Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Flight Guidance System Working Group

Task 1 – Automatic Flight Control and Guidance System

Task Assignment

[Federal Register: August 28, 1997 (Volume 62, Number 167)]
[Notices]
[Page 45691-45692]
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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues--New Task

AGENCY: Federal Aviation Administration (**FAA**), DOT.

ACTION: Notice of a new task assignment for the Aviation Rulemaking Advisory Committee (ARAC).

SUMMARY: Notice is given of a new task assigned to and accepted by the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of ARAC.

FOR FURTHER INFORMATION CONTACT: Stewart R. Miller, Manager, Transport Standards Staff, ANM-110, **FAA**, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Ave. SW., Renton, WA 98055-4056, telephone (425) 227-2190, fax (425) 227-1320.

SUPPLEMENTARY INFORMATION:

Background

The **FAA** has established an Aviation Rulemaking Advisory Committee to provide advice and recommendations to the **FAA** Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the **FAA**'s rulemaking activities with respect to aviation-related issues. This includes obtaining advice and recommendations on the **FAA**'s commitment to harmonize its Federal Aviation Regulations (FAR) and practices with the aviation authorities in Europe and Canada.

One area ARAC deals with is Transport Airplane and Engine issues. These issues involve the airworthiness standards for transport category airplanes in 14 CFR parts 25, 33, and 35 and parallel provisions in 14 CFR parts 121 and 135. The corresponding European airworthiness standards for transport category airplanes are contained in Joint Aviation Requirements (JAR)-25, JAR-E and JAR-P, respectively. The corresponding Canadian Standards are contained in Chapters 525, 533 and 535 respectively.

The Task

This notice is to inform the public that the **FAA** has asked ARAC to provide advice and recommendation on the following harmonization task:

25.1329/25.1335 Automatic Flight Control and Guidance System Requirements Harmonization and Technology Update

1. Review Secs. 25.1329/1335, JAR paragraphs 25.1329/1335 plus that material contained in NPA 25F-243 in addition to Sec. 121.579 and the associated Advisory Circular 25.1329-1 and ACJ 25.1329. Update and harmonize the Part 25 sections and the associated guidance material, in the light of the review of regulatory materials, current certification experience, and changes in technology and system design. Address needed changes in requirements for automatic flight control and guidance functions (including speed/thrust controls), performance, safety, failure and envelope protection functions, warnings, and annunciations. Harmonize acceptable methods of demonstrating compliance with these requirements and propose relevant language for the next revision of the flight test guide AC 25-7-X.

2. Review recommendations that stem from recent transport aviation events and relate to crew error, cockpit automation and in particular, automatic flight control/guidance, made by the NTSB, the **FAA** Human Factors Team, and the JAA Human Factors Steering Group. Make any proposed amendments to Secs. 25.1329/25.1335 and advisory materials that are needed to resolve these recommendations consistent with the entire body of proposed amendments.

The task should be completed within 18 months of tasking.

The **FAA** has also asked that ARAC determine if rulemaking action (e.g., NPRM, supplemental NPRM, final rule, withdrawal) should be taken, or advisory material should be issued or revised. If so, ARAC has been asked to prepare the necessary documents, including economic analysis, to justify and carry out its recommendation(s).

ARAC Acceptance Task

ARAC has accepted this task and has chosen to assign it to a new Flight/Guidance System Harmonization Working Group. The working group will serve as staff to ARAC to assist ARAC in the analysis of the assigned task. Working group recommendations must be reviewed and approved by ARAC. If ARAC accepts the working group's recommendations, it forwards them to the **FAA** as ARAC recommendations.

Working Group Activity

The Flight/Guidance System Harmonization Working Group is expected to comply with the procedures adopted by ARAC. As part of the procedures, the working group is expected to:

1. Recommend a work plan for completion of the tasks, including the rationale supporting such a plan, for consideration at the meeting of ARAC to consider Transport Airplane and Engine Issues held following the publication of this notice.

2. Give a detailed conceptual presentation of the proposed recommendations, prior to proceeding with the work stated in item 3 below.

3. For each task, draft appropriate regulatory documents with supporting economic and other required analyses, and/or any other related guidance material or collateral documents the working group determines to be appropriate; or, if new or revised requirements or compliance methods are not recommended, a draft report stating the

rationale for not making such recommendations.

4. Provide a status report at each meeting of ARAC held to consider Transport Airplane and Engine Issues.

In addition, the working group is expected to:

1. Coordinate with All Weather Operations Harmonization Working Group (AWOHWG) on changes to operational concepts, requirements, rules, and advisory materials that would affect airworthiness requirements to ensure consistency between proposed changes to part 25 rules and advisory materials. Inform the AWOHWG of potential operational implications to proposed part 25 amendments.

2. Coordinate with other working groups to harmonize requirements related to the effects of automatic flight control systems on the loads and dynamics of the airplane.

Participation in the Working Group

The Flight/Guidance System Harmonization Working Group is composed of experts having an interest in the assigned task. A working group member need not be a representative of a member of the full committee.

An individual who has expertise in the subject matter and wishes to become a member of the working group should write to the person listed under the caption FOR FURTHER INFORMATION CONTACT expressing that desire, describing his or her interest in the tasks, and stating the expertise he or she would bring to the working group. The request will be reviewed by the assistant chair, the assistant executive director, and the working group chair, and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the formation and use of ARAC are necessary and in the public interest in connection with the performance of duties imposed on the **FAA** by law.

Meetings of ARAC will be open to the public, except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the Flight/Guidance System Harmonization Working Group will not be open to the public, except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on August 21, 1997.

Joseph A. Hawkins,
Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 97-22923 Filed 8-27-97; 8:45 am]
BILLING CODE 4910-13-M

Recommendation Letter

Pratt & Whitney
400 Main Street
East Hartford, CT 06108

Pratt & Whitney
A United Technologies Company

April 26, 2002

Federal Aviation Administration
800 Independence Avenue, SW
Washington, D.C. 20591

Attention: Mr. Nicholas Sabatini, Associate Administrator for Regulation and Certification

Subject: ARAC Recommendation

Reference: ARAC Tasking, Federal Register, August 28, 1997

Dear Nick,

The Transport Airplane and Engine Issues Group is pleased to submit the following as a recommendation to the FAA in accordance with the reference tasking. This information has been prepared by the Flight Guidance Harmonization Working Group.

- FGHWG report – 25.1329, Automatic Pilot System
- Proposed NPRM – 25.1329, Automatic Pilot System
- Proposed AC 25.1329 – Flight Guidance System Approval

Also attached is a letter from Aerospace Industries Association of Canada and General Aviation Manufacturers Association. This letter recommends NPRM preamble language for consideration by the FAA.

Sincerely yours,

Craig R. Bolt
C. R. Bolt
Assistant Chair, TAEIG

Copy: Letter only
Dionne Krebs – FAA-NWR
Mike Kaszycki – FAA-NWR
Effie Upshaw – FAA-Washington, D.C.
John Acklund – Boeing
Bob Robesen – AIA
Bill Schultz – GAMA
Keith Barnett – Bombardier (AIAC)

April 4, 2002

Mr. Craig Bolt
Assistant Chair, Transport Airplane and Engines Issues Group
Aviation Rulemaking Advisory Committee (ARAC)
C/o Pratt & Whitney
400 Main Street
East Hartford, Connecticut 06108

Subject: Additional Recommendations for Submission to FAA with the FGSHWG Work Package

Dear Mr. Bolt:

The Flight Guidance Harmonization Working Group (FGSHWG) recently completed the development of an amendment to FAR/JAR 25.1329 and an update to the corresponding AC/ACJ. FGSHWG submitted its working group report to the Transport Aircraft and Engines Issues Group (TAEIG) in early February. At the March 19th meeting of TAEIG it was agreed to move the proposal forward to FAA pending either the filing of an official minority opinion (by GAMA, AIA, and AIAC), or the resolution of open administrative details. The purpose of this letter is to record the disposition of our concerns over the final open matters, and to request that this letter be submitted to the FAA together with the FGSHWG data package.

Our industry representatives participated in all FGSHWG activities. Plenary number 15, held in January 2002 in Phoenix, was used by the Working Group to develop a consensus on the content of the rule and advisory material. At that meeting, three issues that could potentially produce an industry minority opinion were discussed. An agreed change in proposed AC/ACJ language satisfied one of these concerns. The plenary did not concur, however, with the proposed method for handling changes suggested by our industry for the other two items. As an alternative, and to avoid a minority opinion, the authorities – **FAA and JAA jointly – offered to include language in the preamble to the Rule (25.1329) to clearly outline its intent.** This language would address the questions raised by our industry and provide clear guidance regarding the application of the Rule. Our industry was satisfied with this outcome and considered it a good resolution.

In the weeks following these agreements, however, it has become evident that the process for submitting a working group report lacks a means for offering regulation preamble text. While the intent of the FGSHWG with regard to our industry issues is stated in the economic analysis portion of the report, it is not explicitly outlined as content for the regulatory preamble. Since the FGSHWG consensus was dependent upon specific preamble language, our industry

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Washington, D.C. 20005-3922
Tel: (202) 371-8400

General Aviation Manufacturers Association
1400 K Street NW, Suite 801
Washington, D.C. 20005-2485
Tel: (202) 393-1500

concludes it important to bring this issue to closure before moving the proposal forward. As no other vehicle exists to convey our concerns, we are using this letter as a means of completing our responsibility to the working group process.

Therefore, the following is the preamble language proposed by our industry in relation to regulatory paragraphs 25.1329(g) and (h). The majority of this language comes directly from the economic analysis portion of the FGSHWG report on which consensus exists. It was also necessary to supplement the report language with introductory material to place the report language into proper context and to align it with the expected format of the preamble:

> **FAR/JAR 25.1329(g)**
> This paragraph is not intended to require compliance substantiation solely through flight tests, especially when relevant service history data exists. An analysis of such data, and its determination of applicability to a given project, may be used by the applicant to meet the stated requirement(s). With regard to certain environmental factors such as icing, and for amended TC and STC projects (e.g. where an existing, approved autopilot is replaced by another autopilot), a review of field history data may be conducted to assist in determining the extent of flight testing that is required. Where there is a lack of autopilot-related accidents and/or incidents in the icing environment, consideration should be given to showing compliance without the need for additional flight tests with ice shapes or in natural icing.
>
> **FAR/JAR 25.1329(h)**
> While this paragraph requires protection from both high and low speed excursions when the flight guidance system is in use, it is not intended to require the incorporation of additional systems (such as AOA) to achieve this goal. If a compatible low speed sensor exists, it may be possible to realize optimum low speed protection performance. If such an input is not available, it is assumed that the flight guidance system will be designed such that it provides the best compromise functionality it can given those limitations.

We believe the text suggested above accurately reflects the consensus agreement reached by the FGSHWG. Please consider these two paragraphs as our submittal for language to be included in the preamble to the rule. We, therefore, kindly request you submit this letter to the FAA together with the FGSHWG work package. Also, we would appreciate the authorities' assistance in capturing this recommendation when they draft the proposed rule notices.

