the elevators or ailerons are held in an out-of-trim position);
- iii) Runaway rates and control forces are such that the pilot can readily overpower the automatic pilot with no significant deviation in flight path; and
- iv) Any lag in aircraft response induced by the CWS mode is acceptable for the intended manoeuvre.

- (g) It should not be possible to revert to the CWS mode by applying an input to the control column or wheel unless the autopilot is in a capture mode (e.g., altitude capture, localizer capture). When the force is released, the autopilot should return to the previously engaged capture mode or to the track mode.

NOTE: CWS, if it is provided, is considered to be an autopilot mode, as it is a specific function of the FGS. However, during CWS operation, it is the pilot and not the autopilot that is in control of the aircraft. Operationally, CWS is identical to the pilot flying the aeroplane during manual flight. In both cases, it is the pilot who is in actual control of the flight path and speed of the aeroplane. The only difference is the mechanization of how the actual flight control surfaces are moved. No “automatic” FGS commands are involved during CWS operation. Therefore, sections in this AMC such as those which discuss Speed Protection and performance objectives should be applied to only those autopilot modes with which the FGS is in control of the flight path of the aeroplane and should not be applied to CWS.

NOTE: The terminology “Control Wheel Steering” is currently used by industry to describe several different types of systems. This section is meant to apply only toward those systems that are implemented in a manner as described above. For comparison, several other functions that are similar in nature, but functionally very different, to CWS are described below. This section does not apply to functions of these types.

- Touch Control Steering (TCS) is a function that is available on many business and commuter aircraft. With TCS, a pilot is able to physically disengage the autopilot servos from the flight control system, usually by pushing and holding a button on the control wheel, without causing the autopilot system itself to disengage or lose its currently selected modes. The pilot may then manoeuvre the aeroplane as desired using the aircraft’s flight control system (i.e., the autopilot servos are not part of the control loop). The pilot is then able to reconnect the autopilot servos to the flight control system by releasing the TCS button. Using the new orientation of the aircraft as a basis, the autopilot will then reassume control the aeroplane using the same mode selections as were present before the selection of TCS. This type of system on some aircraft is also sometimes referred to as Control Wheel Steering.
- Also different from CWS is what is referred to as a “supervisory override” of an engaged autopilot. With this function, a pilot is able to physically overpower an engaged autopilot servo by applying force to the flight deck controls. With a supervisory override, the autopilot does not automatically disengage due to the

pilot input. This allows the pilot to position the aeroplane as desired using the flight deck controls without first disengaging the autopilot. When the pilot releases the controls, the autopilot reassumes control of the aeroplane using the same mode selections as were present before the supervisory override.

- The descriptions of TCS and supervisory override are intended to be generic. Specific implementations on various aircraft may vary in some aspects.

11.7 Special Considerations for the Integration of Fly-By-Wire Flight Control Systems and FGS

Speed protection features may be implemented in the fly-by-wire flight control system. However, if speed protection is also implemented within the FGS, it should be compatible with the envelope protection features of the fly-by-wire flight control system. The FGS speed protection (normal flight envelope) should operate to or within the limits of the flight control system (limit flight envelope).

Information should be provided to the flight crew about implications on the FGS following degradation of the fly-by-wire flight control systems.

12 FLIGHT GUIDANCE SYSTEM INTEGRATION

Throughout the preceding sections of the document, flight guidance systems and functions have been considered as being separate and distinct from other systems and functions on the aircraft. It is recognized that in complex aircraft designs, the flight guidance functions are closely integrated with other avionics functions, and that the physical integration of these systems, may have a bearing on how aeroplane level safety is assessed. The following paragraphs provide guidance on the likely FGS system integration issues found in more complex aircraft system designs, and the interfaces which should be considered within the bounds of demonstrating the intended function, performance and safety of the FGS.

12.1 System Integration Issues

Integration of other aircraft systems with the FGS has the potential of reducing the independence of failure effects and partitioning between functions. This is particularly the case where hardware and software resources are shared by different systems and functions (e.g., aircraft data highway and Integrated Modular Avionics (IMA) architectures). In addition to considering the reliability and integrity aspects of the FGS as a separate system, it may be necessary to address the effects of FGS failures with respect to fault propagation, detection, and isolation within other systems. The overall effect on the aircraft of a combination of individual system failure conditions occurring as a result of a common or cascade failure, may be more severe than the individual system effect. For example, failure conditions classified under CS 25.1309 as Minor or Major by themselves may have Hazardous effects at the aircraft level, when considered in combination. With regard to isolation of failures, and particularly combination failures, the ability of the alerting system to provide clear and unambiguous information to the flight crew, becomes of significant importance. See also Section 13, Safety Assessment.

Complex and highly integrated avionics issues present greater risk for development error. With

non-traditional human-machine interfaces, there is also the potential for operational flight crew errors. Moreover, integration of systems may result in a greater likelihood of undesirable and unintended effects.

Within the FGS, where credit is taken for shared resources or partitioning schemes, these should be justified and documented within the System Safety Analysis. When considering the functional failures of the system, where such partitioning schemes cannot be shown to provide the necessary isolation, possible combination failure modes should be taken into account. An example of this type of failure would be multi-axis active failures, where the control algorithms for more than one axis are hosted on a single processing element. Further, the functional integration of control functions such as control surface trimming, yaw channel, and stability augmentation, while not strictly FGS, should be considered.

12.2 Functional Interfaces

In its simplest form, the FGS may be considered as interfacing with sensors that provide the necessary inputs to enable computation of its various functions. Typically, these sensors will include air and inertial data, engine control, and navigation sensors such as ILS, VOR, and DME. In the case of engine control, a feedback loop may also be provided. The FGS may also be considered as providing inner loop closure to outer loop commands. The most common interface is with the FMS, which provides targets for lateral and vertical navigation in the form of steering orders.

In demonstrating the intended function and performance of both the FGS and systems providing outer loop commands, the applicant needs to address potential inconsistencies between limits of the two (e.g., with basic FGS pitch and bank angle limits). Failure to address these points can result in discontinuities, mode switching, and reversions, leading to erroneous navigation and other possible safety issues (e.g., buffet margin at high altitude). Similar issues arise in the inner loop, across the functional interface between FGS and flight controls. In fly-by-wire aircraft, the loss of synchronization between the two can result in mode anomalies and autopilot disengagement.

The applicant should demonstrate the intended function and performance of the FGS across all possible functional interfaces. The alerting system should also be assessed to ensure that accurate and adequate information is provided to the flight crew when dealing with failures across functional interfaces.

13 SAFETY ASSESSMENT

CS 25.1309 defines the basic safety specifications for airworthiness approval of aeroplane systems and AMC 25.1309 provides an acceptable means of demonstrating compliance with this rule. This section provides additional guidance and interpretive material for the application of CS 25.1309 to the approval of FGS.

A Safety Analysis document should be produced to identify the Failure Conditions, classify their hazard level according to the guidance of AMC 25.1309, and establish that the Failure Conditions occur with a probability corresponding to the hazard classification or are mitigated as intended. The safety assessment should include the rationale and coverage of the FGS protection and monitoring philosophies employed. The safety assessment should include an appropriate evaluation of each of the identified FGS Failure Conditions and an analysis of the exposure to common mode/cause or cascade failures in accordance with AMC 25.1309.

Additionally, the safety assessment should include justification and description of any functional partitioning schemes employed to reduce the effect/likelihood of failures of integrated components or functions.

There may be situations where the severity of the effect of a failure condition identified in the safety analysis needs to be confirmed. Laboratory, simulator or flight test, as appropriate, may accomplish the confirmation.

It is recommended that the Safety Analysis plan is coordinated with the regulatory authority early in the certification program.

13.1 FGS Failure Conditions

One of the initial steps in establishing compliance with CS 25.1309 for a system is to identify the Failure Conditions that are associated with that system. The Failure Conditions are typically characterized by an undesired change in the intended function of the system. The Failure Condition statements should identify the impacted functionality, the effect on the aeroplane and/or its occupants, specify any considerations relating to phase of flight and identify any flight crew action, or other means of mitigation, that are relevant.

Functionality - the primary functions of a FGS may include:

- automatic control of the aeroplane's flight path utilizing the aeroplane's aerodynamic control surfaces,
- guidance provided to the flight crew to achieve a particular desired flight path or manoeuvre, through information presented on a head-down or head-up display system, and
- control of the thrust applied to the aeroplane.

Dependent upon the functionality provided in a specific FGS, the failure conditions could potentially impact the following:

- the control of the aeroplane in the pitch, roll and directional axes,
- the control of thrust,
- the integrity and availability of guidance provided to the flight crew,
- the structural integrity of the aeroplane,
- the ability of the flight crew to cope with adverse operating conditions,
- the flight crew's performance and workload,
- the safety of the occupants of the aeroplane.

NOTE:: The safety assessment of a FGS for use in supporting takeoff, approach and landing operations in low visibility conditions is further addressed in CS-AWO.

13.2 Type and Severity of Failure Conditions

The type of the FGS Failure Conditions will depend, to a large extent, upon the architecture, design philosophy and implementation of the system. Types of Failure Conditions can include:

- Loss of function – where a control or display element no longer provides control or guidance
- Malfunction – where a control or display element performs in an inappropriate manner which can include the following sub-types:
 - a) Hardover – the control or display goes to full displacement in a brief period of time – the resultant effect on the flight path and occupants of the aeroplane are the primary concern.
 - b) Slowover - the control or display moves away from the correct control or display value over a relatively long period of time – the potential delay in recognizing the situation and the effect on the flight path are the primary concern.
 - c) Oscillatory - the control or display is replaced or augmented by an oscillatory element – there may be implications on structural integrity and occupant well being.

Failure Conditions can become apparent due to failures in sensors, primary FGS elements (e.g., autopilot, flight director, HUD), control and display elements (e.g., servos, primary flight displays), interfacing systems or basic services (e.g., electrical and hydraulic power).

The severity of the FGS Failure Conditions and their associated classifications will frequently depend on the phase of flight, aeroplane configuration and the type of operation being conducted. The effect of any control system variability (e.g., tolerances and rigging) on Failure Condition should be considered. The severity of the Failure Conditions can also be mitigated by various design strategies (see Section 13.3).

Appendix A presents some considerations for use when assessing the type and severity of condition that results from functional failures. The classifications of Failure Conditions that have been identified on previous aeroplane certification programs are identified. The classifications of Failure Conditions should be agreed with the authority during the CS 25.1309 safety assessment process.

With exception of the Catastrophic failure condition, the classification of failure conditions leading to the imposition of airframe loads should be assessed in accordance with CS 25.302. This requires that the structure be able to tolerate the limit load multiplied by a factor of safety associated with the probability of occurrence of the failure mode. The assessment needs to take into account loads occurring during the active malfunction, recovery or continuation of the flight with the system in the failed state.

Complex integrated systems may require that the total effect resulting from single failure be assessed. For example, some failures may result in a number of Failure Conditions occur which, if assessed individually may be considered a Major effects, but when considered in combination may be Hazardous. Special consideration concerning complex integration of systems can be found in Section 12, Flight Guidance System Integration.

13.3 Failure Condition – Mitigation

The propagation of potential Failure Conditions to their full effect may be nullified or mitigated by a number of methods. These methods could include, but are not limited to, the following:

- failure detection and monitoring,
- fault isolation and reconfiguration,

- redundancy,
- authority limiting, and
- flight crew action to intervene.

Means to assure continued performance of any system design mitigation methods should be identified. The mitigation methods should be described in the Safety Analysis/Assessment document or be available by reference to another document (e.g., a System Description document).

The design of typical FGS allows for the de-selection of control and guidance elements. The long-term effects on occupants and any structural implication of oscillatory failures can be mitigated by de-selection.

13.4 Validation of Failure Conditions

The method of validating of Failure Conditions will depend on the effect of the condition, assumptions made and any associated risk. The severity of some Failure Conditions may be obvious and other conditions may be somewhat subjective. If flight crew action is used to mitigate the propagation of the effect of a Failure Condition, the information available to the flight crew to initiate appropriate action (e.g., motion, alerts, and displays) and the assumed flight crew response should be identified. It is recommended that there be early coordination with the regulatory authority to identify any program necessary to validate any of these assumptions.

