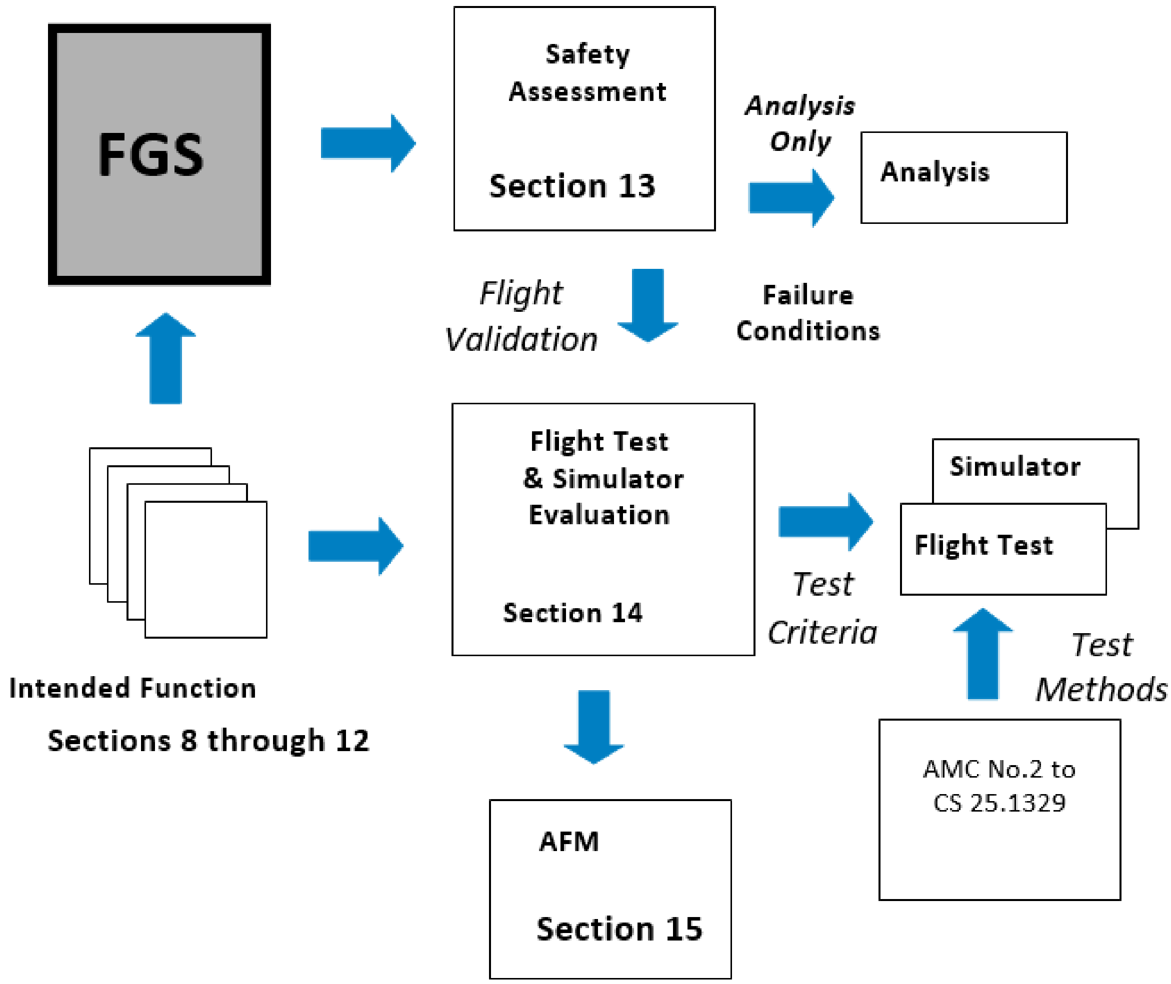

Figure 14-1

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 balked 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 affects 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.

14.2.1Validation 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