Very truly yours,

William H. Schultz	Robert E. Robeson, Jr.	Keith Barnett
Vice President, Engineering	Vice President, Civil Aviation	Manager, Airworthiness
General Aviation Manufacturers Association	Aerospace Industries Association of America, Inc.	Bombardier Aerospace on behalf of AIAC

Acknowledgement Letter

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave S W
Washington, D C 20591

MAY 3 2004

Mr. Craig R. Bolt
Manager, Product Development and Validation
Pratt & Whitney
Mail Stop 162-12
East Hartford, CT 06108

Dear Mr. Bolt:

In an effort to clean up pending Aviation Rulemaking Advisory Committee (ARAC) recommendations on Transport Airplane and Engine Issues, the recommendations from the following working groups have been forwarded to the proper Federal Aviation Administration offices for review and decision. We consider your submittal of these recommendations as completion of the ARAC tasks. Therefore, we have closed the tasks and placed the recommendations on the ARAC website at http://www.faa.gov/avr/arm/arac/index.cfm

Date	Task	Working Group
December 1999	Interaction of Systems and Structure Part 33 Static Parts – task #13	Loads and Dynamics Harmonization Working Group
March 2000	Part 35/JARP: Airworthiness Standards Propellers 8	Engine Harmonization Working Group
April 2000	Flight Characteristics in Icing conditions	Flight Test Harmonization Working Group
May 2000	Thrust Reversing Systems	Powerplant Installation Harmonization Working Group
September 2000	Lightning Protection Requirements	Electromagnetic Effects Harmonization Working Group
July 2001	Main Deck Class B Cargo Compartments	Cargo Standards Harmonization Working Group
April 2002	Design Standard for Flight Guidance	Flight/Guidance Systems Harmonization Working Group

ANM-97-435-A
21264

I wish to thank the ARAC and the working groups for the resources they spent in developing these recommendations. We will continue to keep you apprised of our efforts on the ARAC recommendations at the regular ARAC meetings.

Sincerely,

Tony

Anthony F. Fazio
Executive Director, Aviation Rulemaking
Advisory Committee

Recommendation

Flight Guidance System Harmonization Working Group

Working Group Report

The Flight Guidance System Harmonization Working Group (FGSHWG) is providing its Report to the Transport Airplane and Engines Issue Group (TAEIG) in the format requested by the FAA Transport Directorate. The Group has retained the original directions and formatting as a means to check for accuracy and completeness. The Group found the need to provide additional information to TAEIG, the FAA and JAA. This information is provided as Appendices to the Report.

Table of Contents

Transport Airplane Directorate

WG Report Format

Harmonization and New Projects

1 - BACKGROUND:

- *This section "tells the story."*
- *It should include all the information necessary to provide context for the planned action. Only include information that is helpful in understanding the proposal -- no extraneous information (e.g., no "day-by-day" description of Working Group's activities).*
- *It should provide an answer for all of the following questions:*

a. SAFETY ISSUE ADDRESSED/STATEMENT OF THE PROBLEM

(1) What prompted this rulemaking activity (e.g., accident, accident investigation, NTSB recommendation, new technology, service history, etc.)? What focused our attention on the issue?

The Working Group was tasked by the Transport Airplane and Engine Issues Group of ARAC with the following Terms of Reference:

1) Address needed changes in requirements for automatic flight control and guidance functions (including speed/thrust control),
2) Address performance, safety, failure and envelope protection functions, warnings, and annunciations,
3) Review recommendations that stem from recent transport aviation events and relate to crew error, cockpit automation and in particular, automatic flight control/guidance, made by the NTSB, the FAA human factors team, and the JAA human factors steering group,
4) Make any proposed amendments to §25.1329/ 25.1335 and advisory materials that are needed to resolve these recommendations consistent with the entire body of proposed amendments.

Activity prompting this action includes:

- NTSB recommendations
- Recommendation contained in the Human Factors Team Report
- Various Airworthiness Directives
- The situation that existing Rule and Advisory Material does not address current technology and systems (e.g., Heads Up Display)
- Rules and Advisory Material are not harmonized

The following list provides the specific NTSB Safety Recommendations that were considered as part of the Working Group activities. Recommendations against currently certified airplanes in addition to recommendations for new certification projects were considered. Although the proposed regulations and advisory material would have no consequence against currently certified airplanes, the contributing effects of the accidents and incidents detailed in the following Safety Recommendations were considered when the proposed rule and advisory material were developed.

NTSB Safety Recommendation A-92-035: Revise Advisory Circular 25.1329-1A to add guidance regarding autopilot failures that can result in changes in attitude at rates that may be imperceptible to the flight crew and thus remain undetected until the airplane reaches significant attitude deviations.

NSTB Safety Recommendation A-98-098: Require all manufacturers of transport-category airplanes to incorporate logic into all new and existing transport-category airplanes that have autopilots installed to provide a cockpit aural warning to alert pilots when the airplane's bank and/or pitch exceeds the autopilot's maximum bank and/or pitch command limits.

NTSB Safety Recommendation A-99-041: Require that the MD-11 autopilot system be modified to prevent upsets from occurring when manual inputs to the flight controls are made.

NTSB Safety Recommendation A-99-042: Review the design of all transport-category airplane autopilot systems and require modifications to those determined to be capable of creating upsets when manual inputs to the flight controls are made.

NTSB Safety Recommendation A-99-043: Require all new transport-category airplane autopilot systems to be designed to prevent upsets when manual inputs to the flight controls are made.

Note: The proposed rule and accompanying advisory material may not have addressed the issue contained in the above Safety Recommendations with the exact technical solution recommended by the NTSB. However, it is felt that the ***intent*** of each Safety Recommendation has been addressed.)

The following is a list of airplane accidents and incidents that ***may*** have been mitigated or avoided if the airplanes involved had been certified using the proposed rule and accompanying Advisory Circular. It must be stressed, however, that this is a very subjective assessment. There are many factors that are involved in the entire chain of events that occurred in each accident or incident. The Working Group feels that *some* part of the chain of events for each of the accidents (A) and incidents (I) listed below is addressed by the proposed rule and AC. However, it cannot be stated unequivocally that any of these accidents/incidents would have been avoided had the proposed rule and AC been in effect.

(A)	Feb. 19, 1985	China Airlines Boeing 747SP, San Francisco, CA, USA
(I)	Feb. 11, 1991	Interflug Airbus A310, Moscow, Russia
(I)	Dec. 12, 1991	Evergreen International Airlines Boeing 747-100, Thunder Bay, Ontario, Canada
(A)	Jan. 20, 1992	Lufthansa Airbus A320 Strasbourg, France
(A)	April 26, 1994	China Airlines Airbus A300-600, Nagoya, Japan
(A)	Oct. 31, 1994	American Eagle ATR-72, Roselawn, IN, USA
(I)	June 13, 1996	American Airlines McDonnell Douglas MD-11, Westerly, RI, USA
(A)	Jan. 9, 1997	Comair Embraer EMB-120T, Monroe, MI, USA
(A)	June 8, 1997	Japan Airlines McDonnell Douglas MD-11, Nagoya, Japan
(A)	Sept. 14, 1999	Olympic Airways Dassault Mystere-Falcon 900, Bucharest, Romania
(I)	Oct. 9, 1999	Amway Corporation Dassault Mystere-Falcon 900, Grand Rapids, MI, USA

N*ote*: As this is a harmonized activity, both foreign and domestic manufacturers and operators have been included.

(2) What is the underlying safety issue to be addressed in this proposal?

The following safety issues are being addressed with the proposed revision to the rule and AC/ACJ:

- Insufficient crew awareness of FGS behavior and operation
- Hazardous autopilot disengage transients, including a manual pilot override of an engaged autopilot
- Flight guidance system mode confusion resulting in crew errors (e.g., altitude violation)

- History of lack of awareness of unusual/hazardous attitudes during FGS operations (accidents and incidents)
- History of lack of speed awareness (accidents and incidents)
- Operation in icing conditions (e.g., limits of autopilot authority)

(3) What is the underlying safety rationale for the requirement?

Revise Rule to address the items in (2) above for automatic control systems and guidance systems

(4) Why should the requirement exist?

Most, if not all, large modern transport-category airplanes have Flight Guidance Systems installed. This proposed requirement addresses the safety requirements for a Flight Guidance System.

In responding to the Terms of Reference (TOR), the Working Group decided that the current scope of §/JAR 25.1329 and §/JAR 25.1335 rules does not cover the work that was tasked, and that a more modern rule to address a broader set of functions encompassed by what is now called Flight Guidance System is necessary. This new rule would address the integration of new functionality and technology that is provided in current airplanes and much that is anticipated for future airplane installations.

The Working Group proposed to cancel the current §25.1335 Rule, "Flight Director Systems" and to rename the §25.1329 Rule from "Autopilot System" to "Flight Guidance System" in order to accomplish the tasks listed in the TOR.

b. CURRENT STANDARDS OR MEANS TO ADDRESS

(1) What are the current regulations relative to this subject? (Include both the FAR's and JAR's.)

FAR § 25.1329 Automatic pilot system.

(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 airplane.

(b) Unless there is automatic synchronization, 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 Sec. 25.777 (b) and Sec. 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 airplane, 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) If the automatic pilot system can be coupled to airborne navigation equipment, means must be provided to indicate to the flight crew the current mode of operation. Selector switch position is not acceptable as a means of indication.

Amdt. 25-46, Eff. 12/1/78

FAR § 25.1335 Flight director systems.

If a flight director system is installed, means must be provided to indicate to the flight crew its current mode of operation. Selector switch position is not acceptable as a means of indication.

Amdt. 25-41, Eff. 9/1/77

JAR 25.1329 Automatic Pilot System

Date: October 1, 2000

(See ACJ 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 synchronization, 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 JAR 25.777(b) and JAR 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 JAR 25.1322 and its AMJ.)

JAR 25.1335 Flight Director Systems

Date: October 1, 2000

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.

(2) How have the regulations been applied? (What are the current means of compliance?) If there are differences between the FAR and JAR, what are they and how has each been applied? (Include a discussion of any advisory material that currently exists.)

Compliance with the 25.1329 rule has largely followed the advisory material found in FAA AC 25.1329-1A or in JAA Advisory Circular ACJ 25.1329. Advances in autopilot technology have outpaced both the FAA circa-1968 guidance and the more current JAA ACJ 25.1329 material. Autopilot related issue papers and interim policy guidance have been used to fill these gaps in the regulatory and acceptable means of compliance material.

The regulations are applied in certification and validation of products. As a consequence, the differences between the FAR and JAR have to be addressed by the applicant. As a result, the certification is typically done to the more stringent requirement. The current acceptable means of compliance in the US and Europe also have significant differences which affect the amount and type of compliance demonstration required.

(3) What has occurred since those regulations were adopted that has caused us to conclude that additional or revised regulations are necessary? Why are those regulations now inadequate?

The discussion above relating to accidents, incidents, NTSB recommendations, new technological advances and other safety issues provide the basis and rationale for this activity.

In addition, the Terms of Reference tasked the working group to address a number of factors and considerations that have not been previously addressed by prior certification programs and associated certification documents. The Working Group did include text from an FAA Issue Paper S-7 "Performance after Takeoff") in the advisory material that accompanies this proposed rule change. This Issue Paper has been applied to most certification programs since the early 1980's.

The JAA has issued several NPA's to amend their rule and advisory material to reflect changes in technology and safety issues. To support harmonization, the Working Group worked to reconcile these different documents.

2. DISCUSSION of PROPOSAL

- *This section explains:*
  - → *what the proposal would require,*
  - → *what effect we intend the requirement to have, and*
  - → *how the proposal addresses the problems identified in Background.*
- *Discuss each requirement separately. Where two or more requirements are very closely related, discuss them together.*
- *This section also should discuss alternatives considered and why each was rejected.*

a. <u>SECTION-BY-SECTION DESCRIPTION OF PROPOSED ACTION</u>

(1) What is the proposed action? Is the proposed action to introduce a new regulation, revise the existing regulation, or to take some other action?

The proposed actions are:

1) To replace current FAR/JAR 25.1329 and FAR/JAR 25.1335 with a new FAR/JAR 25.1329 titled, "Flight Guidance System."

2) To provide new advisory material [AC/ACJ] to provide acceptable means of complying with the new Rule.
3) To amend JAR-AWO to be consistent with the new JAR 25.1329 provisions (JAA action).
4) To cancel the FAA interim autopilot policy ANM-99-01.
5) To make additional recommendations for issues that are outside of the Working Group's Terms Of Reference, but that the Working Group felt were important to be addressed. Please see Appendix 1 to this Working Group Report for these recommendations.