The validation options for Failure Conditions include:

- Analysis
- Laboratory Testing
- Simulation
- Flight Test

It is anticipated that the majority of Failure Condition can be validated by analysis to support the probability aspect of the CS 25.1309 assessment. The analysis should take account of architectural strategies (e.g., redundant channels, high integrity components, rate limit/magnitude limiting, etc.).

It may be necessary to substantiate the severity of a Failure Condition effect by ground simulation or flight test. This is particularly true where pilot recognition of the failure condition requires justification or if there is some variability in the response of the aeroplane. Failure Conditions that are projected to be less probable than 10^{-7} per flight hour, independent of effect severity, need not be demonstrated in flight-test.

Section 14 – Compliance Demonstration using Flight Test and Simulation - provides guidance on the assessment of ‘traditional’ Failure Conditions. New and novel functionality may require additional assessment methods to be agreed with the authority.

13.5 Specific Considerations

The following paragraphs identify specific considerations that should be given to potential

Failure Conditions for various phases of flight.

13.5.1 FGS Function during Ground Operations

The potential hazard that may result due to inappropriate autopilot, autothrust or other system control action during maintenance operations, while the aeroplane is parked at the gate or during taxi operations should be assessed. System interlocks or crew or maintenance procedures and placards may mitigate these hazards.

13.5.2 FGS Operations in close proximity to the ground

The response of the aeroplane to failures in an automatic flight control system could have implications on the safety of operations when the aeroplane is close to the ground. For the purpose of this advisory circular, close to the ground can be assumed to be less than 150 m (500 ft) above the lift-off point or touchdown zone or a runway. A specific safety assessment is required if approval is sought for automatic flight control operation where the autopilot is engaged, or remains engaged in close proximity to the ground.

NOTE: Operation in low visibility conditions requires additional consideration and CS AWO Subparts should be used for those additional considerations.

13.5.2.1 Takeoff

If approval is sought for engagement of the autopilot below 150 m (500 ft) after lift-off, an assessment of the effect of any significant FGS failure conditions on the net vertical flight path, the speed control and the bank angle of the aeroplane should be conducted. An Autopilot Minimum Engage Altitude after Takeoff will be established based, in part, on the characteristics of the aeroplane in response to the failures and the acceptability of flight crew recognition of the condition.

A pilot assessment of certain Failure Conditions may be required (see Section 14 – Compliance Demonstration using Flight Test and Simulation). The minimum engagement altitude/height after takeoff based upon the assessment should be provided in the AFM.

13.5.2.1.1 Vertical Axis Assessment

The operational objective during the initial climb is to maintain an appropriate climb profile to assure obstacle clearance and to maintain an appropriate speed profile during climbout (refer to Section 11, Characteristics of Specific Modes).

FGS Failure Conditions should be assessed for the potential for:

- a significant reduction in the net takeoff flight path below 150 m (500 ft),
- a significant increase in pitch attitude that results in the aeroplane speed dropping to unacceptable values.

Failures Conditions with a probability greater than 1×10^{-7} per flight hour that have an effect requiring the pilot to intervene should be evaluated for a potential AFM limitations or procedures.

13.5.2.1.2 Lateral Axis Assessment

The operational objective during the initial climb is to maintain an appropriate heading or track to provide separation from potential adjacent runway operations.

FGS failure conditions should be assessed for the potential for producing a bank angle that results in significant deviation from the runway track or intended track.

Failures Conditions with a probability greater than 1×10^{-7} per flight hour that have an effect requiring pilot action should be evaluated for a potential AFM limitations or procedures.

13.5.2.2 Approach

If the autopilot is to remain engaged below 150 m (500 ft) above the touchdown zone during approach, an assessment of the effect of any significant FGS failure conditions on the net vertical flight path, the speed control and the bank angle of the aeroplane should be conducted. The lowest point on the approach appropriate for the use of the autopilot will be established based on the characteristics of the aeroplane in response to the failure conditions and the acceptability of flight crew recognition of the condition.

A number of approach operations may be conducted using automatic flight control. These can include, but not be limited to, the following:

- ILS, MLS, GLS,
- RNAV (e.g., LNAV and VNAV),
- NAV (e.g., VOR, LOC, Backcourse),
- Open loop flight path management (e.g., Vertical Speed, Flight Path Angle, Track or Heading Select).

Some operations may be conducted with a single autopilot channel engaged and some operations may be conducted with multiple autopilots engaged. The engagement of multiple autopilots may have the effect of mitigating the effect of certain failure conditions. The effectiveness of these mitigation methods should be established.

The type of operation and the prevailing visibility conditions will determine the decision altitude/decision height (DA(H)), or minimum descent altitude or height (MDA(H)), for a particular flight operation. The operation may continue using automatic flight control if the visual requirements are met.

The lowest altitude at which the autopilot should remain engaged could vary with the type of operation being conducted. The resultant flight path deviation from any significant failure condition would impact the autopilot minimum operational use height.

Assessment of certain failure conditions may be required (see Section 14 – Compliance Demonstration using Flight Test and Simulation). The minimum use height for approach should be provided in the AFM.

13.5.2.2.1 Vertical Axis Assessment

The operational objective during the approach is to maintain an appropriate descent profile to assure obstacle clearance and to maintain an appropriate speed profile.

FGS Failure Conditions should be assessed for the potential for:

- a significant reduction in the approach flight path when below 150 m (500 ft) above touchdown,
- a significant increase in pitch attitude that results in the aeroplane speed dropping to unacceptable values.

Failures Conditions with a probability greater than 1×10^{-7} per flight hour that have an effect requiring pilot action should be evaluated for potential AFM limitations or procedures.

13.5.2.2.2 Lateral Axis Assessment

The operational objective during the approach is to maintain an appropriate track to provide alignment with the runway centreline, or intended flight path, to support the landing.

FGS Failure Conditions should be assessed for the potential for producing a bank angle that results in significant deviation from the runway track or intended track.

Failures with a probability greater than 1×10^{-7} per flight hour that have an effect requiring pilot action should be evaluated for appropriate AFM limitations or procedures.

13.5.3 Cruise Operations

The primary concern during cruise operations is the effect the aeroplane response to Failure Conditions may have on the occupants. At a minimum, the accelerations and attitude resulting from any condition should be assessed. The mitigation of the effect of a Failure Condition by the flight crew may not be as immediate as during takeoff and landing operations. Section 14 provides guidance and considerations for this phase of flight.

13.5.4 Asymmetric Thrust during Autothrust Operation

During autothrust operation, it is possible that a failure (e.g., engine failure, throttle lever jam, or thrust control cable jam) could result in significant asymmetric thrust failure condition that may be aggravated by the continued use of the autothrust system. Because the FGS could potentially compensate for the asymmetric condition with roll (and possibly yaw) control, the pilot may not immediately be aware of the developing situation. Therefore, an alert should be considered as a means of mitigation to draw the pilot's attention to an asymmetric thrust condition during FGS operation.

13.6 Failure to Disengage the FGS

The requirement for quick disengagement for the autopilot and autothrust functions is intended to provide a routine and intuitive means for the flight crew to quickly disengage those functions. The implication of failures that preclude the quick disengagement from functioning should be assessed consistent with the guidelines of AMC 25.1309.

The CS 25.1309 assessment should consider the effects of failure to disengage the autopilot and/or autothrust functions during the approach using the quick disengagement controls. The feasibility of the use of the alternative means of disengagement defined in Section 8.1.2.3 should be assessed.

If the assessment asserts that the aircraft can be landed manually with the autopilot and/or autothrust engaged, this should be demonstrated in Flight Test.

14 COMPLIANCE DEMONSTRATION USING FLIGHT TEST AND SIMULATION

The validation of the performance and integrity aspects FGS operation will typically be accomplished by a combination of the following methods:

- Analysis
- Laboratory Test
- Simulation
- Flight Test

The criteria to be used for establishing compliance with CS 25.1301, 25.1309 and 25.1329 may be found in Sections 8, 9, 10, 11, 12, and 13 of this document. The type and extent of the various validation methods may vary dependent upon the FGS functionality, certification considerations, the applicant's facilities, and various practicality and economic constraints.

This section focuses on compliance demonstration by flight test or simulation with flight crew participation. The section includes the evaluation necessary to confirm acceptable performance of intended functions, including the human-machine interface, and the acceptability of failure scenarios. The specific requirements for flight or simulator evaluation will consider the specifics of the applicant's design, the supporting engineering analysis and the scope and depth of the applicants laboratory testing.

The certification flight test program should investigate representative phases of flight and aircraft configurations used by the FGS. The program should evaluate all of the FGS modes throughout appropriate manoeuvres and representative environmental conditions, including turbulence. Combinations of FGS elements (e.g., autopilot engaged and autothrust disengaged) should be considered. Certain failure scenarios may require flight or simulator demonstration. The aeroplane should contain sufficient instrumentation such that the parameters appropriate to the test are recorded (e.g. normal acceleration, airspeed, height, pitch and roll angles, autopilot engagement state). The flight test instrumentation should not affect the behaviour of the autopilot or any other system.

Figure 14-1 depicts the relationship between this section and the rest of the document.

An important part of the pilot in the loop evaluation is validation of human factors. A thorough evaluation of the human-machine interface is required to ensure safe, effective, and consistent FGS operation. Portions of this evaluation will be conducted during flight test. Representative simulators can be used to accomplish the evaluation of human factors and workload studies. The level and fidelity of the simulator used should be commensurate with the certification credit being sought and its use should be agreed with the regulatory authority.

If the FGS includes takeoff and/or approach modes, the criteria in CS-AWO Subparts 1, 2, 3 and 4 should be considered for applicability in developing the overall and integrated flight test and simulation requirements. AMC No.2 to CS 25.1329 contains procedures that may be used to show compliance.

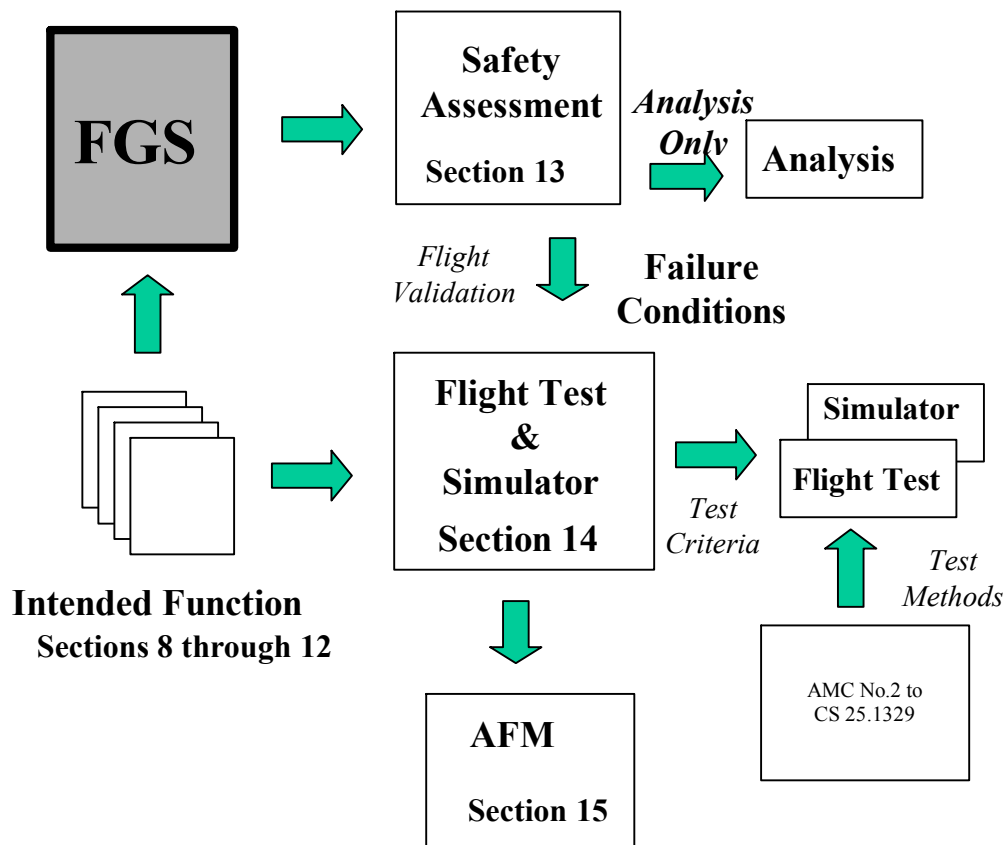


Figure 14-1

14.1 Performance Demonstration (Fault Free) – CS 25.1301

The Certification Plan should identify the specific functionality provided by the FGS. The flight test and/or simulator program will typically assess this functionality under representative operational conditions including applicable aeroplane configurations and a representative range of aeroplane weight, centre of gravity and operational envelope.