(2) If regulatory action is proposed, what is the text of the proposed regulation?

Please refer to Appendix 2 to this Working Group Report for a graphical depiction of the tracing between the existing and proposed rules.

Note: If viewing a software version of this appendix, use the Microsoft Word toolbar to select VIEW – PAGE LAYOUT to view the accompanying graphics.)

§/JAR 25.1329 Flight Guidance System
[See AC/ACJ 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 requirements of §/JAR25.1309.

(c) Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a significant transient response affecting the control or flight path of the airplane.

(d) Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path.

(e) Under other than normal conditions, transients affecting the control or flight path of the airplane resulting from the disengagement of any automatic control functions of a flight guidance system must not require exceptional piloting skill or strength to remain within, or recover to, the normal flight envelope.

(f) Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be 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 airplane (in accordance with §/JAR 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 FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.

(j) Following disengagement of the autopilot, a visual and aural warning 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.

(3) If this text changes current regulations, what change does it make? For each change:

- **What is the reason for the change?**
- **What is the effect of the change?**

The proposed change includes requirements for Flight Guidance Systems, which is defined to include automatic flight control systems (i.e., automatic pilots), automatic thrust control (i.e., automatic throttles), and flight guidance (i.e., flight directors). The current rule 25.1329 applies only to automatic pilots and the current rule 25.1335 applies only to flight directors. There are rules in Part 25, subpart E - Powerplant, which do deal with some aspects of the autothrust system. However, these rules do not cover the flight guidance aspects of autothrust. There is no current rule that directly addresses automatic thrust control. Flight Guidance Systems (automatic flight control, automatic thrust control and guidance) need to follow compatible principles for ensuring safe flight and for flight crew awareness.

Consistent with the above discussion, the Working Group proposes to change the title of the regulation to "Flight Guidance System" to reflect the inclusion of autopilot, autothrust and flight director in a single rule.

25.1329 (a) This sub-section combines some requirements from the current rule [sub-sections (a), (c) and (d)] regarding the quick disengagement controls. The first sentence requires the controls, as does the current sub-section 25.1329(a) for autopilot, but also for automatic thrust systems. The next sentence stipulates that the autopilot disengagement controls be on the control wheel (or equivalent) in keeping with the intent of sub-sections 25.1329(c) and (d). The third and fourth sentences adapt the current autopilot requirement for accessibility and location of the quick disengagement control to the autothrust system.

Rationale for the change: It seemed logical to combine the requirements for quick disengagement of automatic control systems into a single rule. The pilot may need to disengage the autothrust system, as well, during a high workload condition, when removing hands from the primary controls and throttle levers would hinder task performance.

25.1329 (b) This is a new statement addressing the effects of a failure to disengage the autopilot or autothrust functions.

Rationale for the change: The group considered fixed requirements for the probability of such failures, but decided that given the variety of installations and characteristics of airplane types, that a system safety analysis in accordance with 25.1309 is the best course. This statement requires that such an analysis be conducted.

25.1329 (c) Sub-sections (c), (d) and (e) are essentially new and they provide standards for transients for FGS engagement, switching, and normal and non-normal disengagements. The intent of the current 25.1329(b) requirement for automatic synchronization is related to the need to limit transients during engagement, disengagement and mode changes of the autopilot system.

Rationale for the changes: Transients can adversely affect continued safe flight and the ability of the flight crew to safely intervene. Normal (non-failure) characteristics should be very benign, while rare normal and non-normal (failure) characteristics need to be safe.

25.1329 (d) See text for 25.1329 (c) above.

25.1329 (e) See text for 25.1329 (c) above.

25.1329 (f) The new material is adapted from the requirement for attitude controls found in the current 25.1329(e), extending it to the design of all command reference controls. The objective is that the applicant follow the same criteria for plane and sense of motion and marking that is required for other flight controls by FAR sections 25.777 and 25.779. The new material is adapted from the requirement for attitude controls found in

Rationale for the change: The increasing variety of flight guidance systems can lead to non-intuitive designs that would promote flight crew error. Command reference controls for airspeed, vertical speed, flight path angle, heading, altitude and so on, are considered vulnerable to crew error if the plane sense of motion and control marking are not consistent.

25.1329 (g) This is the same requirement stated in the current 25.1329 (f).

25.1329 (h) This is a new requirement for speed protection.

Rationale for the change: During FGS operation, flight crew awareness of or attention to airspeed may not be sufficient to provide timely detection of unintended speed changes that compromise safety. Also, in certain conditions, the current modes of the autopilot and/or autothrust may not be designed to prevent speed excursions outside the normal range. 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. This requirement is intended to avoid unwanted excursions by enhancing flight crew awareness and possibly by mode reversions of the automatic flight control or thrust control systems.

25.1329 (i) This paragraph expands on the current 25.1329 (h) requirement for mode indications by adding a statement of the safety objective to minimize crew errors and confusion. It also addresses logical grouping and presentation of the mode indications and controls for the sake of visibility from each pilot position and for flight crew awareness of active modes and mode changes. It also incorporates the existing 25.1335 provisions.

Rationale for the change: Studies have shown that the lack of sufficient flight crew awareness of modes, transitions and reversions is a key safety vulnerability. This paragraph provides the regulatory basis for several provisions of the proposed advisory circular related to enhanced flight crew awareness of flight guidance system active/armed modes, and changes in flight guidance system behavior which may otherwise be unanticipated by the flight crew.

25.1329 (j) This requirement for a visual and aural autopilot disengagement warning is adopted from the JAR 25.1329 (i) and does not exist in the current FAR.

Rationale for the change: The current JAR requirement is valid because disengagement of the autopilot, for whatever reason, necessitates immediate flight crew intervention to assume manual control of the airplane. Likewise, the requirement that the aural warning be distinct from other cockpit warnings is meant to provide unequivocal awareness that the flight crew must assume manual control of the airplane.

25.1329 (k) This paragraph is a new requirement that provides requirement for an indication of autothrust disengagement.

Rationale for the change: The flight crew needs to be aware that the autothrust system has disengaged, so that they do not continue to expect the desired speed control to be provided. Normally, however, the autothrust disengagement would not require immediate thrust control changes by the flight crew. Hence, the less specific "indication" rather than "warning" is required.

25.1329 (l) This new paragraph requires that flight crew override of the autopilot must be safe.

Rationale for the change: Several accidents and incidents, some with serious injuries and some with fatalities, have occurred after flight crew override of the autopilot. Nevertheless, it is not advisable to prohibit flight crew override in all cases, because the override might be the last resort for the flight crew to regain control of the airplane in certain abnormal (i.e., failure) conditions.

25.1329 (m) This new paragraph requires that the flight crew be able to affect thrust changes without exerting excessive force to override the operating autothrust system or creating an unsafe condition.

Rationale for the change: There may be times when the flight crew needs to immediately change thrust without needing to disengage the autothrust system. There may be cases when the normal controls for disengaging the autothrust system have failed and the ability to override the autothrust system is the only means available to manually control thrust.

25.1335 Existing FAR section deleted. The existing requirement has been incorporated into proposed 25.1329 (i).

(4) If not answered already, how will the proposed action address (i.e., correct, eliminate) the underlying safety issue (identified previously)?

This question is addressed under the rationale for change.

(5) Why is the proposed action superior to the current regulations?

The rationale for each paragraph of the proposed rule answers this question. In summary, the proposed rule expands the scope of 25.1329 beyond autopilot systems to include guidance for manual control and autothrust. These functions are increasingly integrated into the same equipment and the fundamental principles for engagement, disengagement, flight crew awareness of changes in system operation, etc., apply to each of the functions in a similar manner. The NTSB has recommended changes for enhanced flight crew awareness of system operation and changes in airplane condition. Often, during FGS operation, the flight crew is insufficiently aware of changes in attitude, airspeed, trim and so forth that could adversely affect flight safety. This rule and accompanying advisory material would increase the level of safety through improved system indications, annunciations, and speed protection.

b. ALTERNATIVES CONSIDERED

(1) What actions did the working group consider other than the action proposed? Explain alternative ideas and dissenting opinions.

See b.(2) below.

(2) Why was each action rejected (e.g., cost/benefit? unacceptable decrease in the level of safety? lack of consensus? etc.)? Include the pros and cons associated with each alternative.

List of rejected actions:

- Envelop FAA and JAA requirements without adding new requirements.

  Pro: Enveloping the FAA and JAA rules (i.e., adopting the most rigorous requirements of each) would have been a much simpler rulemaking task and easier for industry to adjust to. It would at least have harmonized the requirements and simplified bilateral validation programs.

  Con: The current requirements are out-of-date. They do not adequately address safety issues related to current designs and the anticipated direction of future designs. Service history and studies gives evidence that previous assumptions about the effectiveness of flight crew awareness of the airplane during autopilot operation are out of date as well. Flight crew reliance on automated flight control systems has increased markedly since the current regulations were issued. The FAA Human Factors Team Report, numerous NTSB safety recommendations, and other information point out the need to enhance flight crew awareness of autopilot and guidance system operation. Newer designs enable functions that were not possible for automated systems when the current regulations were developed. The newer designs tend to be more complex from the crew's perspective, and vulnerable to flight crew confusion over mode behavior and transitions. Newer designs integrate the functions of many related systems and are far more complex. Standards cannot be effective if they simply address a particular avionics system, they need to address the functionality, regardless of which systems host the functionality. For reasons like these, the simple adoption of current requirements would not provide adequate safety standards.

- To define the scope of the rule to include all automatic control and guidance systems including FMS, yaw damping, integrated energy management, etc.

  Pro: A fully integrated system as described above would provide increased safety as a result of complex interactions between systems being transparent to the flight crew, and all Human-Man Interfaces (HMI) would be consistent between the various functions. All functionality would be totally integrated and would not (if designed correctly) ever result in a situation where the individual systems "expectations" conflicted with each other.

  Con: The activity was considered out of scope of the Group's term of reference, although such a system may be desirable for future development. Many of the functions listed are not considered part of a Flight Guidance System, and would therefore require coordination and buy-in from several other harmonization groups. This would jeopardize completion of the task within a reasonable timeframe. Additionally, the cost of such as system would most likely be prohibitive when applied to some of the smaller Part 25 category aircraft.

- To require full Flight Envelope Protection

  Pro: Enhanced safety in all flight phases and Flight Guidance System modes.

  Con: It was felt that the cost/benefit return is not sufficient, as the primary focus in accidents and incidents was speed, rather than full flight envelope. Therefore, it was felt that the most cost effective approach would be obtained by requiring speed protection only. Additionally, full Flight Envelope Protection is more of a function of design of the overall flight control system of the airplane, and not the

Flight Guidance System. It makes little sense to require full Flight Envelope Protection only with FGS operation and not require it for manual flight.

- To require that Speed Protection always involve some form of automatic autothrust wakeup

  Pro: Enhance safety by having low speed protection thrust control engage automatically, even if the autothrust system is not currently active.

  Con: Many aircraft are not equipped with an autothrust system, so those airplanes would not benefit from any regulation of this type. Additionally, many autothrust systems require that the autothrust system be manually armed by manipulating a switch before the automatic function is allowed to become active. This is a necessary safeguard in some systems to prevent inadvertent activation when it could be hazardous, e.g., on the ground. Therefore, those system designs which depend on the manually switch before the system may be activated would make the design of such a "wake up" feature very difficult and costly to implement. It was felt that the rule and guidance material that was decided upon adequately addresses low speed awareness and protection without requiring this feature.

Minority Opinions

The Working Group members feel that all possible diligence was used when considering alternatives and dissenting opinions. The Working Group was not able to satisfy every member's concerns during our deliberations. One Minority Opinions was placed on record and that opinion can be found in Appendix 3.

Note: This Minority Opinions is, for the most part, against the proposed advisory material and not the proposed rule.)

c. HARMONIZATION STATUS

(1) Is the proposed action the same for the FAA and the JAA?