The performance of the FGS system in each of its guidance and control modes should be evaluated. The acceptability of the performance of the FGS may be based on test pilot assessment, taking into account the experience acquired from similar equipment capabilities, and the general behaviour of the aeroplane. The level of acceptable performance may vary according to aeroplane type and model. The FGS should be evaluated for its low and high manoeuvring capability. AMC No.2 to CS 25.1329 may provide additional information on FGS test procedures.

The acceptability of mode controls and annunciations, any associated alerts and general compatibility with cockpit displays should be evaluated. The FGS should be free from unexpected disengagement and confusion resulting from changing FGS modes. Additional considerations relating to the assessment of Human Factors is provided in Section 14.5.

14.1.1 Normal Performance

Normal performance is considered to be performance during operations well within the aeroplane's flight envelope and with routine atmospheric and environmental conditions. Normal performance should be demonstrated over a range of conditions that represent typical conditions experienced in operational use.

The FGS should be evaluated to determine the acceptability of the following characteristics:

- The stability and tracking of automatic control elements
- The flyability and tracking of guidance elements
- The acquisition of flight paths for capture modes
- Consistency of integration of modes (Section 12)

Performance should be assessed in the presence of errors that can reasonably be expected in operation (e.g., mis-selection of approach speed).

14.1.2 Rare Normal Performance

Rare normal performance is considered to be performance of the system under conditions that are experienced infrequently by the aeroplane during operational use. These conditions may be due to significant environmental conditions (e.g., significant wind, turbulence, etc.) or due to non-routine operating conditions (e.g., out-of-trim due to fuel imbalance or under certain ferry configurations, or extremes of weight and c.g. combinations). Specific rare normal conditions are discussed below

The test program should assess the FGS performance in more challenging operational environments e.g., winds, wind gradients, various levels of turbulence. Rare environmental conditions may require the FGS to operate at the limits of its capabilities. The intent of the evaluation is to assess the performance of the FGS under more demanding conditions that may be experienced infrequently in-service.

Due to the severity of some environmental conditions, it is not recommended, or required, that the FGS flight evaluations include demonstration in severe and extreme turbulence, or include flights into a microburst. These conditions are more appropriately addressed by simulator evaluation.

The FGS should be evaluated to determine the acceptability of the following characteristics:

- The stability of automatic control elements and ability to resume tracking following any upset
- The flyability of guidance elements and ability to resume tracking following any upset
- The acceptability of mode transitions and overall cockpit system integration.

14.1.2.1 Icing Considerations

The implications of continued use of the automatic flight control elements of the FGS in icing conditions should be assessed. Ice accumulation on the aeroplane wings and surfaces can progressively change the aerodynamic characteristics and stability of the aeroplane. Even though the FGS may perform safely under these conditions, its continued use may mask this

change which in turn can lead to pilot handling difficulties and potential loss of control, should the autopilot become disengaged (either automatically or manually).

A test program should assess the potential vulnerability of the FGS to icing conditions by evaluating autopilot performance during ice shape tests or during natural icing tests. Sufficient autopilot testing should be conducted to ensure that the autopilot's performance is acceptable.

In general, it is not necessary to conduct an autopilot evaluation that encompasses all weights, centre of gravity positions (including lateral asymmetry), altitudes and deceleration device configurations. However, if the autopilot performance with ice accretion shows a significant difference from the non-contaminated aeroplane, or testing indicates marginal performance, additional tests may be necessary.

FGS performance and safety in icing conditions should be demonstrated by flight test and/or simulation tests, supported by analysis where necessary.

If significant autopilot inputs are required to compensate for the icing conditions, then the acceptability of the indication of a significant out of trim condition should be made and the subsequent response of the aeroplane when the autopilot disengages (manual or automatic) should be determined (Refer to Sections 8.1.2 and 9.3.3).

If the aeroplane is configured with a de-icing system, the autopilot should demonstrate satisfactory performance during the shedding of ice from the aeroplane.

Where degradation is noted which is not significant enough to require changes to the autopilot system or to de-icing/anti-icing systems, appropriate limitations and procedures should be established and presented in the AFM.

14.1.2.2 Windshear

If the FGS provides windshear escape guidance, performance demonstration requirements should be conducted consistent with FAA AC 25-12.

14.1.2.3 Indication and Response to an Out of Trim Condition

An assessment should be performed to determine the acceptability of the out of trim annunciation and subsequent response to disengagement (Refer to Section 9.3.3).

14.1.3 Specific Performance Conditions

The following paragraphs identify specific performance conditions requiring evaluation by flight test and/or simulation.

14.1.3.1 Low Speed Protection

The FGS should be assessed for the acceptability of the low speed protection performance under the following conditions:

- High Altitude Cruise with a simulated engine failure.
- Climb to Altitude Capture at Low Altitude with a simulated engine failure during capture

- Vertical Speed with insufficient climb power
- Approach with speed abuse

14.1.3.2 High-speed Protection

The FGS should be assessed for the acceptability of the high-speed protection performance under the following conditions:

- High altitude level flight with Autothrust function
- High altitude level flight without Autothrust function
- High altitude descending flight with Autothrust function

14.1.3.3 Go-around

The objective of the go-around mode (refer to Section 11.3.2) is to quickly change the flight path of the aeroplane from approach to landing to a safe climbout trajectory. The mode has specific utility in low visibility conditions when operations are predicated on a decision altitude/height (DA/H) and a go-around is necessary if visual references are not acquired at the DA/H. Therefore, the assessment of the go-around mode may be conducted in conjunction with the evaluation of the FGS to support low visibility operations, using additional criteria contained in FAA AC 120-28D, AC 120-29A and CS AWO Subparts 2 or 3.

The flight evaluation should be conducted to assess the rotation characteristics of the aeroplane and the performance of the aeroplane in acquiring and maintaining a safe flight path. The acceptability of the operation if contact is made with the runway during the missed approach or bailed landing should be established.

A demonstration program should be established that confirms acceptable operation when the following factors are considered:

- Aeroplane weight and CG
- Various landing configurations
- Use of manual thrust or autothrust
- Consequences of thrust de-rates with selection of Go around mode
- An Engine Failure at the initiation of Go-around
- An Engine failure during GA – after go-around power is reached
- Initiation altitude (e.g., in ground effect or not, during flare)

The following characteristics should be evaluated:

- The pitch response of the aeroplane during the initial transition
- Speed performance during aeroplane reconfiguration and climbout
- Integrated autopilot and autothrust operation
- Transition to Missed Approach Altitude
- Lateral performance during an engine failure

Where height loss during a go-around manoeuvre is significant or is required to support specific operational approval, demonstrated values for various initiation heights should be included in the AFM.

14.1.3.4 Steep Approach (Special Authorization)

Typical approach operations include glidepath angles between 2.5 and 3.5 degrees. Application for approval to conduct operations on glidepath angles of greater than 3.5 degrees requires additional evaluation. For such an approval, the FGS flight test and simulator demonstration should include:

- Approach path capture, tracking and speed control
- Recovery of the system from abuse cases e.g. glidepath angle and speed
- Assessment of autopilot disengagement transient
- Demonstration of go-around mode from a Steep Approach

For autopilot use at approach angles greater than 4.5 degrees the applicant is recommended to contact EASA for the applicable Special Condition criteria

14.1.4 Flight Director / HUD Considerations

The guidance aspect of an FGS may be provided by a head down Flight Director (F/D) or by a Head-Up Display (HUD) system. F/D's can utilize various guidance cues (e.g., cross pointer, single cue, flight path vector, etc.) whilst HUD's typically use a symbology linked to a flight path vector. The guidance elements may have a fixed aeroplane reference (e.g., the traditional F/D) or may use a moving reference such as a flight path vector. Various new display mediums are evolving (e.g., EVS and SVS) that may integrate guidance elements with situational elements.

The flight test or simulator program should demonstrate that the F/D or HUD guidance elements provide smooth, accurate and damped guidance in all applicable modes, so as to achieve satisfactory control task performance without pilot compensation or excessive workload.

The flight director guidance should provide adequate performance for operations with:

- stability augmentation off
- alternate fly-by-wire control modes (e.g., direct law), if any
- an engine inoperative.

Some pilot compensation may be acceptable for these conditions

Flight directors designed to work with a non-stationary tracking reference (such as a flight path angle or flight path vector which are commonly used with HUD guidance) should be evaluated in conditions which bring these guidance symbols to the field of view limits of the display. Crosswinds, and certain combinations of airspeed, gross weight, centre of gravity and flap/slat/gear configurations might cause such conditions. At these limits, the dynamics of the guidance response to pilot control inputs can differ with potentially adverse effects on tracking

performance, pilot compensation and workload.

Movement of the flight director and its tracking reference should also be demonstrated not to interfere with primary instrument references throughout their range of motion. The pilot's ability to interpret the guidance and essential flight information should not be adversely affected by the movement dynamics or range of motion.

14.1.4.1 Specific Demonstrations for Head-Up Display

These demonstrations are intended to show compliance with the following paragraphs of this AMC:

- Section 8.2 Flight Director Engagement/Disengagement and Indications, with its subparagraphs
- Section 9.2 Flight Guidance Mode Selection, Annunciation and Indication
- Section 9.4 FGS Considerations for Head-Up Displays (HUD)
- Section 10.1 Normal Performance (specifically criteria for flight director guidance)

When the pilot flying (PF) is using the HUD, the HUD is where the pilot is looking for the basic flight information and the pilot is less likely to be scanning the head down instruments. Therefore:

- It should be demonstrated that the location and presentation of the HUD information (e.g., guidance, flight information and alerts/annunciations) does not distract the pilot or obscure the pilot's outside view. For example, the pilot should be able to track the guidance to the runway without having the view of runway references or hazards along the flight path obscured by the HUD symbology.
- It should be demonstrated that pilot awareness of primary flight information, annunciations and alerts is satisfactory when using any HUD display mode. Some display modes that are designed to minimize "clutter" could degrade pilot awareness of essential information. For example, a "digital-only" display mode may not provide sufficient speed and altitude awareness during high-speed descents.
- It should be demonstrated that the pilot could positively detect cases when conformal symbology is field of view limited.
- Approach mode guidance, if provided, should be satisfactory throughout the intended range of conditions, including at the minimum approach speed and maximum crosswind, with expected gust components, for which approval is sought.
- It should be demonstrated that visual cautions and warnings associated with the flight guidance system can be immediately detected by the pilot flying while using the HUD.
- It should be demonstrated that the pilot flying can immediately respond to windshear warnings, ground proximity warnings, ACAS/TCAS warnings, and other warnings requiring immediate flight control action, such as a go-around, while using the HUD without having to revert to a head down flight display.

In certain phases of flight, it is important from a flight crew coordination standpoint that the

pilot not flying (PNF) be aware of problems with the HUD used by the PF. Therefore it should also be demonstrated that the PNF could immediately be made aware of any visual cautions and warnings associated with the HUD for applicable phases of flight.

If approach mode guidance is provided, satisfactory performance should be demonstrated throughout the intended range of operating conditions for which approval is sought e.g. at the minimum approach speed and maximum crosswind, with expected gust components.

If recovery guidance is provided, it should be demonstrated that the pilot could immediately detect and recover from unusual attitudes when using the HUD. Specialized unusual attitude recovery symbology, if provided, should be shown to provide unequivocal indications of the attitude condition (e.g., sky/ground, pitch, roll, and horizon) and to correctly guide the pilot to the nearest horizon. The stroke presentation of flight information on a HUD may not be as inherently intuitive for recognition and recovery as the conventional head down attitude display (e.g., contrasting colour, area fill, shading vs. line strokes). The HUD display design needs to be able to compensate for these differences to provide adequate pilot recognition and recovery cues.

14.1.4.2 Simulator Demonstration for Head-Up Display (HUD)

If a pilot-in-the-loop flight simulation is used for some demonstrations, then a high fidelity, engineering quality facility is typically required. The level of simulator may vary with the functionality being provided and the types of operation being conducted. Factors for validation of the simulation for demonstration purposes include the following:

- guidance and control system interfaces
- motion base suitability
- adequacy of stability derivative estimates used
- adequacy of any simplification assumptions used for the equations of motion;
- fidelity of flight controls and consequent simulated aircraft response to control inputs
- fidelity of the simulation of aircraft performance
- adequacy of flight deck instruments and displays
- adequacy of simulator and display transient response to disturbances or failures (e.g., engine failure, auto-feather, electrical bus switching)
- visual reference availability, fidelity, and delays
- suitability of visibility restriction models such as appropriate calibration of visual references for the tests to be performed for day, night, and dusk conditions as necessary
- fidelity of any other significant factor or limitation relevant to the validity of the simulation.

Adequate correlation of the simulator performance to flight test results should be made.

14.1.5 Flight Crew Override of the Flight Guidance System

A flight evaluation should be conducted to demonstrate compliance with Section 8.4. The

flight evaluation should consider the implication of system configuration for various flight phases and operations.

14.1.5.1 Autopilot Override

Effect of flight crew override should be assessed by applying an input on the cockpit controller (control column, or equivalent) to each axis for which the FGS is designed to disengage, i.e. the pitch and roll yoke, or the rudder pedals (if applicable).

If the autopilot is designed such that it does not automatically disengage due to a pilot override, verify that no unsafe conditions are generated due to the override per Section 8.4. The evaluation should be repeated with progressively increasing rate of force application to assess FGS behaviour. The effects of speed and altitude should be considered when conducting the evaluation.

If the design of the autopilot provides for multiple channel engagement for some phases of flight that results in a higher override force, these conditions should be evaluated.

14.1.5.2 Autothrust Override

The capability of the flight crew to override the autothrust system should be conducted at various flight phases. The evaluation should include an override of the autothrust system with a single hand on the thrust levers while maintaining control of the aeroplane using the opposite hand on the control wheel (or equivalent). This action should not result in an unsafe condition per Section 8.4, either during the override or after the pilot releases the thrust levers. If the autothrust system automatically disengages due to the override, the alerts that accompany the disengagement should be assessed to ensure flight crew awareness.

14.1.5.3 Pitch Trim System Evaluation during an Autopilot Override

The effect of flight crew override during automatic control on the automatic trim systems should be conducted. The pilot should then apply an input to the pitch cockpit controller (i.e., control column or sidestick) below that which would cause the autopilot to disengage and verify that the automatic pitch trim system meets the intent in Section 8.4.

If the system design is such that the autopilot does not have an automatic disengagement on override feature, the pilot should initiate an intentional override for an extended period of time. The autopilot should then be disengaged, with the Quick Disconnect Button, and any transient response assessed in compliance with Section 8.4. The effectiveness and timeliness of any Alerts used to mitigate the effects of the override condition should be assessed during this evaluation.

14.2 Failure Conditions Requiring Validation – CS 25.1309

The Safety Assessment process identified in Section 13 should identify any Failure Condition responses that would require pilot evaluation to assess the severity of the effect, the validity of any assumptions used for pilot recognition and mitigation. The classification of a Failure Condition can vary according to flight condition and may need to be confirmed by simulator or flight test.

This section provides guidance on the test criteria, including recognition considerations, for flight evaluation of these Failure Conditions. In addition, certain probable failures should be demonstrated to assess the performance of the FGS and the adequacy of any applicable flight crew procedures.

AMC No. 2 to CS 25.1329, Flight Testing of Flight Guidance Systems, provides guidance on test methods for particular types of Failure Condition that have been identified by the Safety Assessment.

14.2.1 Validation Elements

The Safety Assessment described in Section 13 establishes the FGS Failure Condition for which appropriate testing should be undertaken. Assessment of Failure Conditions has four elements:

- Failure Condition insertion
- Pilot recognition of the effects of the Failure Condition
- Pilot reaction time; i.e., the time between pilot recognition of the Failure Condition and initiation of the recovery
- Pilot recovery

14.2.1.1 Failure Condition

Failure Conditions of the autopilot including, where appropriate, multi-axis failures and automatic-trim failures, should be simulated such that when inserted represents the overall effect of each Failure Condition.

Where necessary, Flight Director Failure Conditions should be validated in accordance with the criteria for the respective phase of flight.

The flight conditions under which the failure condition is inserted should be the most critical (e.g., centre of gravity, weight, flap setting, altitude, speed, power or thrust). If an autothrust system is installed, the tests should be performed with the autothrust system engaged or disengaged whichever is the more adverse case.

14.2.1.2 Pilot Recognition

The pilot may detect a Failure Condition through aeroplane motion cues or by cockpit flight instruments and alerts. The specific recognition cues will vary with flight condition, phase of flight and crew duties.

- a) Hardover – the recognition point should be that at which a pilot operating in non-visual conditions may be expected to recognize the need to take action. Recognition of the effect of the failure may be through the behaviour of the aeroplane (e.g., in the pitch axis by aircraft motion and associated normal acceleration cues and in the roll axis by excessive bank angle), or an appropriate alerting system. Control column or wheel movements alone should not be used for recognition. The recognition time should not normally be less than 1 second. If a recognition time of less than 1 second is asserted, specific justification will be required (e.g. additional tests to ensure that the time is

representative in the light of the cues available to the pilot).

- b) Slowover – this type of Failure Conditions is typically recognized by a path deviation indicated on primary flight instruments (e.g., CDI, altimeter and vertical speed indicator). It is important that the recognition criteria are agreed with the regulatory authority. The following identify examples of recognition criteria as a function of flight phase:

- En-route cruise – recognition through the Altitude Alerting system can be assumed for vertical path deviation. The lateral motion of the aeroplane may go unrecognised for significant period of time unless a bank angle alerting system is installed.
- Climb and Descent – recognition through increasing/decreasing vertical speed and/or pitch or roll attitude or heading can be assumed.
- On an Approach with vertical path reference - A displacement recognition threshold should be identified and selected for testing that is appropriate for the display(s) and failure condition(s) to be assessed.

NOTE:

- (1) For an ILS or GLS approach in a significant wind gradient, a value of 1 dot is considered a reasonable value for crew recognition. In smooth atmospheric conditions with steady state tracking, with the vertical flight path typically maintained at less than a fraction of a needle width, a detection and recognition threshold even below 1/2 dot may be suitable.
- (2) For RNAV systems, which do not use dots, some multiple of needle width, related to an established crew monitoring tolerance of normal performance may be appropriate (e.g., x needle widths of deviation on the VNAV scale).
- (3) Credit may be taken for excessive deviation alerts, if available.

- On an Approach without vertical path reference – criteria similar to the climb/descent condition can be assumed.

- c) Oscillatory – it is assumed that oscillatory failures that have structural implications are addressed under CS 25.302. It can be assumed that the flight crew will disengage the automatic control elements of the FGS that have any adverse oscillatory effect and will not follow any adverse oscillatory guidance. However, if there are any elements of the FGS that can not be disconnected in the presents of an oscillatory Failure Condition, the long term effects on crew workload and the occupants will need to be evaluated.

14.2.1.3 Pilot Reaction Time

The pilot reaction time is considered to be dependent upon the pilot attentiveness based upon the phase of flight and associated duties. The following assumptions are considered acceptable:

- a) Climb, Cruise, Descent and Holding – Recovery action should not be initiated until three seconds after the recognition point
- b) Manoeuvring Flight - Recovery action should not be initiated until 1 second after the recognition point

- c) Approach - the demonstration of malfunctions should be consistent with operation in non-visual conditions. The pilot can be assumed to be carefully monitoring the aeroplane performance and will respond rapidly once the malfunction has been recognized. A reaction time of 1 second between recognition point and initiation of recovery is appropriate for this phase of flight.

NOTE:

- (i) For the final phase of landing (e.g., below 25 m (80 ft)), the pilot can be assumed to react upon recognition without delay.
- (ii) For phases of flight where the pilot is exercising manual control using control wheel steering, if implemented, the pilot can be assumed to commence recovery action at the recognition point.

14.2.1.4. Pilot Recovery

Pilot recovery action should be commenced after the reaction time. Following such delay the pilot should be able to return the aeroplane to its normal flight attitude under full manual control without engaging in any dangerous manoeuvres during recovery and without control forces exceeding the values given in CS 25.143 (d). During the recovery the pilot may overpower the automatic pilot or disengage it.

For the purpose of determining the minimum height at which the autopilot may be used during an approach, or for height loss assessments, a representative recovery appropriate to the aeroplane type and flight condition should be performed. This manoeuvre should not lead to an unsafe speed excursion to resume a normal flight path. An incremental normal acceleration in the order of 0.5 g is considered the maximum for this type of manoeuvre.

14.2.2 Takeoff

The primary concern for the takeoff phase of flight is the effect of the worst case Failure Condition, identified by the Safety Assessment, on the net flight of the aeroplane after takeoff and the aeroplane's attitude and speed during climbout. The effects should be evaluated in the pitch up, pitch down and bank as applicable.

If the FGS provides on runway guidance for takeoff, the effect of the failures on that takeoff guidance should be assessed in accordance with CS AWO Subpart 4.

14.2.3 Climb, Cruise, Descent and Holding

Where the Safety Analysis identifies a Failure Condition requiring flight/simulator evaluation with pilot assessment, the height loss should be established in accordance with the method described in the flight test procedures – see AMC No. 2 to CS 25.1329, section 4.2.3.3.

14.2.4 Manoeuvring

Where the Safety Analysis identifies a Failure Condition that has a dynamic effect on the roll control of the aeroplane, the Failure Condition should be introduced at the bank angle for normal operation. The bank angle should not exceed 60 degrees when the pilot recognition and

recover times identified above are applied.

14.2.5 Approach

A discussion of the operational considerations for approach operations is contained in Section 14.3. This section identifies test criteria to support those considerations. The safety assessment process should identify the demonstration of specific Failure Conditions during the approach.

The fault demonstration process during approach should include the four phases identified in Section 14.2.1. The Failure Condition should be inserted at a safe but representative height. The deviation profile should be identified and applied as indicated in the later sections.

14.2.5.1 Approach with Vertical Path Reference

Approach with vertical path reference includes xLS and RNAV operations.

a) xLS (ILS, MLS, GLS)

ILS and MLS operations are typically conducted on instrument approach procedures designed in accordance with United States TERPS or ICAO PANS-OPS criteria, or equivalent. These criteria together with ICAO Annex 14 are generally intended to take into account obstacles beneath a reference obstacle identification surface. It is expected that the same or equivalent criteria will be applied to GLS operations. Hence, in assessing the implication of the effect of failures during autopilot operations a reference 1:29 slope penetration boundary has been applied against the deviation profile to identify an appropriate altitude for continued autopilot operation. The 1:29 slope has been found to provide an acceptable margin above obstacles on an approach.