For 25.1329, essentially the FAA and JAA actions are the same. Text for the rule and advisory material is intended to be identical, except possibly for differences in spelling. Recommendations for changes to All-Weather Operations criteria to be consistent with the new 25.1329 will result in different actions for FAA and JAA due to different document structures.

(2) If the proposed action differs for the JAA, explain the proposed JAA action.

Material recommended for inclusion in the FAA Flight Test Guide AC 25-7A will be placed in a new ACJ No. 2 to JAR 25.1329.

(3) If the proposed action differs for the JAA, explain why there is a difference between FAA and JAA proposed action (e.g., administrative differences in applicability between authorities).

The JAA has a different document structure. The JAA does not have an equivalent document to the FAA AC 25-7A, Flight Test Guide.

3. COSTS AND OTHER ISSUES THAT MUST BE CONSIDERED

The Working Group should answer these questions to the greatest extent possible. What information is supplied can be used in the economic evaluation that the FAA must accomplish for each regulation. The more quality information that is supplied, the quicker the evaluation can be completed.

The following list of contacts can be used by the FAA Economist to initiate a discussion on cost associated with rulemaking.

Company	Contact	Telephone	E-mail address
Airbus			
Boeing	Jim VandenBrook	(425) 266-5566	james.d.vandenbrook@boeing.com
Bombardier			
Embraer S.A.			
Honeywell	Chris Durkin	(913) 712-6013	chris.durkin@honeywell.com
Rockwell-Collins	Peter Lyons		pdlyons9@rockwellcollins.com

a. COSTS ASSOCIATED WITH THE PROPOSAL

(1) Who would be affected by the proposed change? How? (Identify the parties that would be materially affected by the rule change – airplane manufacturers, airplane operators, etc.)

Avionics manufacturers would incur the added expense and time of designing and developing systems with additional features that would meet new proposed regulations, e.g., high and low speed protection. Airplane manufacturers would be impacted as well. Operators could be impacted by additional training requirements and the need to update equipment and documentation.

The new rule will be automatically applied to new TC programs. There will be additional development costs incurred by both the avionics and airplane manufacturers to meet the new regulations. As the new requirements are known in advance, the new features can be incorporated as part of the basic design.

If the new rule is applied to STC programs which will update an existing, previously certified airplane and to amended TC programs in which the changes are "cut-in" to an existing production line, new functionality of the airplane could be required (e.g., speed protection) and therefore additional costs will be incurred. These additional costs will be dependent upon the configuration of the airplane being modified and functionality of the system that is required to be installed in that airplane. The STC/ATC applicant could incur costs to modify the airplane to add additional sensors, wiring, etc. There will be increased costs associated with increased cost of equipment, development and flight test, etc. Both the avionics vendor and the STC/ATC applicant will incur increased costs to cover extended development and certification of the modified airplane. The operator and airplane manufacturer could incur increased costs by the fact that, if part of a fleet is required to meet the latest regulations, the operator might elect to bring their entire fleet up to the latest standards for fleet commonality and training considerations.

(2) What is the cost impact of complying with the proposed regulation? Provide any information that will assist in estimating the costs (either positive or negative) of the proposed rule. *(For example:*

- ***What are the differences (in general terms) between current practice and the actions required by the new rule?***
- ***If new tests or designs were required, how much time and costs would be associated with them?***

- ***If new equipment is required, what can be reported relative to purchase, installation, and maintenance costs?***
- ***In contrast, if the proposed rule relieves industry of testing or other costs, please provide any known estimate of costs.***
- ***What more-- or what <u>less</u> -- will affected parties have to do if this rule is issued?***

NOTE: "Cost" does not have to be stated in terms of dollars; it can be stated in terms of work-hours, downtime, etc. Include as much detail as possible.)

All quantitative values and qualitative statements are based on the "delta" costs that would be incurred if this new rule is enacted, above and beyond what is already required by the existing rule.

Because the costs associated with any program will depend greatly on what kind of program it is, the following breakdowns have been used.

a) New TC Program – New development program with no airplanes having been manufactured.
b) Amended TC Program – Development program with changes being "cut-in" in ongoing production line.
c) Existing airplanes modified via STC or ATC in which the new FAR 21.101 (Changed Product Rule) Applies.
d) Existing airplanes modified via STC or ATC in which the new FAR 21.101 (Changed Product Rule) Does NOT Apply.

Additionally, each category listed above is broken down by technical subject for clarity.

a. <u>New TC Program – New development program with no airplanes having been manufactured</u>:

All new TC programs will be required to comply to the proposed revision to FAR 25.1329 when it takes effect. The costs associated with a new development program (e.g., design, testing, manufacture, training, etc.) which comply with the proposed revision to the regulations will not be, for the most part, significantly different than complying with the existing regulations. There are several possible exceptions, which are discussed individually below. All other aspects of the proposed regulations are either very similar to the existing regulations, or put into a regulatory basis that which should be considered as a "best design practice", such that no additional costs are incurred by compliance to the proposed regulation.

<u>Autopilot Override</u>

The proposed FAR 25.1329 (d) states:

> "Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path."

Also, proposed FAR 25.1329 (l) states:

> "The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls."

The proposed Advisory Material AC/ACJ 25.1329 that accompanies this revised regulation indicates that *one possible method of compliance* for the above paragraphs could be that any automatic horizontal trim be inhibited from moving, or should not be allowed to continue to move, when a pilot applies a force to the control column without first disengaging the autopilot. Many current designs are normally based on the assumption that the pilot will always disengage the autopilot before attempting manual control, and therefore, the horizontal trim system is not inhibited.

If this method of compliance described above is chosen by industry as the best method for compliance, then it could mean (depending on the flight control system design of the particular airplane in question) that installation of a force sensor(s) on the control column is needed. There would be costs associated with this new installation, such as the cost of the transducer(s) itself, the mechanical interface to the control column mechanism, the electrical wiring associated with the transducer(s), the new interface to the autopilot by these new sensor(s), and additional autopilot design and testing of this new feature. There would be non-recurring costs associated with the design and testing, as well as a recurring cost per airplane for the additional hardware this feature would require.

Estimated Non-Recurring Design, Development, and Testing Costs associated with new force transducer(s):

Specific Data

GAMA	In first application of technology in type of airplane (i.e. hydraulic controls, cable controls, fly-by-wire controls): $200K Estimated Non-Recurring Design, Development, and Testing Costs associated with new force transducer(s) in subsequent application of technology in type of airplane: $120K
Company #2	
Company #3	

Estimated Recurring Hardware and Manufacturing Costs (per airplane) associated with new force transducer(s):

Specific Data

GAMA	$12K
Company #2	
Company #3	

Estimated Crew Training and Operational Costs: TBD. However, as this is a new TC program which will require new crew training for all flight crews (unless it is a "common type rating" with another existing airplane model), it is felt that the training costs associated with this item will be minimal, if not zero.

Specific Data

GAMA	None
Company #2	
Company #3	

Pilot Awareness Flight Deck Annunciation

The proposed FAR 25.1329 (i) states:

> "The FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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."

The proposed Advisory Material that accompanies this revised regulation states that one method of compliance is to include an additional alert(s) in the flight deck to ensure pilot awareness of an unusual operating condition which may be masked by the use of the autopilot. This alert(s) would annunciate conditions such as when the autopilot is holding a significant and sustained out of trim command (which would indicate a condition for which the autopilot is compensating, such as icing, fuel imbalance, or an engine failure), or if the airplane is in an unusual bank or pitch attitude beyond those meant for autopilot operations.

If this is determined by industry as the best means of compliance to the revised regulations, there would be the costs associated design, development, and testing of this new alert(s).

Estimated Non-Recurring Design, Development, and Testing Costs associated with new flight deck alert(s):

<u>Specific Data</u>

GAMA — In first application of technology in type of airplane: $120K
Estimated Non-Recurring Design, Development, and Testing Costs associated with subsequent application of technology in type of airplane: $59K

Company #2

Company #3

Estimated Recurring Hardware and Manufacturing Costs (per airplane) associated with new flight deck alert(s): *Minimal. Most, if not all, newly designed airplanes are equipped with "glass cockpits" that do not rely on discrete indicators and wiring, the costs associated with the hardware and manufacture of this new alert(s) are assumed to be minimal. The existing functionality of the flight deck will most likely support addition of a new alert without the need for more hardware and/or wiring. Therefore, any recurring costs should only be associated with the increased costs of the autopilot system itself, and those costs are felt to be minimal when compared to the entire cost of the system for a new TC program.*

<u>Specific Data</u>

GAMA — Minimal

Company #2

Company #3

Estimated Crew Training and Operational Costs: *TBD. However, as this is a new TC program which will require new crew training for all flight crews (unless it is a "common type rating" with another existing airplane model), it is felt that the training costs associated with this item will be minimal, if not zero.*

<u>Specific Data</u>

GAMA — Minimal

Company #2

Company #3

<u>Speed Protection</u>

The proposed FAR 25.1329 (h) states:

Company #1 Minimal

Company #2

Company #3

b. Amended TC Program – Development program with changes being "cut-in" in ongoing production line:

Please refer to 1) above for description of each technical category listed below.

It is assumed that the autopilot system can be updated without requiring major changes to other existing systems, such as requiring installation of a glass cockpit instead of more conventional mechanical flight deck instruments. If systems which interface with the autopilot system are required to change because of this rule, such as the display system requiring an update to support new flight deck annunciation, those costs are included in both the recurring and non-recurring costs shown above in 1).

Autopilot Override

All manufacturing recurring and non-recurring costs associated with this change in 1) above would also apply to 2). Additionally, costs would be incurred by the manufacturer for changes, updates, revisions, etc. to the manufacturing and installation processes, engineering documentation, tooling, and functional testing. Also, the operator would incur some expense for additional/updated crew training.

Estimated costs due to updated/revised manufacturing and installation processes, engineering documentation, tooling, and functional testing:

Specific Data

Company #1

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

Company #1

Company #2

Company #3

Pilot Awareness Flight Deck Annunciation

All manufacturing recurring and non-recurring costs associated with this change in 1) above would also apply to 2). Additionally, costs would be incurred by the manufacturer for changes, updates, revisions, etc. to the manufacturing and installation processes, engineering documentation, tooling, and functional testing. Also, the operator would incur some expense for additional/updated crew training.

Estimated costs due to updated/revised manufacturing and installation processes, engineering documentation, tooling, and functional testing:

Specific Data

Company #1

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

Company #1

Company #2

Company #3

Speed Protection

All manufacturing recurring and non-recurring costs associated with this change in 1) above would also apply to 2). Additionally, costs would be incurred by the manufacturer for changes, updates, revisions, etc. to the manufacturing and installation processes, engineering documentation, tooling, and functional testing. Also, the operator would incur some expense for additional/updated crew training.

Estimated Recurring Hardware and Installation Costs (per airplane) associated with Speed Protection: Minimal. It is assumed that this change can be made to existing airplanes by installation of a new autopilot(s) without any other new/revised hardware or wiring required. Therefore, the only recurring costs associated with this change would be the additional cost of the modified autopilot system itself. For those airplanes which are not equipped with Angle of Attack (AOA) sensors, it is assumed that the system will be designed such that it provides the best functionality it can given those limitations, but installation of AOA sensors to support this functionality will not be required.

Specific Data

Company #1

Company #2

Company #3

Estimated costs due to updated/revised manufacturing and installation processes, engineering documentation, tooling, and functional testing:

Specific Data

Company #1

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

Company #1

Company #2

Company #3

Dedicated Autoflight System Flight Testing in Icing Conditions

Dedicated autopilot testing, either in real icing conditions or with simulated ice shapes on the wing, may be required to certify a new autoflight system for use in icing conditions on an existing airplane. It cannot be stated conclusively, either one way or the other, that this testing will definitely be required. All that can be said is that it *may* be required. If this dedicated testing *is* required, however, it is felt by most that this will be a substantial economic impact to the applicant.