The worst case Failure Condition identified by the Safety Assessment (see Section 13.4) should be demonstrated against the deviation profile criteria and a Minimum Use Height (MUH) established (See AMC No.2 to CS 25.1329, Section 4.2.3.2).

b) RNAV

For RNAV coupled approach operations, a vertical flight path similar to an xLS flight path will be used (e.g., 3° path starting 15 m (50 ft) above the threshold). However, due to sensor characteristics it is assumed that RNAV operations will be conducted with a DA(H) or MDA(H) that is higher than an equivalent MUH on an xLS approach to the same runway. Further, for this type of operation it should be noted that the MUH is always in the visual segment of the approach, where it is assumed that the failure recognition and recovery are conducted with the pilot having established outside visual reference.

In order to derive only one MUH value for simplicity of use, it is assumed that the effects of failure on the autopilot in RNAV operation are no worse than for the xLS operation, and no further determination or demonstration is required. However, the applicant should show that due account has been taken in the Safety Assessment of the differences between the RNAV and xLS inputs to the autopilot (e.g. barometric altitude input, FMS position and guidance commands, and their failure effects). If these effects can be bounded or otherwise reconciled,

then the xLS demonstrated MUH might also be considered applicable to RNAV operations.

If these effects cannot be bounded or accounted for within those for the xLS operation, the MUH should be determined in accordance with an Approach Without Vertical Path Reference – see below.

14.2.5.2 Approach Without Vertical Path Reference

For an approach without vertical path reference (e.g., VOR, NDB, localizer only) the FGS mode of operation is typically vertical speed/flight path angle (i.e. a cruise mode). The worst case Failure Condition for this type of mode should be demonstrated in the approach configuration, and an appropriate height loss established in accordance with the method described in AMC No.2 to CS 25.1329, Section 4.2.3.3.

14.2.5.3 Steep Approach

In support of an approval to use the FGS on glidepath angles of greater than 3.5 degrees (see Section 14.1.3.4) an assessment should be made of the effects of failure conditions for this type of operation. For the use of autopilot, an appropriate MUH should be established in accordance with the deviation profile method described in Section 14.2.5. For this assessment, the obstacle plane associated with a nominal 3-degree glidepath angle (1:29 slope) should be adjusted according to the maximum approach angle, for which approval is sought.

14.2.6 Specific Conditions

The following are failure conditions that should be considered as part of the FGS evaluation program:

- Engine Failure during approach - continue approach to DA(H)/MDA(H)
- The effect of potential fuel imbalance
- Aeroplane System Failures (as necessary – requiring specific flight evaluation), e.g.,
 - Hydraulics
 - Electrical
 - Flight Controls
 - FGS related Sensors

The probability of failure of a FGS element to disengage when the quick disengagement control is operated should be shown to be acceptable by the Safety Analysis process. If credit is to be taken for acceptable continued manual operation with the FGS elements remaining engaged i.e. without operating any of the other disengagement controls, then a flight demonstration should be conducted though approach, landing and rollout.

14.3 Criteria Supporting the Operational Use of an Autopilot

The criteria contained in this section are intended to identify how the functional capability of the FGS, established during the certification, can be utilized to support typical flight operations. The criteria are based on experience gained from certification programs and functionality provided by traditional systems. A FGS providing non-traditional functionality, using new or novel technology, and/or implementation techniques, may require additional

criteria to be established.

14.3.1 Autopilot Operations in close proximity the ground

The minimum engagement point for the autopilot after takeoff and the minimum use of the autopilot during approach should take into consideration the effect of:

- Failures and their effects (i.e., Failure Conditions),
- Fault-free performance,
- Any specific operational considerations and/or mitigation.

During low visibility operations, multiple redundant autopilot channels may be used and the effect of any autopilot failures on the flight path may be eliminated, or substantially minimized, by the protection provided by that redundancy. The following considerations apply primarily to single channel operations where performance or integrity aspects may require further consideration. See also Section 13.5.2, which identifies specific considerations relating to autopilot operations close to the ground in the presence of failures.

14.3.1.1 Autopilot Engagement Altitude or Height after Takeoff – Failure Effects

The potential deviation of the aeroplane from the desired flight path due to the effect of a Failure Condition may necessitate delaying the engagement of an autopilot to an acceptable height above the departure runway.

To support this determination, if an autopilot Failure Condition, or Failure Conditions, are identified that will cause a significant deviation below the intended vertical flight path, the worst-case deviation profile should be identified. This profile and the recovery of the aeroplane should not result in penetration of the net flight path as defined in CS 25.115. If the Failure Condition(s) has a neutral effect on the flight path but has implications for speed control during takeoff, the acceptability of cues for the flight crew detection of the condition should be made. The effect of any Failure Condition relating to the bank angle of the aeroplane should also be assessed. In all of the above, account should be taken of operating the aeroplane at the WAT limit.

The minimum engagement height will typically be established based on the greater of the following considerations:

- The lowest altitude or height where the flight crew could reasonably be assumed to engage the autopilot. Consideration should be given to normal flight crew tasks during rotation and lift-off (typically 30 m (100 ft) or greater).
- Any allowance for the acceptability of the performance of the autopilot during the basic engagement/mode transition.
- The lowest altitude or height consistent with the response of the aeroplane to any identified autopilot Failure Condition(s).
- Activation of stall identification system (e.g. stick pusher) armed (if installed).

If the response to the worst-case failure condition causes a significant transition below the intended vertical flight path, the deviation information should be provided in the AFM.

14.3.1.2 Autopilot Engagement during Approach

The potential deviation of the aeroplane from the desired flight path due to the effect of a Failure Condition may necessitate the disengagement of an autopilot at an appropriate height on the approach to landing.

The operational minimum engagement height will be established based on the following considerations:

- the altitude or height at which the performance of the automatic control is no longer acceptable,
- the lowest altitude or height consistent with the response of the aeroplane to a subsequent autopilot failure,
- any specific operational consideration.

The following paragraphs provide assessment criteria for operations that have guidance to the runway threshold, and for those that do not.

14.3.1.2.1 Approach with Vertical Path Reference – Failure Effects

Approaches with vertical path reference can include xLS (i.e., ILS, MLS and GLS) or RNAV. Operations using xLS, can be assumed to be conducted with respect to a flight path prescribed or established as an integral part of navigation service provided by the State of the airport. RNAV approach operations will be conducted using an onboard database that provides a navigation flight path to the runway.

The operational consideration for this type of operations relates an assessment of the adequacy of continued use of the autopilot in maintaining the desired vertical flight path. Considerations include the lowest altitude consistent with the response of the aeroplane to an autopilot failure.

To support this determination, if an autopilot Failure Condition, or Failure Conditions, is identified that causes a significant transition below the intended vertical flight path, the worst-case deviation profile should be identified using the method identified in Section 14.2.5.1. If the Failure Condition(s) has a neutral effect on the flight path, the acceptability of cues for the flight crew detection of the condition should be made. The effect of any Failure Condition relating to the bank angle of the aeroplane should be assessed.

For the purpose of the airworthiness assessment, the vertical flight path an xLS and RNAV approach can be assumed to be a flight path of three degrees that passes through the runway threshold at an altitude of 15 meters (50 ft). Considerations for steep approaches are provided in a preceding section.

The vertical flight path control for an xLS approach will be made with reference to the path defined by the navigation service. The RNAV vertical flight path will typically be conducted with reference to barometric altitude. An appropriate adjustment to the minimum use height may be appropriate to take into account the vertical accuracy of RNAV operations.

NOTE: Any operational considerations such as temperature effect compensation should be considered as part of the operational authorization.

The Minimum Use Height can be determined using the method identified in AMC No.2 to CS

25.1329, Section 4.2.3.2.

14.3.1.2.2 Approach without Vertical Path Reference

Flight operations with no vertical path reference are conducted with an appropriate visual segment for final approach path. In the interest of providing appropriate automatic control to assist in a stabilized approach, the minimum use of the autopilot should be consistent with the performance needed for the descent (e.g., vertical speed/flight path angle) and the pilot detection and recovery from an autopilot failure.

To support this determination, if an autopilot Failure Condition, or Failure Conditions, is identified that causes a significant transition below the intended vertical flight path, the worst-case deviation profile should be identified. If the Failure Condition(s) has a neutral effect on the flight path but has implications for speed control during takeoff, the acceptability of cues for the flight crew detection of the condition should be made. The effect of any Failure Condition relating to the bank angle of the aeroplane should be assessed.

For FGS that are failure protected (i.e., fail passive), the minimum engagement height will typically be no lower than 15 m (50 ft) above runway elevation. However, when determining this limitation, account should be taken of the handling task presented to the pilot when regaining manual control, especially in limiting crosswind conditions.

For FGS that are not failure protected (i.e., not fail-passive), the demonstrated minimum use height will typically be established based on the greater of the following considerations:

- a. 15 m (50 ft) above runway elevation
- b. Two times the Height Loss for the aeroplane as a result of any identified autopilot Failure Condition(s) using the method identified in AMC No.2 to CS 25.1329, Section 4.2.3.3.

14.3.1.3 Circling Approach

For the purposes of this AMC, circling approaches may be considered to have three visual segments associated with the approach; a segment at or above the minimums prescribed by the procedure that parallel the runway in the opposite direction of the landing runway, a turning segment to align with the runway that can be level or partially descending, and a final descending segment to landing. Operationally, the autopilot may remain engaged even after leaving the minimum altitude (MDA(H)) for safety and flight crew workload relief reasons. This operational procedure should be balanced against unacceptable performance or failure characteristics. As this procedure is in the visual segment, no specific constraints for the use of the autopilot are considered necessary for this phase of flight unless specific unacceptable performance or failure characteristics related to circling approach are identified during the certification program.

14.3.2 Climb, Cruise, Descent, and Holding

The value of the use of the autopilot in providing flight crew workload relief in climb, cruise, descent and holding phases of flight should be balanced against the failure characteristics of the autopilot. No specific constraints for the use of the autopilot are considered necessary for these phases of flight unless specific unacceptable performance or failure characteristics are identified

during the certification program, related to climb, cruise, descent or holding.

14.3.3 Manoeuvring

No specific constraints for the use of the autopilot are considered necessary for manoeuvring flight unless unacceptable performance or failure characteristics are identified during the certification program. Section 14.2.4 provides assessment criteria for manoeuvring flight for autopilot failures.

14.4 Automatic Disengagement of the Autopilot

Automatic disengagement of the FGS will occur for several reasons such as system failures, sensor failures, unusual accelerations, etc. The automatic disengagement characteristics of the FGS should be investigated throughout the flight envelope. These disengagement cases should be analysed to determine the ones requiring demonstration during the test program. For each disengagement, the transients, warnings, and pilot workload for recovery should be evaluated, and compliance with CS 25.1329 (d) and (e) should be verified. The use of simulation is recommended for all conditions that are expected to result in significant transients.

14.5 Assessment of Human Factors Considerations

The evaluation, demonstration and testing should assess the acceptability of the human-machine interface with the FGS and the potential for flight crew errors and confusion concerning the behaviour and operation of the FGS, based on the criteria described in earlier Sections.

The evaluation of normal and non-normal FGS operations should include the representative range of conditions in terms of crew mental or physical workload, required crew response timeliness, or potential for confusion or indecision. The set of test cases should represent operationally relevant scenarios and the assumptions about pilot training and skill level should be documented.

Flight evaluation during certification is a final assessment and is intended to validate the design. Prior evaluations are typically conducted in a variety of ways and at different levels of fidelity in order to finalize the design. These may include:

- Engineering evaluations and task analyses, including cognitive and physical tasks;
- Mock-up evaluations and demonstrations;
- Part-task evaluations and demonstrations;
- Simulator evaluations, demonstrations, and tests; and
- Engineering flight evaluations, demonstrations, and tests.

The data and/or experience from such evaluations may be useful for credit to establish FGS compliance with regulations having human factors considerations. In some cases, certification credit or demonstration of compliance using simulations cannot be granted due to inability to find simulation conformity. In such cases, certification authorities may consider that less flight testing may be required to show compliance if the simulation evaluations have added confidence with respect to the reduced potential for crew error and confusion and other human factors attributes of the pilot/FGS interface. Also, applicants have successfully used comparisons to previously certificated designs to obtain such credit (although such credit is not assured). Additional testing may be warranted, e.g., for new FGS flight crew interface designs

or functions.