Estimated dedicated autopilot testing in icing conditions, including flight time (airplane and crew), any instrumentation necessary, engineering analysis and documentation of test results, etc.:

Specific Data

Company #1

Company #2

Company #3

c. Existing airplanes modified via STC or ATC in which the new FAR 21.101 (Changed Product Rule) Applies:

All new STC or ATC programs will be begin with the "default" position of being required to comply to the proposed revision to FAR 25.1329 (when it is accepted and published). In order to request the Certifying Authorities for a change from this default position to an earlier (most likely the original) certification basis, an assessment of whether the change to be made to the airplane is considered to be "Significant" or "Not Significant", per FAR 21.101 and AC 21.101-1A. If the change is deemed to be Significant, then this section applies. If the change is deemed to be Not Significant, then see section 4) below.

Given a change is Significant, the costs associated with a program of this nature are very much dependent upon both the airplane itself and the autoflight system which is to be installed. The costs (in general) are similar to those described above for a new TC program. Specific costs, such as numbers for the installation of force transducers on the control column, will be different, as new production recurring costs will be different than retrofit costs (which are generally higher).

It is assumed that the autopilot system can be updated without requiring major changes to other existing systems, such as requiring installation of a glass cockpit instead of more conventional mechanical flight deck instruments. If systems which interface with the autopilot system are required to change because of this rule, such as the display system requiring an update to support new flight deck annunciation, those costs are included below in both the recurring and non-recurring costs.

Specific Data

GAMA Some costs, however, such as for tests with icing shapes or in natural icing, will be higher (these type tests are often part of a new TC program, but they are not normally part of an FGS retrofit program).

Company #2

Company #3

Autopilot Override

The same stipulation applies here as in 1) above, that the use of a force transducer(s) is deemed by the applicant as the best method of compliance to the new rule.

Estimated Non-Recurring Design, Development, and Testing Costs associated with new force transducer(s):

Specific Data

GAMA In first application of technology in type of airplane (i.e. hydraulic controls, cable controls, fly-by-wire controls): $200K
Estimated Non-Recurring Design, Development, and Testing Costs associated with new force transducer(s) in subsequent application of technology in type of airplane: $120K

Company #2

Company #3

Estimated Recurring Hardware and Installation (including airplane downtime) Costs (per airplane) associated with new force transducer(s):

Specific Data

GAMA $18K

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

GAMA None

Company #2

Company #3

Pilot Awareness Flight Deck Annunciation

Estimated Non-Recurring Design, Development, and Testing Costs associated with new flight deck alert(s):

Specific Data

GAMA In first application of technology in type of airplane: $120K
Estimated Non-Recurring Design, Development, and Testing Costs associated with subsequent application of technology in type of airplane: $59K

Company #2

Company #3

Estimated Recurring Hardware and Installation (including airplane downtime) Costs (per airplane) associated with new flight deck alert(s)*: TBD. This item will depend heavily if it is being installed on a conventional flight deck which uses mechanical indicators and discrete lights for warnings, or if the airplane being modified is equipped with a modern "glass cockpit".*

Specific Data

GAMA Minimal

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

GAMA Minimal

Company #2

Company #3

Speed Protection

Estimated Non-Recurring Design, Development, and Testing Costs associated with Speed Protection:

Specific Data

GAMA In first application of technology in type of airplane: $210K
Estimated Non-Recurring Design, Development, and Testing Costs associated with Speed Protection in subsequent application of technology in type of airplane: $120K

Company #2

Company #3

Estimated Recurring Hardware and Installation (including airplane downtime) Costs (per airplane) associated with Speed Protection: Minimal. It is assumed that this change can be made to existing airplanes by installation of a new autopilot(s) without any other new/revised hardware or wiring required. Therefore, the only recurring costs associated with this change would be the additional cost of the modified autopilot system itself. For those airplanes which are not equipped with Angle of Attack (AOA) sensors, it is assumed that the system will be designed such that it provides the best protection it can, given those limitations, but installation of AOA sensors to support this functionality will not be required.

Specific Data

GAMA $40K

Company #2

Company #3

Estimated Crew Training and Operational Costs:

Specific Data

GAMA Minimal

Company #2

Company #3

Dedicated Autoflight System Flight Testing in Icing Conditions

Dedicated autopilot testing, either in real icing conditions or with simulated ice shapes on the wing, may be required to certify a new autoflight system on an existing airplane. It cannot be stated conclusively, either one way or the other, that this testing will definitely be required. All that can be said is that it *may* be required. If this dedicated testing *is* required, however, it is felt by most that this will be a substantial economic impact to the applicant.

Estimated dedicated autopilot testing in icing conditions, including flight time (airplane and crew), any instrumentation necessary, engineering analysis and documentation of test results, etc.:

Specific Data

GAMA It is anticipated that the preamble to the rule will contain the language as discussed in the plenary to meeting #15 of FGSHWG:

For amended TC and STC projects (e.g. where an existing, approved autopilot is replaced by another autopilot), a review of field history data may be conducted to assist in determining the extent of flight testing that is required. Where there is a lack of autopilot-related accidents and/or incidents in the icing environment, consideration should be given to showing compliance without the need for additional flight tests with ice shapes or in natural icing.

If it is determined during compliance plan negotiations with the Authority that testing of the FGS with ice shapes or in natural icing is NOT required, and compliance is shown through analysis of field history data, then the following additional costs will be incurred:

Estimated Non-Recurring field history analysis costs associated with showing compliance to the new icing environment assessment: $10K

Company #2

Company #3

Estimated Crew Training and Operational Costs: Minimal

Specific Data

GAMA — If it is determined during compliance plan negotiations with the Authority that testing of the FGS with ice shapes or in natural icing IS required, then the following additional costs will be incurred:

Estimated Non-Recurring Design, Development, and Testing Costs associated with icing environment tests: $270K

Estimated Recurring Hardware and Installation costs (per airplane) associated with autopilot flight tests in the icing environment: Minimal

Estimated Crew Training and Operational Costs: Minimal

Company #2

Company #3

d. Existing airplanes modified via STC or ATC in which the new FAR 21.101 (Changed Product Rule) Does NOT Apply:

Refer to the discussion above for applicability of the Changed Product Rule to a program involving an autoflight system change or addition. A change that could be considered to be Not Significant would be a replacement of one autoflight system (such as an analog system with individual hardware elements) with another autoflight system (such as an integrated digital system) of exactly the same capabilities and functionality. Per AC 21.101-1A, this change could considered to be Not Significant and therefore not be subject to the proposed regulations.

No "delta" costs are associated with a program of this type.

Specific Data

GAMA — Minimal

Company #2

Company #3

b. Other Issues

(1) Will small businesses be affected? *(In general terms, "small businesses" are those employing 1,500 people or less. This question relates to the Regulatory Flexibility Act of 1980 and the Small Business Regulatory Enforcement Fairness Act of 1996.)*

Possibly. A small business, either an airplane owner and/or an STC applicant, could desire to install an autopilot in a previously certified Part 25 airplane and that change is deemed Significant under the Changed Product Rule (21.101). Therefore, that changed product would then be required to meet the new (proposed) 25.1329 rules, rather than the ones that were in place for the original certification. This could result in design changes to the system and airplane that would not have been required otherwise. However, it is felt that scenarios of this type will not often occur that would involve a small business.

Part 25 OEM's are typically not small businesses, and therefore there are not any small business manufacturers (i.e., new type certification programs) that will be affected.

(2) Will the proposed rule require affected parties to do any new or additional recordkeeping? If so, explain. *[This question relates to the Paperwork Reduction Act of 1995.]*

No.

(3) Will the proposed rule create any unnecessary obstacles to the foreign commerce of the United States -- i.e., create barriers to international trade? *[This question relates to the Trade Agreement Act of 1979.]*

No. This will be a harmonized rule between the FAA and JAA, and will be recognized by other certification agencies as well.

(4) Will the proposed rule result in spending by State, local, or tribal governments, or by the private sector, that will be $100 million or more in one year? *[This question relates to the Unfunded Mandates Reform Act of 1995.]*

No.

4. ADVISORY MATERIAL

a. Is existing FAA or JAA advisory material adequate? Is the existing FAA and JAA advisory material harmonized?

No, the existing advisory material is made obsolete by this rule change. Yes, the Working Group developed a proposed new harmonized advisory circular.

b. If not, what advisory material should be adopted? Should the existing material be revised, or should new material be provided?

New advisory material has been developed to provide an acceptable means of compliance to the new rule.

c. Insert the text of the proposed advisory material here (or attach), or summarize the information it will contain, and indicate what form it will be in (e.g., Advisory Circular, Advisory Circular – Joint, policy statement, FAA Order, etc.)

The proposed draft of AC/ACJ 25.1329-1x is attached to this report.

Appendix 1

Recommendations to the Transport Airplanes and Engines Issues Group (TAEIG) from the Flight Guidance Systems Harmonization Working Group (FGSHWG)

The FGSHWG identified a number of regulatory issues in the process of conducting its activities in response to the Terms of Reference provided by TAEIG. These issues have been developed into recommendations for additional work, or for further consideration, as the activity was considered outside of the scope of work for the FGSHWG. Some of the issues may need further coordination between the regulatory authorities and Industry to determine if, or how, to proceed. This Appendix documents those recommendations and requests that TAEIG consider the information provided in its response to the FAA and JAA is response to the ARAC tasking.

1) The FGSHWG was tasked to:

   Review recommendations that stem from recent transport aviation events and relate to crew error, cockpit automation and in particular, automatic flight control/guidance made by the NTSB, the FAA Human Factors Team, and the JAA Human Factors Steering Group.

   The Group found it necessary to limit the scope of its work and determined it was not in the Group's purview to address the human factors and potential crew confusion issues associated with flight management systems. The Group did address the FGS crew confusion and error issues relating to use of a FGS. In doing so, the FGS interface with an FMS was addressed. However, the Group agreed that a similar activity should be undertaken to address similar crew confusion and error issues associated with FMS operations.

   Recommendation – Consideration should be given to producing an AC/ACJ, or similar material, that provides guidance on human machine interface issues associated with the use of flight management systems (FMS).

2) The FGSHWG was tasked to:

   Harmonize acceptable methods of demonstrating compliance with FGS requirements and to propose relevant language for the next revision of the flight test guide AC 25-7(x).

   The JAA does not have an equivalent document to AC 25-7A. The Working Group decided to produce an Appendix to the 25.1329 AC/ACJ that documents flight test procedures related to the update to the 25.1329 rule and the associated guidance material. The JAA members have indicated a preference to make the 'Flight Test' Appendix a second ACJ or AMJ to the rule. The FAA would update AC 25-7A to include the addition material.

   Note: The Working Group has used a philosophy of the "What needs to be evaluated" material goes in the body of the AC/ACJ and the "How to evaluate" material goes in the Flight Test Guide, or ACJ/AMJ Appendix.

   Recommendation – The FAA should consider the material provided in the Flight Test Appendix of the proposed AC/ACJ 25.1329 for integration into AC 25-7A. Care should be taken to ensure that the connectivity between AC/ACJ 25.1329 and AC 25-7A is maintained during that integration. Additionally, the structure of both documents should be carefully considered such that there is little or no duplication of FGS test procedures between the two, and it is readily apparent what material resides in each document. The relative timing and implications of the issuance of AC/ACJ 25.1329 and a revision to AC 25- 7A needs to be considered.

3) The Working Group has attempted to address the overlap in criteria in current autopilot and All Weather Operations [AWO] material. The low visibility aspects have been removed from AC/ACJ 25.1329 and deferred

to the appropriate AWO material. This activity was anticipated as part of the work of the All Weather Operations Harmonization Working Group that shares a significant number of members with the FGSHWG. The effectiveness and consistency of the joint work of the two groups should be reviewed.