In many cases the evaluation, demonstration and test scenarios, including failures and environmental events, will determine whether the data should be obtained in simulation or in flight, because of safety considerations or unavailability of the necessary environmental conditions. In some of these cases a very high fidelity simulation will be needed. In addition to the simulation validation considerations identified in Section 14.1.4.2, the simulation used may need to include the following features, depending on the functionality of the FGS:

- Physical implementation of flight deck controls, displays, indicators and annunciators for all flight crew positions that are relevant to the objectives of the evaluation.
- Adequate emulations of relevant equipment (hardware and software function, including capability to introduce failures) should be incorporated in the simulation.
- Weather simulation including gusts, turbulence, windshear and visibility.
- Representation of the operational environments, including interaction with air traffic services, day/night operations, etc, as relevant to the functions and pilot tasks being evaluated
- Data collection capabilities

Simulator evaluations and tests are intended to generate objective and/or subjective data. It may not always be possible or necessary to obtain quantifiable measurements of flight crew performance, even with high fidelity flight or simulation evaluation, demonstration, or test scenarios. In these cases, evaluation procedures should be based on the use of structured, subjective methods such as rating scales, questionnaires and/or interviews. When there is dependence on this type of data, evaluations should consider multiple data collection techniques with an appropriate number of pilot evaluators.

In order to provide sound evaluations, pilots should be trained appropriately on the FGS system operation and procedures. They should also have experience in the kinds of operation and aircraft types for which the FGS is intended, be familiar with the intended function of the FGS, its operational and design philosophy, and how this philosophy fits with the overall flight deck and its operational and design philosophy.

Rationale should be provided for decisions regarding new or unique features in a design. It should be confirmed that the data resulting from the evaluations support acceptability of any new or unique features.

The certification planning documentation should describe the means to show compliance of the Human Factors-related considerations of the FGS, with this AMC.

15 AEROPLANE FLIGHT MANUAL (AFM)

The following sections provide guidance on material to be provided in the Aeroplane Flight Manual (AFM) to ensure that the appropriate information related to FGS operation is translated into air carrier operations. For additional guidance, note that AMC 25.1581 addresses requirements of the AFM for Large Aeroplanes and distinguishes between those aircraft that are used in Commercial Air Transportation and those that are not.

The terminology used in the AFM should be consistent with the intended operational use.

Appropriate AFM information related to low-visibility operations is addressed in CS-AWO Subparts 1-4.

15.1 Information Supporting Operational Use of the Autopilot

The airworthiness certification process will assess the effect of autopilot Failure Conditions as identified in Sections 13 and 14. If a specific Minimum Use Height (MUH) is necessary, then the height should be provided in the Limitations section of the AFM. If the design is such that the effects of Failure Condition(s) do not require establishment of a MUH, then the pertinent deviation profile or height loss information should be provided in the Normal or Non-normal section of the AFM, as applicable.

If MUH or a Height Loss value is applicable, it should be specified as follows:

(a) Takeoff - Autopilot Engagement Altitude or Height.

NOTE: If minimum engagement altitude(s) or height(s) are not specified, then “maximum displacement deviation” information from a pertinent takeoff flight path and approach profile should be provided in the AFM Normal Procedures section, or in the associated Flight Crew Operation Manuals (FCOM).

(b) Cruise – Height Loss

(c) Approach - MUH or Height Loss

i) Approach – with Vertical Path Reference

- the MUH should be determined based on clearance above a 1:29 plane using the Deviation Profile Method.

ii) Approach – without Vertical Path Reference

- the Height Loss should be determined using the Height Loss Method

15.2 Limitations

The Limitations section of the AFM presents those FGS operating limitations appropriate to the aeroplane model as established in the course of the type certification process, and as necessary (Ref. CS 25.1581(a)(1) and CS 25.1583). FGS operational limitations (should any exist) should specify, any configuration/envelope restrictions, if and as applicable.

15.3 Non-normal/Emergency Procedures

The AFM should include Non-normal or Emergency procedures appropriate to the FGS identified during the certification program (Ref. CS 25.1581(a)(1), CS 25.1585(a)(2) and CS 25.1585(a)(3)).

15.4 Normal Procedures

The normal procedures for use of the FGS should be documented in the AFM or FCOM, as appropriate. These procedures should be demonstrated during the type certification process.

In lieu of specification of minimum engagement altitude(s) or height(s) (see Section 15.1 above), the AFM may alternately specify “maximum displacement deviations” from a specified takeoff flight path, or from a specified approach profile. This information may be based on typical departure or approach flight paths suited for the aircraft type and for failure conditions that are determined applicable to the type of FGS system and modes suitable for use.

The flight manual should include any necessary procedures for the use of the flight guidance system in icing conditions (including severe icing conditions). In particular, the procedures should include any necessary changes in operating speeds required either operationally or as a result of relevant design features of the speed protection function of the FGS; e.g., variations in minimum speeds as a function of de/anti-icing system selection; speed increments during approach and landing in turbulence.

15.4.1 Aircraft with Published Flight Crew Operation Manuals

The AFM’s for aircraft for which the manufacturer has published a FCOM should contain essential information on normal operating procedures that are considered “peculiar” to the operation of the FGS for the aircraft type or are otherwise necessary for safe operation (Ref. CS 25.1581(a)(2) and CS 25.1585(a)(1)). FGS description and integration with the overall flight deck design philosophy; specification and operational procedures that are normally associated with flight guidance systems should be made available for inclusion in the FCOM.

If applicable, a FCOM may contain the “maximum displacement deviation” information described in Section 15.1, above, in either numeric or graphic form.

15.4.2 Aircraft without Published FCOM’s

For aircraft that rely on the AFM as the sole operating manual, the AFM must contain operating information sufficient for flight crew reference (Ref. CS 25.1581(a)(2)). FGS description and integration with the overall flight deck design philosophy, specification and operational procedures that are normally associated with flight guidance systems should be made available so that an appropriately trained flight crew may operate the FGS under normal conditions.

APPENDIX A - SAFETY ASSESSMENT

A1 General

This section provides material that may be useful in supporting the safety assessment activities identified in Section 13.

A2 Identification of Failure Conditions

The following “failures” should be considered for applicability when establishing Failure Conditions as indicated in Section 13:

- Loss of autopilot in single or multiple axes
- Loss of guidance in single or multiple axes

- Loss of thrust control
- Partial loss or degradation of autopilot function
- A failure resulting in unintended autopilot commands in a single axis or multiple axes simultaneously (e.g., hardover, slowover, and oscillatory failure modes)
- A failure resulting in unintended guidance commands in a single axis or multiple axes
- A failure resulting in unintended thrust control
- A sustained out-of-trim condition with the autopilot engaged without a warning
- An autopilot disengagement in an out-of-trim condition
- Autopilot disengagement without a warning
- Inability to disengage the autopilot or autothrust function
- Un-commanded engagement of an autopilot or autothrust
- Jamming or loading of primary flight controls
- Un-intended thrust asymmetry

A typical Failure Condition statement may be of the form:

{Failure} during ***{Phase of Flight}*** that ***{Effect}*** when ***{Mitigation Consideration}***

Failure Conditions may result from failures within the FGS or from failure associated with aircraft interfacing systems or components (e.g., navigation receivers, attitude heading reference systems, flight management systems, hydraulics, electrical systems, etc.).

A3 Considerations when Assessing the Severity of Failure Condition Effects

The Failure Condition definition is complete (as defined in AMC 25.1309) when the effects resulting from “failure” are identified. A complete definition of the Failure Condition and its effect will then support the subsequent Failure Condition classification.

When assessing the effect that results from a failure, the following items should be considered for various phases of flight:

- The impact of the loss of control, or unintended control, on the structural integrity of the aeroplane as a result of simple loading or as a result of excitation of aerodynamic or structural modes, both at the time of occurrence and while the flight continues.
- Implications of the aeroplane response in terms of attitude, speed, accelerations, flight path, and the impact on the occupants and on flight crew performance.
- Degradation in the stability or other flying qualities of the aeroplane.
- The duration of the condition.

- The aircraft configuration.
- The aircraft motion cues that will be used by the flight crew for recognition.
- Availability, level, and type of alerting provided to the flight crew.
- Expected flight crew corrective action on detection of the failure.

Failure Conditions may include the following characteristics:

- “Hardover” effects - typically considered to significant and are readily detectable by the flight crew based on the resulting aircraft motion or guidance cues.
- “Slowover” effects - typically not readily detected by the flight crew. The effect may involve departures from intended flight path that are not initially detectable by aircraft motion alone, and may only be detectable by motion cues when a significant flight path deviation has occurred or by the provision of an appropriate flight crew alert.
- “Oscillatory” effects – typically a repetitive motion or guidance condition not related to intended guidance or control. The magnitude, period and duration of the condition and any mitigation considerations will determine the final effect.
- “Loss of” effects – typically the removal of control, guidance or functionality that may have an immediate effect or may not be immediately apparent to the flight crew.

Section 14 provides guidance on crew recognition considerations.

A4 Failure Condition Classification

The following are examples of the type of Failure Condition effects that have been identified in previous aeroplane certification programs. The specific number and type of Failure Condition may vary with aeroplane type, aeroplane system architecture and FGS system design philosophy (e.g., failure detection, redundancy management, failure annunciation, etc.).

A4.1 Catastrophic Failure Conditions

The following effects have been assessed Catastrophic in previous aeroplane certification programs:

- A load on any part of the primary structure sufficient to cause a structural failure preventing safe flight and landing (Refer to CS 25.302).
- Unrecoverable loss of flight path control.
- Exceedance of V_{DF}/M_{DF} .
- Flutter or vibration that causes a structural failure preventing safe flight and landing (Refer to CS 25.302).
- A temporary loss of control (e.g., stall) where the flight crew is unable to prevent contact with obstacles or terrain.

- Deviations in flight path from which the flight crew are unable to prevent contact with obstacles, terrain, or other aircraft.

A4.2 Hazardous Failure Conditions

The following effects have been assessed Hazardous in previous aeroplane certification programs:

- Exceedance of airspeed halfway between V_{MO} and V_{DF} or a Mach number halfway between M_{MO} and M_{DF} .
- A stall, even if the flight crew is able to recover safe flight path control.
- A load factor less than zero.
- Bank angles of more than 60 degrees en route or more than 30 degrees below a height of 300 m (1000 ft). above an applicable airport elevation.
- Degradation of the flying qualities of the aeroplane that excessively increases flight crew workload.
- Failure that could result in a RTO and high speed overrun (e.g., 110 km/h (60 kt)).
- A flight path deviation that requires a severe manoeuvre to prevent contact with obstacle, terrain or other aircraft.

NOTE: Severe manoeuvre includes risk of serious injury or death of a small number of occupants.

A4.3 Major Failure Conditions

The following effects have been assessed Major in previous aeroplane certification programs:

- A flight path deviation, a required recovery manoeuvre, which may result in passenger injuries (e.g., consideration should be given to phases of flight where the occupants may reasonably be moving about the aeroplane or be serving or consuming hot drinks).
- Degradation of the flying qualities of the aeroplane that significantly increase flight crew workload.

AMC No.2 to CS 25.1329

Flight Testing of Flight Guidance Systems

1. General

Some aspects of a Flight Guidance System (FGS) design may be validated by laboratory testing or by simulation, other aspects may necessitate test pilot expertise and subjective judgment in a representative aircraft environment. The purpose of this AMC is to provide FGS flight test procedures without specifying the test means to be used, i.e. actual aircraft or representative flight simulator.

A flight test program should be established that confirms the performance of the FGS for the modes of operation and the operational capabilities supported by its design. The operational implications of certain failures and Failure Conditions may require flight evaluation. The pilot interface with FGS controls and displays in the cockpit should also be assessed.

The scope of the flight demonstration program will be dependent on the operational capability being provided including any new and novel features. Early coordination with the regulatory authorities is recommended to reduce certification risks associated with the flight demonstration program.

The intent of the flight demonstration program is to confirm that the operation of the FGS is consistent with its use for the intended flight operations of the aeroplane type and configuration.

The modes of the FGS should be demonstrated in representative aeroplane configurations and under a representative range of flight conditions.

The following are specific test procedure that can assist in that demonstration program. The procedures should be read in conjunction with Sections 10, 11 and 14 of AMC No. 1 to CS 25.1329.

2. Protection Features

Protection feature are included in the design of an FGS to assist the flight crew in ensuring that boundaries of the flight envelope or operational limits are not exceeded leading to an unsafe condition. The means to alert the flight crew to a condition or for the system to intervene to preclude the condition may vary but certain operational scenarios can be used to assess the performance of the system in providing the protection function. The following procedures can be used to evaluate the protection functions of an FGS.

2.1 Low Speed Protection

The low speed protection feature in an FGS is intended to prevent loss of speed to an unsafe condition (Refer to AMC No.1 to CS 25.1329 – Section 10.4.1). This may be accomplished by a number of means but should be evaluated under a number of scenarios.

There are four cases that should be considered when evaluating when the Low Speed Protection function of a FGS:

1. High Altitude Cruise Evaluation.

- a) At high altitude at normal cruise speed, engage the FGS into an Altitude Hold

- mode and a Heading or LNAV mode.
- b) Engage the autothrust into a speed mode.
- c) Manually reduce one engine to idle thrust.
- d) As the airspeed decreases, observe the FGS behaviour in maintaining altitude and heading/course.
- e) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

2. Altitude Capture Evaluation at Low Altitude.

- a) At about 1000 m (or 3000 ft) MSL and 460 km/h (or 250 kt), engage the FGS into Altitude Hold and a Heading or LNAV mode.
- b) Engage the autothrust into a speed mode.
- c) Set the Altitude Pre-selector to 2500 m (or 8000 ft) MSL.
- d) Make a flight level change to 2500 m (or 8000 ft) with a 460 km/h (250 kt) climb at maximum climb power.
- e) When the FGS first enters the altitude capture mode, retard an engine to idle power.
- f) As the airspeed decreases, observe the aeroplane trajectory and behaviour.
- g) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operations.

3. High Vertical Speed Evaluation.

- a) Engage the FGS in Vertical Speed Mode with a very high rate of climb.
- b) Set the thrust to a value that will cause the aeroplane to decelerate at about 1.8 km per second (1 knot per second).
- c) As the airspeed decreases, observe the aeroplane trajectory and behaviour.
- d) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

4. Approach Evaluation.

- a) Conduct an instrument approach with vertical path reference.
- b) Couple the FGS to the localizer and glideslope (or LNAV/VNAV, etc.).
- c) Cross the Final Approach Fix/Outer Marker at a high-speed (approximately $V_{ref} + 74$ km/h (40 kt)) with the thrust at idle power until low speed protection activates.
- d) As the airspeed decreases, observe the aeroplane trajectory and behaviour.
- e) When the Low Speed Protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciation for acceptable operation.

- f) Note the pilot response to the alert and the recovery actions taken to recover to the desired vertical path and the re-capture to that path and the acceleration back to the desired approach speed.

NOTE: If the FGS remains in the existing mode with reversion to Low Speed Protection, the FGS should provide a suitable alert to annunciate the low speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to accelerate back to the desired approach speed.

2.2 High-speed Protection

The high-speed protection feature in an FGS is intended to prevent a gain in airspeed to an unsafe condition (Refer to AMC No.1 to CS 25.1329 – Section 10.4.2). This may be accomplished by a number of means but should be evaluated under a number of scenarios.

There are three cases that should be considered when evaluating the High-speed protection function of a FGS:

1. High Altitude Level Flight Evaluation with Autothrust function

- a) Select Autothrust Off (if an automatic wake-up function is provided; otherwise, select Autothrust on).
- b) Engage the FGS in altitude hold.
- c) Select a thrust level that will result in acceleration beyond VMO/MMO.
- d) As the airspeed increases, observe the behaviour of the High-speed protection condition and any autothrust reactivation and thrust reduction, as applicable.
- e) Assess the performance of the FGS to control the airspeed to VMO/MMO, or other appropriate speed.

2. High Altitude Level Flight Evaluation without Autothrust function

- a) Select a thrust value that will result in acceleration beyond VMO/MMO.
- b) As the airspeed increases, observe the basic aeroplane overspeed warning activate between VMO + 1 and VMO + 11 km/h (6 kt).
- c) Observe the high-speed protection condition become active as evidenced by the unique visual alert and note possible FGS mode change.
- d) Maintain the existing thrust level and observe the aeroplane depart the selected altitude.
- e) After sufficient time has elapsed to verify and record FGS behaviour has elapsed, reduce the thrust as necessary to cause the aeroplane to begin a descent.
- f) Observe the FGS behaviour during the descent and subsequent altitude capture at the original selected altitude.

3. High Altitude Descending Flight Evaluation with Autothrust function

- a) Select Autothrust Off (with automatic wake-up function) with thrust set to maintain airspeed 10% below VMO/MMO with the FGS engaged in altitude hold.

- b) Select vertical speed mode that will result in acceleration beyond VMO/MMO.
- c) As the airspeed increases observe the autothrust function reactivate and reduce thrust towards idle.
- d) Observe the activation of FGS high-speed protection condition.
- e) Observe the reduction in pitch.

GENERAL NOTE: If the FGS remains in the existing mode with reversion to High Speed Protection, the FGS should provide a suitable alert to annunciate the high-speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to decelerate back to the desired speed.

3. Environmental Conditions

Some environmental conditions have created operational problems during FGS operations. It should be the objective of the flight demonstration program to expose the FGS to a range of environmental conditions as the opportunity presents itself. These include winds, windshear, mountain-wave, turbulence, icing, etc. However, some specific test conditions may have to be created to emulate operational conditions that are not readily achieved during normal flight test.

3.1 Icing

The accumulation of ice on the wing and airframe can have an effect on aeroplane characteristics and FGS performance. FGS operations may mask the onset of an aeroplane configuration that would present the pilot with handling difficulties when resuming manual control, particularly following any automatic disengagement of the FGS.

During the flight test program the opportunity should be taken to evaluate the FGS during natural icing conditions including the shedding of the ice, as applicable.

It is recommended that the opportunity should be taken to evaluate the operation of the FGS during basic aeroplane evaluation with 'ice shapes'.

The following conditions should be considered for evaluating FGS performance under 'icing conditions':

- (a) "Holding ice" as defined by CS-25 Appendix C
- (b) Medium to light weight, symmetric fuel loading

(1) High lift devices retracted configuration:

Slow down at 1.8 km per second (1 knot per second) to automatic autopilot disengage, stall warning or entry into speed protection function.

Recovery should be initiated a reasonable period after the onset of stall warning or other appropriate warning. The aeroplane should exhibit no hazardous characteristics.

(2) Full Instrument Approach:

If the autopilot has the ability to fly a coupled instrument approach and go-

around, it should demonstrate the following:

- (i) Instrument approach using all normal flap selections.
 - (ii) Go-around using all normal flap selections.
 - (iii) Glideslope capture from above the glidepath.
- (3) If the aeroplane accretes or sheds ice asymmetrically it should be possible to disengage the autopilot at any time without unacceptable out of trim forces.
 - (4) General manoeuvrability including normal turns, maximum angle of bank commanded by the FGS in one direction and then rapid reversal of command reference to the maximum FGS angle of bank in the other direction.

4. Failure Conditions

This section contains criteria relating to aeroplane system Failure Conditions identified for validation by a system Safety Assessment.

4.1 Test Methods

The test method for most Failure Conditions will require some type a fault simulation technique with controls that provide for controlled insertion and removal of the type of fault identified as vulnerability. The insertion point will typically be at a major control or guidance point on the aeroplane (e.g., control surface command, guidance command, thrust command).

The implication of the effect of the Failure Condition on various flight phases should be assessed and the demonstration condition established. This assessment should identify the parameters that need to be measured and the instrumentation required.

The role of any monitoring and alerting in the evaluation should be identified.

The alertness of the crew to certain aeroplane response cues may vary with phase of flight and other considerations. Guidance on this is provided below.

The 'success criteria' or operational implications should be identified and agreed with the regulatory authority prior to the conduct of the test. Guidance on this is provided below.

4.2 Fault Recognition and Pilot Action

The Safety Assessment process may identify a vulnerability to the following types of Failure Condition:

- hardover
- slowover
- oscillatory

The various types of effect will cause differing response in the aeroplane and resultant motion and other cues to the flight crew to alert them to the condition. The flight crew attention may be gained by additional alerting provided by systems on the aeroplane. The recognition is then followed by appropriate action including recovery.

The assessment of the acceptability of the Failure Condition and the validation of the Safety Assessment assumptions are complete when a stable state is reached as determined by the test pilot.

The following paragraphs provide guidance for specific phases of flight.

4.2.1 Takeoff

This material addresses the use of an FGS after rotation for takeoff.

Section 13 of AMC No.1 to CS 25.1329 identifies the key considerations for this phase of flight to be the effect on the net flight path and the speed control after lift-off. Automatic control is not typically provided for the takeoff roll. It may however be selected soon after lift-off. Failure Conditions may be introduced with this engagement.

For the initial lift-off through flap retraction, it can be assumed that the flight crew is closely monitoring the aeroplane movements and a maximum crew response time after recognition would be 1 second.

4.2.2 Climb, Cruise, Descent and Holding and Manoeuvring

The demonstration of applicable failure conditions during these phases of flight would include the potential for occupants to be out of their seats and moving about the cabin.

4.2.3 Approach

There are two types of approach operations to consider – an approach with and without vertical path reference. The approach with vertical path reference will be assessed against ground-based criteria using a deviation profile assessment. A height loss assessment is used for approaches without vertical path reference.

4.2.3.1 Fault Demonstration Process

The worst-case malfunction has first to be determined, based on factors such as:

- i) Failure Conditions identified by the system safety assessment.
- ii) System characteristics such as variations in authority or monitor operation.
- iii) Mitigation provided by any system alerts.
- iv) Aircraft flight characteristics relevant to failure recognition.

Once the worst-case malfunction has been determined, flight tests of the worst-case malfunction should be flown in representative conditions (e.g. coupled to an ILS), with the malfunction being initiated at a safe height. The pilot should not initiate recovery from the malfunction until 1 second after the recognition point. The delay is intended to simulate the variability in response to effectively a “hands off” condition. It is expected that the pilot will follow through on the controls until the recovery is initiated.