Recommendation - Advisory Circulars 120-28D and 120-29A should be reviewed and possibly amended such that the two ACs are consistent with new §25.1329 provisions contained in this package, and that there is no conflicting material contained in those Advisory Circulars and the proposed AC/ACJ 1329. The JAA AWOSG should be tasked to produce Category I criteria consistent JAR ACJ 25.1329 and to review and amend JAR AWO Subparts, as necessary.

4) The FGSHWG was tasked to:

Review §25.1329/1335, JAR paragraphs 25.1329/1335 plus the material contained in NPA 25F-243 in addition to §121.579, and the associated Advisory Circulars 25.1329-1 and ACJ 25.1329. Update and harmonize the Part 25 §/paragraphs and the associated guidance material, in the light of the review of regulatory materials, current certification experience, and changes in technology and system design.

In reviewing FAR 121.579, the Working Group found an inconsistency with current autopilot operations and the operational objectives identified by the Commercial Aviation Safety Team (CAST). This involves the calculation of the autopilot Minimum Use Height (MUH). The Working Group undertook a proposed revision to FAR 121.579 to make it compatible and consistent with all aspects of the work assigned to the Group.

Recommendation – TAEIG should recommend that FAA Flight Standards revise FAR 121.579 as identified in Appendix 5: Additionally, similar changes should be considered for FAR 135.93 for Commuter and On-Demand airplanes. The Working Group feels it vitally important that this rule be updated in lockstep with the final release of the revisions to FAR 25.1329 and AC/ACJ 25.1329. Unless this is done, the operational rule FAR 121.579 will be inconsistent with the material developed by the FGSHWG, as both the operational rule (FAR 121.579) and AC/ACJ 25.1329, discuss how to calculate the autopilot Minimum Use Height (MUH). This could lead to significant confusion for both an applicant and the certifying authority if this material is used without the operational rule being updated. The FGSHWG also recommends that the JAA consider an Operational Rule similar to FAR 121.579, as proposed, to ensure a similar level of consistency.

5) During the course of the proposed rulemaking activity and the writing of the advisory material, it became apparent to the Working Group that there are many operational aspects of a flight guidance system that are not well understood by the flight crew. There was discussion within the Group on the level of information necessary, and the means, to make the information available to the flight crew. The role of the Airplane Flight Manual was discussed (i.e., regulated) along with various other documents such as Flight Crew Operations Manuals and Flight Crew Training Manuals. The Group believes that improvements are necessary in the material made available to the flight crew if improvements are to be made in reducing crew confusion and error.

The type of information that the Working Group feels should be made available to pilots include:

<u>Overall flight deck design/operating philosophy</u>. This would include such things as any high level concepts, such as a "quiet dark cockpit", or overall philosophy which drove the design of flight deck controls, displays, aural warnings, etc. In other words, an equal emphasis should be given to "Why" it is designed the way it is, in addition to "How" it is operated.

<u>The Flight Guidance System Human/Machine Interface (HMI) design philosophy</u>. Examples include:

The functionality of controls (e.g., the MD-11 Glareshield Control Panel controls "Pull to Engage, Push to Hold" concept).

The use of color or shapes for target bugs on the displays.

<u>Additional information regarding the operation and behavior of the autoflight system, over and above the normal "system description"</u>. An area that causes confusion is the divergence of the pilot's expectations of how the system is going to operate vs. the actual system response. Examples include:

- Detailed operation of the various flight modes (such as how does the Altitude Capture function work when a new altitude is dialed in when the flight guidance system is already in the process of capturing the old altitude, how the engaged flight guidance systems (both autopilot and autothrust) respond when they are in a Go Around mode and what must the pilot do to exit from that mode, any specific automatic mode reversions that may take the pilot by surprise).
- The response of not only the flight guidance system but also the basic airplane when a pilot manually overrides an engaged autopilot or autothrust system without first disengaging it.

<u>(Possibly complex) interactions between systems</u>. The interactions of such systems as flight director and autopilot, autopilot and autothrust, and autopilot and the flight management system are a source of pilot confusion. Examples include:

- A description of when the airplane speed is being controlled by thrust vs. when it is being controlled by pitch control.
- What autopilot mode will become active when it is engaged if a flight director has already been selected on.
- How the flight management system modes are integrated with the autopilot modes.

<u>System response to and recovery from unusual flight conditions</u>. Examples include:

- How the system will respond if the airplane exceeds the normal limits of FGS operation (e.g., 35 degrees bank, inverted flight) while the FGS system is engaged.
- How the system will respond if the pilot attempts to be engaged the system when the airplane is already outside the normal limits of operation (e.g., will the FGS system attempt to return the airplane to a normal attitude, will it disconnect immediately).

<u>Speed/Envelope Protection</u>. A detailed explanation should be provided of how speed protection (both high and low speed) and envelope protection (if provided) will operate. Examples include:

- How the system will respond with and without an operational autothrust system.
- Will the aircraft divert altitude to protect speed in all operational modes vs. only specific modes.
- Will the system disconnect at any time beyond the speed protection limits vs. always staying engaged and attempt to return the airplane within the normal operational limits.
- When the system will take active control vs. when the system relies on the pilot taking appropriate action based on a flight deck alert.
- Will the autothrust system automatically engage if not already engaged and speed protection is required.

Recommendation - This issue should be highlighted to the FAA Aircraft Evaluation Group (AEG) and JAA Operations communities with a recommendation that work should be undertaken with Industry to determine how to standardize the type and scope of material necessary to improve the flight crew's understanding of modern highly automated flight decks.

(*Note*: This type of recommendation has been made previously in the FAA Human Factors Team Report titled "The Interfaces Between Flightcrews and Modern Flight Deck Systems".)

6) The FAA developed autopilot interim policy to address many of the issues in the Working Group's Terms of Reference.

Recommendation - FAA interim Autopilot policy ANM-99-01 should be canceled upon publication of §25.1329 and AC/ACJ 25.1329.

7) The Working Group is aware that tasking is in work to update AC/AMJ 25-11 on display systems. The Working Group has developed generic Heads Up Display (HUD) criteria that should be considered in the

update to this AC/AMJ. Generic HUD criteria is contained in Appendix 4 of this Working Group Report. This material is currently contained in a generic FAA HUD Issue Paper, which is then applied to every certification program that involve a HUD. By placing this material in a published AC, the need for applying the generic Issue Paper to all HUD certification programs would be removed.

Recommendation - The general HUD criteria of Appendix 4 should be made available to the Avionics Harmonization Working Group tasked with updating the AC/AMJ 25-11.

8) The Working Group has defined "Flight Guidance Systems" as being the sum of the autopilot, flight director, and autothrust systems in both the proposed FAR/JAR 25.1329 and proposed accompanying advisory material. The autothrust function is the new addition, as it has not been treated as part of autopilot systems in the past. Nothing in the current AC 25.1329-1A or ACJ 25.1329 addresses any aspect of the autothrust system. However, the autothrust system interfaces with Propulsion Systems. FAR?JAR 25.901 regulates aspects of the autothrust system not covered by the proposed FAR/JAR 25.1329, as do other FAR's, JAR's, Advisory Circulars, FAA notices, and published policy statements. The Working Group concluded that the autothrust system has never been treated as a system and that the current published material governing its design and certification is scattered, not of the same type (e.g., Advisory Circular, rule, policy statement), and has not been rigorously examined for potential areas of confusion, overlap, and conflict.

Recommendation - Consideration should be given to performing a detailed study of the rules, advisory material, notices, policy, etc. that govern the certification of an autothrust system with the intent of:

- Determining what currently published material deals with the autothrust system.
- Determining that the currently published material adequately covers all aspects of the autothrust system.
- Determining if there are any overlaps in coverage, or more importantly, any conflicts in the currently published material.
- If necessary, produce additional Advisory Circular material to cover all aspects of the autothrust system that are currently not covered by the FGS Advisory Circular, specifically those aspects that are currently covered only by FAR's, notices, and policy statements. The ultimate goal should be to have all aspects of the autothrust system covered in Advisory Circulars, so that there is no need to depend on notices and policy statements.

  Note: Theconcern is that an applicant, when looking at the proposed AC/ACJ 25-1329, may not understand that there is additional material that must be considered when designing and certifying an autothrust system, or where it may be found.
- Ensuring that there is sufficient cross-referencing between Advisory Circulars so that an applicant understands, without undue difficulty, where additional advisory material may be found concerning autothrust systems.

Appendix 2
Graphical Representation – Tracing Between Existing and Proposed § 25.1329 Paragraphs

Existing Paragraphs	*Proposed Paragraphs*
(a) [redacted]	(a) [redacted] 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. [redacted] ***Autothrust requirements are new.***
(b) Unless there is automatic synchronization, 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.	(b) The effects of a failure of the system to disengage the autopilot or autothrust functions when manually commanded by the pilot shall be assessed in accordance with the requirements of § 25.1309. ***NEW***
	[redacted]
(c) Each manually operated control for the system must be readily accessible to the pilots.	[redacted]
(d) Quick release (emergency) controls must be on both control wheels, on the side of each wheel opposite the throttles.	[redacted]
	[redacted]

(e) Attitude controls must operate in the plane and sense of motion specified in Sec. 25.777 (b) and Sec. 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 airplane, 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.	(f) Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §§ 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be plainly indicated on, or adjacent to, each control if necessary to prevent inappropriate use or confusion.
(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.	(g) Under any condition of flight appropriate to its use, the Flight Guidance System must not: • produce unacceptable loads on the airplane (in accordance with § 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) If the automatic pilot system can be coupled to airborne navigation equipment, means must be provided to indicate to the flight crew the current mode of operation. Selector switch position is not acceptable as a means of indication.	(h) When the flight guidance system is in use, a means shall 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. ***NEW***
JAR 25.1329(I) [(i) A warning must be provided to each pilot in the event of automatic or manual disengagement of the automatic pilot. (See JAR 25.1322 and its AMJ.)]	(i) The FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.
	(j) Following disengagement of the autopilot, a visual and aural warning 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. ***NEW***
		(l) The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls. ***NEW***
		(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. ***NEW***

Appendix 3

Airbus

FGSHWG Minority Opinion

The Flight Guidance Harmonization Working Group [FGSHWG] was chartered to produce proposed revisions to FAR/JAR 25.1329 and the associated AC/ACJs. The FGSHWG has made a best effort attempt to reach consensus on all issues. This document identifies a Minority Opinion that has been expressed following the consensus building process.

Originator: Didier Delibes

Affiliation: Airbus

Summary of Issue:

New standard for FGS emphasizes the need for a warning in case of Autopilot volunteer disengagement by the crew. It also states that this warning should only be canceled after a second crew action.

The need for a warning to cover Autopilot disengagement not triggered by the crew (Autopilot internal monitoring, failures, …) is commonly agreed. But the recommendation to activate the very same warning at each Autopilot volunteer disengagement does not seem commensurate with the need.

Rule or AC/ACJ Reference(s):

AC/ACJ 25.1329 § 8.2.2.1

Discussion:

The new standard offers some advantages from a pure engineering point of view: a simple and single implementation can cover all cases of AP disengagement. So the issue here is not driven by feasibility or development considerations. The issue that we foresee is from the cockpit perspective and its every day operational use:

The aural alert associated to AP failure should be an aggressive sound. Its activation at each volunteer Autopilot disengagement will contribute to a noisier cockpit, and can generate a burden, typically in approach when coming in the middle of Radio Altitude call-outs or Air Traffic Control landing clearances.

The nuisance rate, i.e. the ratio between warnings triggered by volunteer and conscious disengagement in every day flight, and warnings triggered by undue activation of the Instinctive Disconnect Pushbutton will be very high. There is a risk to train the crew with the reflex action to click or double-click on the Autopilot Instinctive Disconnect just to kill the warning thus compromising crew awareness and warning efficiency the day it will be needed. The fact is that in case of Autopilot volunteer disengagement this warning is unique: All the aircraft systems are healthy!