4.2.3.2 Assessment – Approach with Vertical Path Reference

Figure FT-1 provides a depiction of the deviation profile method. The first step is to identify the deviation profile from the worst-case malfunction. The next step is to ‘slide’ the deviation profile down the glidepath, until it is tangential to the 1:29 line or the runway. The Failure Condition contribution to the Minimum Use Height may be determined from the geometry of the aircraft wheel height determined by the deviation profile, relative to the 1:29 line

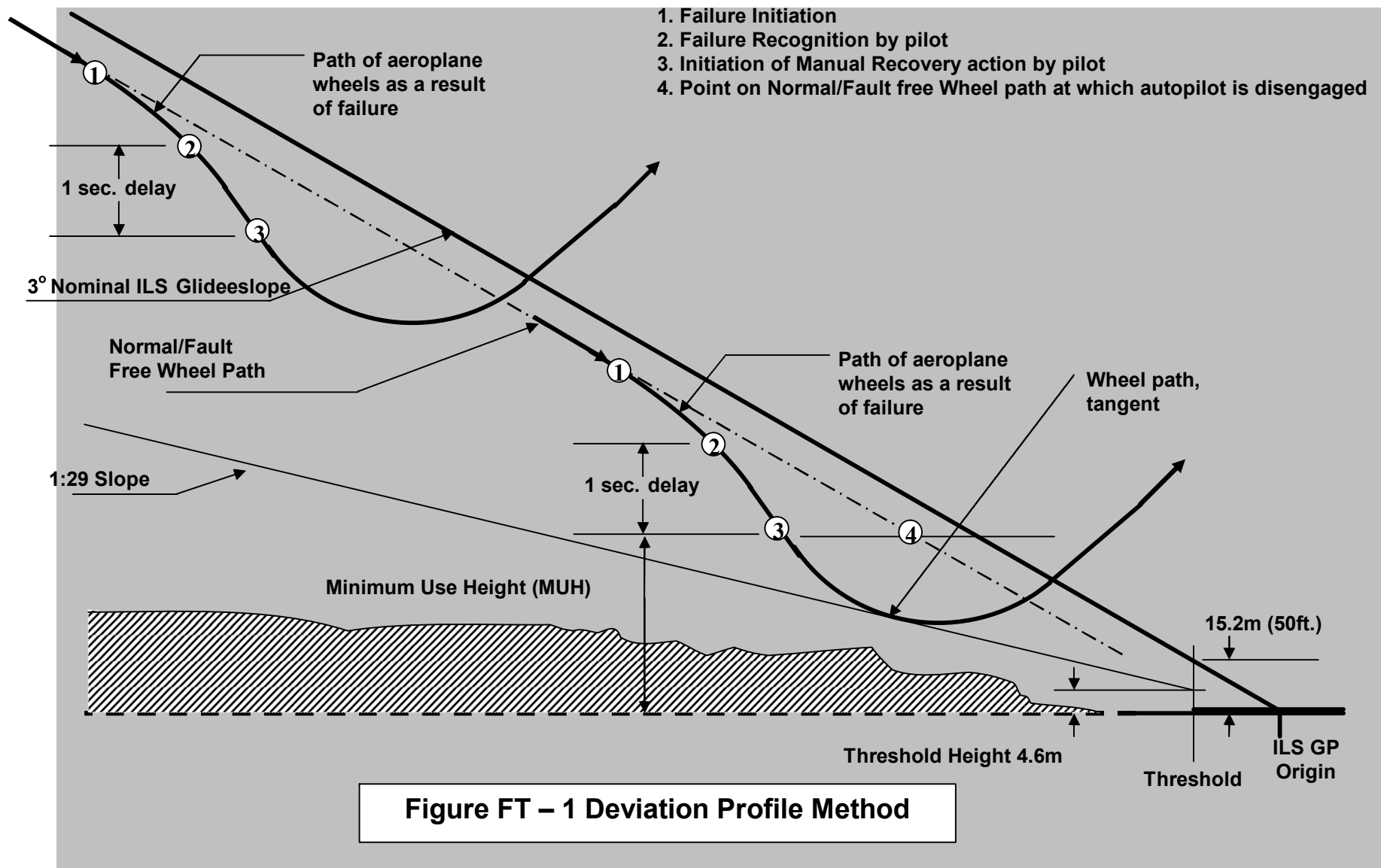
intersecting a point 4.5 m (15 ft) above the threshold. The method of determination may be graphical or by calculation.

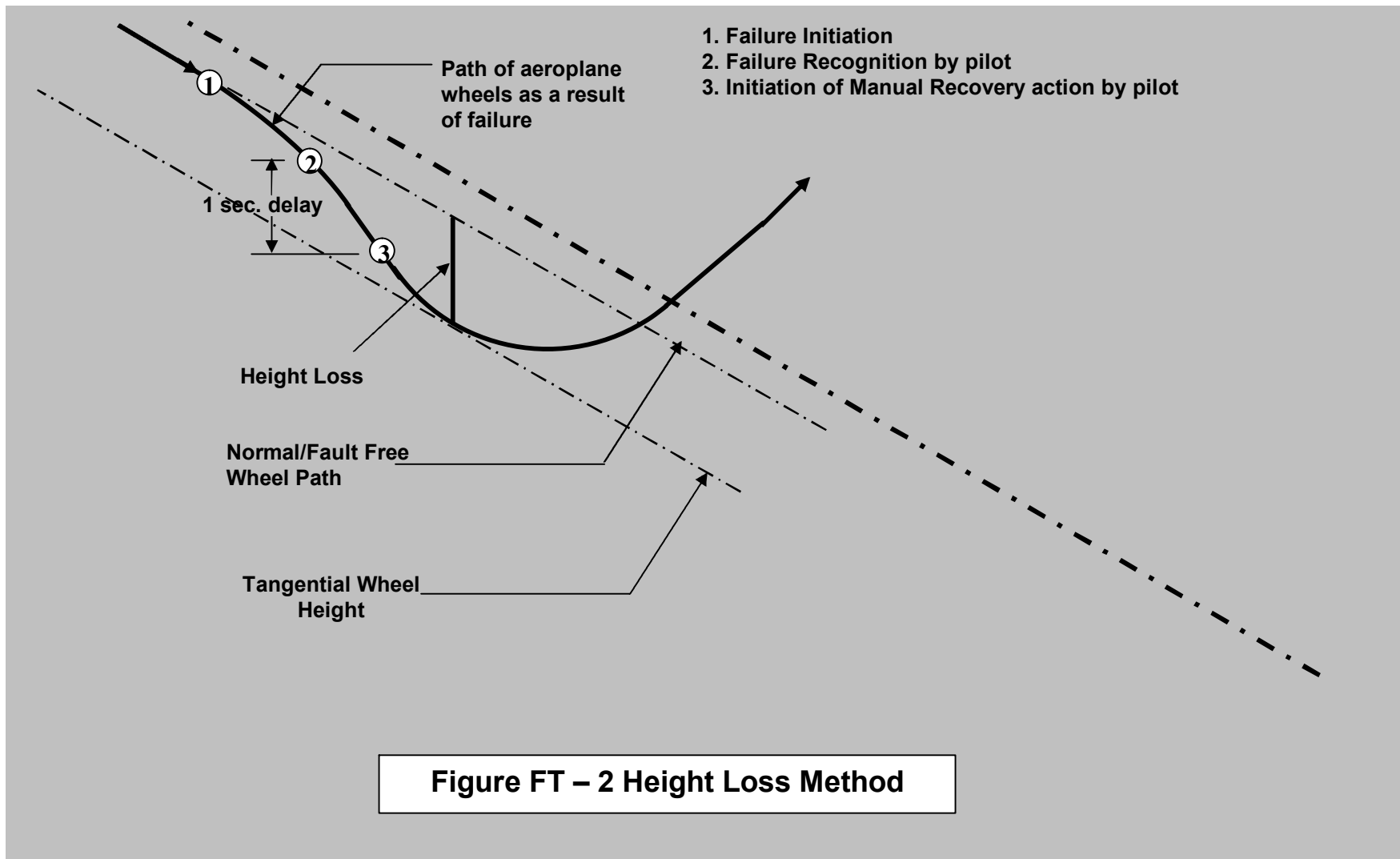
NOTE: The Minimum Use Height is based on the recovery point because:

- i) It is assumed that in service the pilot will be “Hands off” until the autopilot is disengaged at the Minimum Use Height in normal operation.
- ii) The test technique assumes a worst case based on the pilot being “Hands off” from the point of malfunction initiation to the point of recovery.
- iii) A failure occurring later in the approach than the point of initiation of the worst case malfunction described above is therefore assumed to be recovered earlier and in consequence to be less severe.

4.2.3.3 Assessment – Approach without Vertical Path Reference

Figure FT-2 provides a depiction of the height loss method. A descent path of three degrees, with nominal approach speed, should be used unless the autopilot is to be approved for significantly steeper descents. The vertical height loss is determined by the deviation of the aircraft wheel height relative to the nominal wheel flight path.





4.3 Autopilot Override

The initial tests to demonstrate compliance should be accomplished at an intermediate altitude and airspeed e.g. 4500 m (15000 ft) MSL and 460 km/h (250 kt). With the autopilot engaged in altitude hold, the pilot should apply a low force (sustained and incremental) to the control wheel (or equivalent) and verify that the automatic trim system does not produce motion resulting in a hazardous condition. The pilot should then gradually increase the applied force to the control wheel (or equivalent) until the autopilot disengages. When the autopilot disengagement occurs, observe the transient response of the aeroplane. Verify that the transient response is in compliance with Section 8.4 of AMC No. 1 to CS 25.1329.

Disengagement caused by flight crew override should be verified by applying an input on the control wheel (or equivalent) to each axis for which the FGS is designed to disengage, i.e. the pitch and roll yoke, or the rudder pedals (if applicable). The inputs by the pilot should build up to a point where they are sharp and forceful, so that the FGS can immediately be disengaged for the flight crew to assume manual control of the aeroplane.

If the autopilot is designed such that it does not automatically disengage during an autopilot override and instead provides a flight deck Alert to mitigate any potentially hazardous conditions, the timeliness and effectiveness of this Alert. The pilot should follow the evaluation procedure identified above until such time as an Alert is provided. At that time, the pilot should respond to the Alert in a responsive manner consistent with the level of the alert (i.e., a Caution, a Warning) and with the appropriate flight crew procedure defined for that Alert. When the autopilot is manually disengaged, observe the transient response of the aeroplane and verify that the transient response is in compliance with AMC No.1 to CS 25.1329 Section 8.4.

After the initial tests have been successfully completed, the above tests should be repeated at higher altitudes and airspeeds until reaching MMO at high cruise altitudes.

21. Delete existing AMC 25.1439(b)(5).

~~AMC 25.1439(b)(5)~~

~~Protective Breathing Equipment~~

~~1 — If a demand system is used, a supply of 300 litres of free oxygen at 21°C (70°F) and 760 mm Hg pressure is considered to be of 15 minutes duration at the prescribed altitude and minute volume.~~

~~2 — Any other system such as a continuous flow system is acceptable provided that it does not result in any significant increase in the oxygen content of the local ambient atmosphere above that which would result from the use of a demand oxygen system.~~

~~3 — A system with safety over pressure would be an acceptable means of preventing leakage.~~

~~4 — A continuous flow system of the closed circuit rebreather type is an acceptable system.~~

22. Delete existing AMC 25.1453.

~~AMC 25.1453~~

~~Protection of Oxygen Equipment from Rupture~~

~~1—Parts of the system subjected to high oxygen pressure should be kept to a minimum and should be remote from occupied compartments. Where such parts are installed within occupied compartments they should be adequately protected from accidental damage.~~

~~2—Each container, component, pipe and coupling should have sufficient strength to withstand a pressure equivalent to not less than the maximum working pressure acting on that part of the system when multiplied by the appropriate Proof and Ultimate factors given in Table 1. The maximum working pressure includes tolerances of any pressure limiting means and possible pressure variations in the normal operating modes. Account should also be taken of the effects of temperature up to the maximum anticipated temperature to which the system may be subjected. Transient or surge pressures need not be considered except where these exceed the maximum working pressure multiplied by 1.10.~~

~~TABLE 1~~

Systems Element	Proof Factor	Ultimate Factor
Containers	1.5	2.0
Flexible hoses	2.0	4.0
Pipes and couplings	1.5	3.0
Other components	1.5	2.0

~~3—Each source should be provided with a protective device (e.g. rupture disc). Such devices should prevent the pressure from exceeding the maximum working pressure multiplied by 1.5.~~

~~4—Pressure limiting devices (e.g. relief valves), provided to protect parts of the system from excessive pressure, should prevent the pressures from exceeding the applicable maximum working pressure multiplied by 1.33 in the event of malfunction of the normal pressure controlling means (e.g. pressure reducing valve).~~

~~5—The discharge from each protective device and pressure limiting device should be vented overboard in such a manner as to preclude blockage by ice or contamination, unless it can be shown that no hazard exists by its discharge within the compartment in which it is installed. In assessing whether such hazard exists consideration should be given to the quantity and discharge rate of the oxygen released, the volume of the compartment into which it is discharging, the rate of ventilation within the compartment and the fire risk due to the installation of any potentially flammable fluid systems within the compartment.~~

~~6 In addition to meeting the requirements of CS 25.1453, oxygen containers may have to be approved in accordance with national regulations.~~

~~NOTES:~~

~~1 The proof pressure should not cause any leakage or permanent distortion.~~

~~2 The ultimate pressure should not cause rupture but may entail some distortion.~~