It is understood that the need is :

- to alert the crew of an undue activation of the Autopilot instinctive disconnect
- to ensure Pilot Not Flying awareness of Pilot Flying action.

One can imagine future design responding to these needs without the activation of a warning.

Recommendation:

It is suggested to adopt a more flexible wording for JAR/FAR 25.1329 and AC/ACJ 25.1329 § 8.2.2.1, to describe the need and the safety concern rather than to prescribe a solution, in order to allow crew awareness of AP volunteer disengagement by alternate means to an aural warning:

- JAR/FAR 25.1329

(j) Following disengagement of the autopilot, a visual and**/or** aural ~~warning~~ **alert** must be provided to each pilot and be timely and distinct from all other cockpit ~~warnings~~ **alerts**.

- AC/ACJ 25.1329

8.1.2.1 Autopilot Disengagement Alerts

Since it is necessary for a pilot to immediately assume manual control following **automatic** disengagement of the autopilot ~~(whether manual or automatic)~~, a visual and aural warning must be given. This warning must be given without delay, and must be distinct from all other cockpit warnings. 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 must 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.

Manual disengagement of the autopilot should cause an alert to be issued to ensure PNF awareness. This alert may be a caution, or a warning if the applicant chooses to implement a common design for both manual and automatic disengagement.

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.

APPENDIX 4

General HUD Material

Background

This material was assembled by the FGSHWG in the conduct of its work developing criteria relating to the guidance aspects of Head Up Displays [HUD]. The following material is considered 'generic HUD criteria, not guidance, and is more appropriately addressed in AC/AMJ 25-11. The FGSHWG is providing this information to TAEIG with the request that it be forwarded to the working group that will work on an update to AC/AMJ 25-11 for consideration in their work.

HUD Characteristics

Restrictions on view

When installed, whether in use or not, the HUD equipment must not create additional obstructions to the pilot's required external field of vision (see JAR 25.773 (a)(1)). The equipment must not restrict the pilot's view of any controls, indicators or other flight instruments.

Restrictions on movement

The HUD equipment must not hinder the movement of the pilots whilst carrying out their normal tasks and emergency procedures, entering or leaving the cockpit, or during emergency egress.

Additional hazards

The HUD equipment must not increase significantly the likely-hood of injury to the pilots in the event of an accident (see JAR 25.785c(2)). It must not present dangers under normal operating conditions or abnormal conditions (e.g. dazzle, high voltage, implosion, projection, un-pressurized flight, presence of smoke).

External lighting levels

The display must be visible in expected operational light levels and against expected operational external scenes. Manually selectable and automatically maintained brightness control suitable for day and night operation must be provided.

Field of view

The binocular instantaneous field of view (IFOV) must not be unduly sensitive to the position of the pilot's head in the wind and turbulence conditions. In the event of a total loss of the display as a result of head movement, the pilot must be able to regain the display symbology rapidly and without difficulty.

From the Eye Reference Point (ERP), the azimuth Instantaneous Field Of View (IFOV) must be sufficient to allow the display to be used without display limitations at the crosswind certified for approach operations in combination with the critical engine inoperative when the airplane is trimmed out.

Optical performance

The HUD combiner and the windshield together must not cause significant optical degradation or distortion of the pilot's view of the outside world.

Symbology design

The designed symbol set (size and font) must be clear and uncluttered and enable easy assimilation of the displayed information. It must have no features that might lead to confusion or to an error by the pilot.

The display format must contain features minimizing the possibility of pilot fixation on the symbology when the aircraft is near the ground.

There must be clear and unambiguous indication to the pilot of pitch and bank. If non-conformal positioning of normally conformal display elements occurs (e.g. horizon line and flight path vector), this must be clearly indicated.

Symbology hierarchy

A symbology hierarchy must be established such that higher priority symbology clearly and unambiguously overwrites lower priority symbology.

Outside world view

As far as practicable the display must not degrade, distort or detract from the pilot's view of the runway or of other aircraft. If an artificial runway or other external ground references are provided they must correlate with the real world as seen by the pilot.

Brightness Variation

The brightness of the outside visual scene may be considered to range from 100 to 8000 foot lamberts over a time period of 5 seconds and from 5 to 1000 foot-lamberts over a similar time period. Manual control of the HUD brightness level should be available to provide compensation beyond this range and to provide the means to set a reference level for automatic brightness control.

Color HUD

As for any color HUD, care must be taken that the interaction of the HUD colors and the background (i.e., out the window) color of lights and terrain does not create confusion for the pilot. Real world color shift should not be misleading.

APPENDIX 5

Proposed Revision to FAR 121.579

Original Text *as of Amdt. 121-265, 62 FR 27922, May 21, 1997*

§ 121.579 Minimum altitudes for use of autopilot.

(a) Enroute operations. Except as provided in paragraphs (b), (c), and (d) of this section, no person may use an autopilot enroute, including climb and descent, at an altitude above the terrain that is less than twice the maximum altitude loss specified in the Airplane Flight Manual for a malfunction of the autopilot under cruise conditions, or less than 500 feet, whichever is higher.
(b) Approaches. When using an instrument approach facility, no person may use an autopilot at an altitude above the terrain that is less than twice the maximum altitude loss specified in the Airplane Flight Manual for a malfunction of the autopilot under approach conditions, or less than 50 feet below the approved minimum descent altitude or decision height for the facility, whichever is higher, except -
(1) When reported weather conditions are less than the basic VFR weather conditions in § 91.155 of this chapter, no person may use an autopilot with an approach coupler for ILS approaches at an altitude above the terrain that is less than 50 feet higher than the maximum altitude loss specified in the Airplane Flight Manual for the malfunction of the autopilot with approach coupler under approach conditions; and
(2) When reported weather conditions are equal to or better than the basic VFR minimums in § 91.155 of this chapter, no person may use an autopilot with an approach coupler for ILS approaches at an altitude above the terrain that is less than the maximum altitude loss specified in the Airplane Flight Manual for the malfunction of the autopilot with approach coupler under approach conditions, or 50 feet, whichever is higher.
(c) Notwithstanding paragraph (a) or (b) of this section, the Administrator issues operations specifications to allow the use, to touchdown, of an approved flight control guidance system with automatic capability, in any case in which -
(1) The system does not contain any altitude loss (above zero) specified in the Airplane Flight Manual for malfunction of the autopilot with approach coupler; and
(2) He finds that the use of the system to touchdown will not otherwise affect the safety standards required by this section.
(d) Takeoffs. Notwithstanding paragraph (a) of this section, the Administrator issues operations specifications to allow the use of an approved autopilot system with automatic capability below the altitude specified in paragraph (a) of this section during the takeoff and initial climb phase of flight provided:
(1) The Airplane Flight Manual specifies a minimum altitude engagement certification restriction;
(2) The system is not engaged prior to the minimum engagement certification restriction specified in the Airplane Flight Manual or an altitude specified by the Administrator, whichever is higher; and
(3) The Administrator finds that the use of the system will not otherwise affect the safety standards required by this section.

[Doc. No. 6258, 29 FR 19219, Dec. 31, 1964, as amended by Amdt. 121-13, 30 FR 14781, Nov. 30, 1965; Amdt. 121-33, 32 FR 13912, Oct. 6, 1967; Amdt. 121-130, 41 FR 47229, Oct. 28, 1976; Amdt. 121-206, 54 FR 34331, Aug. 18, 1989; Amdt. 121-265, 62 FR 27922, May 21, 1997]

Proposed Revised Text

§ 121.579 Minimum heights for use of autopilot.

Unless otherwise approved by the administrator, an autopilot may not be used lower than the applicable heights specified below. Enroute altitudes or heights are considered to be above terrain as applicable to the route flown. For takeoff, approach, or landing, the heights are above the runway touchdown zone elevation, runway elevation, or airport elevation, as applicable.

(a) Takeoff and initial climb.

An autopilot may not be used for takeoff or initial climb below the following height:

(1) Below the value specified in the approved AFM for takeoff, or

(2) If a minimum engagement height is not specified by the AFM, an autopilot may not be used below 500'above the departure airport elevation.

Not withstanding (1) or (2) above, the Administrator may determine that an autopilot engagement height lower than 500 feet above airport elevation, or an engagement height different than that specified by the AFM may be used by issuing operations specifications authorizing an alternate minimum engagement height.

(b) Enroute.

(1) For autopilots certificated in accordance with AC 25.1329 (dated ....), as amended, the autopilot may not be used during cruise at a height less than twice the demonstrated height loss, or 500 feet above applicable terrain, which ever is higher. For autopilots that do not specify a height loss or specify a negligible height loss, the autopilot may not be used during cruise at a height less than 500 feet above applicable terrain.

(2) For autopilots not certificated in accordance with paragraph (1) above, the autopilot may not be used during cruise at a height less than twice the demonstrated height loss, or 500 feet above applicable terrain, which ever is higher. For autopilots that do not specify a height loss, the autopilot may not be used during cruise at a height less than 750 feet above applicable terrain.

(c) Approach.

Except in accordance with section (d) below, no person may use an autopilot during approach at a height that is less than the following, as applicable:

(1) The minimum height specified in the AFM for autopilot approach for the mode(s) used, or

(2) Not lower than a height equal to twice the maximum height loss specified in the Airplane Flight Manual for a malfunction of the autopilot under applicable approach conditions, or less than 50 feet above the landing runway touchdown zone, whichever is higher, or

(3) For systems that are demonstrated to have negligible or zero height loss (below the intended descent flight path) for applicable failure conditions, the autopilot may not be used below 50 feet above the landing runway touchdown zone, runway elevation or airport elevation; or

(4) For systems where a minimum use height, or height loss for approach is not specified in the AFM, an autopilot may not be used at any altitude less than 50 feet below the lowest applicable DA(H) or MDA(H) for the instrument procedure being used, except as follows:

(i) If the pilot determines that suitable visual reference, as specified in § 91.175 of this chapter, has been established during an instrument approach, and can reasonably be expected to be maintained, or

(ii) If weather conditions do not require use of an approved instrument approach procedure, an autopilot may be used for approach no lower than the greatest of the applicable minimum use height specified in the AFM, or twice the applicable height loss, or 50 feet above the landing runway touchdown zone elevation, runway elevation, or airport elevation, as applicable, or

(iii) If an approved and appropriately functioning autoland capability is used in accordance with section (d) below, or

(iv) If the Administrator issues operations specifications authorizing use of a lower autopilot minimum use height, but not less than 50 feet above the landing runway touchdown zone elevation, runway elevation, or airport elevation, as applicable. Issuance of operations specifications based on this provision requires that the certificate holding office determine that a lower minimum use height can be safely used by that operator, for that operators type(s) of aircraft, authorized airport(s), underlying approach terrain, instrument procedures used, applicable DA(H) or MDA(H), and flight crew procedures, or

(v) If executing an autopilot coupled go-around or missed approach, using an appropriately certificated and functioning autopilot with go-around capability.

(d) Landing.

Notwithstanding paragraph (c) of this section, autopilot minimum use height provisions do not apply to autopilot operations when an approved automatic landing system mode is used. Automatic landing systems may not be used except in accordance with approved operations specifications.

(e) Go-Around.

Following a go-around, unless an automatic go-around is accomplished, an autopilot may not be engaged below the minimum height specified in section (a) above for takeoff or initial climb. For an automatic go-around initiated with an autopilot already engaged, an autopilot minimum use height does not apply. Use of automatic go-around capability must not adversely affect safe obstacle clearance.

[Doc. No. 6258, 29 FR 19219, Dec. 31, 1964, as amended by Amdt. 121-13, 30 FR 14781, Nov. 30, 1965; Amdt. 121-33, 32 FR 13912, Oct. 6, 1967; Amdt. 121-130, 41 FR 47229, Oct. 28, 1976; Amdt. 121-206, 54 FR 34331, Aug. 18, 1989; Amdt. 121-265, 62 FR 27922, May 21, 1997; Amdt. 121-xxx, YY FR ZZZZZ, June xx, 2002]

§/JAR 25.1329 Flight Guidance System
[See AC/ACJ 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 requirements of §/JAR 25.1309.

(c) Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a significant transient response affecting the control or flight path of the airplane.

(d) Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path.

(e) Under other than normal conditions, transients affecting the control or flight path of the airplane resulting from the disengagement of any automatic control functions of a flight guidance system must not require exceptional piloting skill or strength to remain within, or recover to, the normal flight envelope.

(f) Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be 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 airplane (in accordance with §/JAR 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 FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.

(j) Following disengagement of the autopilot, a visual and aural warning 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.

TABLE OF CONTENTS

1 PURPOSE

This AC/ACJ describes an acceptable means for showing compliance with the requirements of §/JAR 25.1329 of the Federal Aviation Regulations (FAR) and Joint Airworthiness Requirements (JAR). These means are intended to provide guidance to supplement the engineering and operational judgment that must form the basis of any compliance demonstration.

2 CANCELLATION/EFFECTIVE DATE

AC 25.1329-1A, dated July 8, 1968; and ACJ 25.1329, Change 15 (Amend. 96/1, Effective. 19.4.96) are hereby canceled.

3 RELATED FAR/JAR SECTIONS AND ADVISORY MATERIAL.

FAR/JAR

The following are related FAR/JAR standards:

§ 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	Installation, General Subpart E – Powerplant
§ 25.903	Engines, General Subpart E – Powerplant
§ 25.1301	Function and installation
§ 25.1309	Equipment, systems, and installations
§ 25.1322	Warning, caution, and advisory lights
JAR-OPS 1	Commercial Air Transportation - Aeroplanes
JAR-AWO	All Weather Operations

Advisory Circulars, Advisory Material Joint.

The following guidance and advisory materials are referenced in this AC:

AC 20-115B	Radio Technical Commission for Aeronautics Document RTCA/DO 178B
AC 20-129	Airworthiness Approval of Vertical Navigation (VNAV) Systems for use in the U.S. National Airspace System (NAS) and Alaska
AC 25-7A	Flight Test Guide for Certification of Transport Category Airplanes
AC 25-11	Transport Airplane Electronic Display Systems

AC 25-12	Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category Airplanes
AC 25.1309-1A	System Design and Analysis
AC 25.1581-1	Airplane Flight Manual
AC 120-28D	Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout
AC 120-29A	Criteria for Approving Category 1 and Category II Landing Minima for FAR 121 Operators
AC 120-41	Criteria for Operational Approval of Airborne Windshear Alerting and Flight Guidance Systems
AC for 25.671	(in work from FCHWG)
ACJ 25.1309	System Design Analysis
AMJ 25-11	Electronic Display systems
AMJ 25.1581	Airplane Flight Manual
AMJ 25.1322	Alerting Systems

4 RELATED DOCUMENTS

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	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 requirements of §/JAR 25.1329 and the guidance material provided in this AC/ACJ. They should not be assumed to apply to the same or similar terms used in other regulations or AC's/ACJ's. Terms for which standard dictionary definitions apply are not defined in this AC.

5.1 Definitions

Abnormal Condition	See Non-normal
Advisory	JAA: Crew awareness is required and subsequent crew action may be required. (AMJ 25.1322)
Alert	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 airplane 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. JAA 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. (AMJ 25.1322)
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 [AC/ACJ 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 [AC/ACJ 25.1309].
Autopilot	The autopilot function provides automatic control of the airplane, 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 airplane. 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 airplane 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 [AC/ACJ 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 airplane 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 [AC/ACJ 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 crew member or maintenance personnel, or a mistake in requirements, design, or implementation [AC/ACJ 25.1309].
Failure	An occurrence which 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). NOTE: Errors may cause failures, but are not considered to be failures [AC/ACJ 25.1309].
Failure Condition	A condition having an effect on the airplane 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 [AC/ACJ 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:

(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 airplane as command information to direct the pilot how to maneuver the airplane, 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 A system consisting of one or more of the following elements:

(a) autopilot,

(b) flight director,

(c) automatic thrust control,

and any interactions with stability augmentation and trim systems.

Flight Management System 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).

Head-Up Display (HUD) 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 light guidance system.

Inadvertent A condition or action that was not planned or intended.

Latent Failure 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 [AC/ACJ 25.1309].

Limit Flight Envelope This envelope is the most outside flight envelope, generally associated with airplane design limits

Mode A mode is system configuration that corresponds to a single (or set of) FGS behavior(s).

Non-normal Condition	A condition or configuration of the airplane that would not normally be experienced during routine flight operations - usually due to failures.
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 airplane manufacturer as consistent with conducting flight operations for which the airplane 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 airplane due to significant environmental conditions (e.g., significant wind, turbulence, or icing, etc.) or non-routine operating conditions (e.g., out-of-trim due to fuel imbalance or under certain ferry configurations, or extremes of weight/c.g. combinations).
Redundancy	The presence of more than one independent means for accomplishing a given function or flight operation [AC/ACJ 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 airplane (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 [AC/ACJ 25.1309].
Transient	A disturbance in the control or flight path of the airplane that is not consistent with response to flight crew inputs or environmental conditions. a. Minor transient: A transient that would not significantly reduce airplane safety, 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: that would lead to a significant reduction in safety margins, an increase in flight crew workload, discomfort to the flight crew, or physical distress to passengers or cabin crew, possibly including non-fatal injuries. __NOTE__: The flight crew should be able to respond to any

significant transient without:

- exceptional piloting skill, alertness, or strength,
- forces greater than those given in §/JAR 25.143(c), and
- accelerations or attitudes in the airplane 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 airplane system requiring immediate recognition. Immediate corrective or compensatory action by the flight crew is required.

5.2 Acronyms

AC	Advisory Circular
ACJ	Advisory Circular Joint
AFM	Airplane Flight Manual
AGL	Above Ground Level
AIM	Airman's Information Manual
AMJ	Advisory Material Joint
ARP	Accepted and Recommended Practice
ATC	Air Traffic Control
AWO	All Weather Operations
CG	Center 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 System
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 AC/ACJ 25.1329 for autopilots. 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 AC, 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 airplane. 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 behavior; modes of operation; pilot interface with controls, indications, and alerts; and mode functionality.

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

Subsequent sections of this advisory material provide acceptable means of compliance with §/JAR 25.1329 and the applicability of other Part 25 rules to FGS (e.g., §/JAR 25.1301, §/JAR 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 program, 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 AC/ACJ the term "FGS" includes all the equipment necessary to accomplish the FGS function, including the sensors, computers, power supplies, servo-motors/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 FAR/JAR 25.1329

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

TABLE 7.3-A.

Where Means of Compliance Can Be Found in this AC

Section / Paragraph	Rule Text	Where Acceptable Means of Compliance Found in this AC
§/JAR 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.*	Section 8.1, Autopilot Engagement/Disengagement and Indications Section 8.3, Autothrust Engagement/Disengagement and Indications
§/JAR 25.1329 (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 requirements of §/JAR 25.1309.*	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
§/JAR 25.1329 (c)	*Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a significant transient response affecting the control or flight path of the airplane.*	Section 8, FGS Engagement, Disengagement, and Override Section 13, Safety Assessment
§/JAR 25.1329(d)	*Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path.*	Section 8, FGS Engagement, Disengagement, and Override Section 13, Safety Assessment

§/JAR 25.1329 (e)	*Under other than normal conditions, transients affecting the control or flight path of the airplane resulting from the disengagement of any automatic control functions of a flight guidance system must not require exceptional piloting skill or strength to remain within, or recover to, the normal flight envelope.*	Section 8, FGS Engagement, Disengagement, and Override
§/JAR 25.1329 (f)	***Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be plainly indicated on, or adjacent to, each control if necessary to prevent inappropriate use or confusion.***	**Section 9, Controls, Indications and Alerts**
§/JAR 25.1329 (g)	*Under any condition of flight appropriate to its use, the Flight Guidance System must not:* • *produce unacceptable loads on the airplane (in accordance with §/JAR 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.*	Section 10, Performance of Function Section 13, Safety Assessment Section 14, Compliance Demonstration using Flight Test and Simulation
§/JAR 25.1329 (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.***	**Section 10.4, Speed Protection**
§/JAR 25.1329 (i)	*The FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.*	Section 9, Controls Indications and Alerts

§/JAR 25.1329 (j)	*Following disengagement of the autopilot, a visual and aural warning must be provided to each pilot and be timely and distinct from all other cockpit warnings.*	Section 8.1.2.1, Autopilot Disengagement Alerts Section 13, Safety Assessment
§/JAR 25.1329 (k)	*Following disengagement of the autothrust function, a caution must be provided to each pilot.*	Section 8.3.2, Autothrust Disengagement Section 13, Safety Assessment
§/JAR 25.1329 (l)	*The autopilot must not create an unsafe condition when the flight crew applies an override force to the flight controls.*	Section 8.4.1, Flight Crew Override of the FGS – Autopilot Section 13, Safety Assessment
§/JAR 25.1329 (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.*	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 airplanes. 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 §/JAR 25.1329(i)].

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

For airplanes 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.

In non-maneuvering flight, the engagement of the autopilot should be free of perceptible transients. Under dynamic conditions, including maneuvering 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 airplane to wings level and then hold the airplane 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

Under normal conditions, automatic or manual disengagement of the autopilot should be free of significant transients or out-of-trim forces that are not consistent with the maneuvers being conducted by the airplane at the time of disengagement. If multiple autopilots are engaged, any disengagement of an individual autopilot should be free of significant transients and should not adversely affect the operation of the remaining engaged autopilot(s).

In other than normal conditions (non-normal and rare normal conditions), 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 §/JAR 25.143(c), and
- accelerations or attitudes in the airplane 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

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. This warning must be given without delay, and must be distinct from all other cockpit warnings. 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 must 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

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" should be located on each control wheel or equivalent 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 §/JAR 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.

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, indications should be provided to denote which flight director is engaged (e.g., FD1, FD2). For airplanes 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 maneuvering 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 airplanes equipped with a flight director windshear guidance system, flight director engagement should be provided, consistent with the criteria contained in AC 25-12 and AC 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) 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) and the disengagement should not preclude, inhibit, or interfere with timely thrust changes for go-around, landing, or other maneuvers 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. For automatic disengagement, visual indications should persist until canceled 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 canceled 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 (thrust lever or equivalent). 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**: 25 lbs. of force 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 sidestick or centerstick controller may be different.

A significant transient should not result from autopilot disengagement when the flight crew applies an override force to the controls.

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

2) If the FGS is not designed to disengage in response to any override force, then the response shall be shown to be safe (§/JAR 25.1329 (l)). A significant transient should not result from manual autopilot disengagement after the flight crew has applied an override force to the controls

> **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 maneuver (such as responding to a 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 which 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 maneuver.

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. (§/JAR 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 must 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 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 should be so designed as to minimize flight crew errors and confusion. 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 should be grouped and presented in a logical and consistent manner and be visible from each pilot's station under all expected lighting conditions. The choice of colors, 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 behavior 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 crew member and to prevent crew errors, confusion and inadvertent operation. To achieve this, §/JAR 25.1329 (f) requires that command reference controls to select target values (e.g., heading select, vertical speed) should operate as specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control should be readily apparent or plainly indicated on, or adjacent to, each control if needed to prevent inappropriate use or confusion. §/JAR 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 airplane 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.

9.2 Flight Guidance Mode Selection, Annunciation, and Indication

Engagement of the Flight Guidance System functions should be suitably annunciated to each pilot, as described in Section 8, Flight Guidance System Engagement, Disengagement, and Override. The FGS mode annunciations should effectively and unambiguously indicate the active and armed modes of operation. 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 should indicate the state of the system and not just switch position or selection. 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 airplane. 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. 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. Colors, 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.

Color should be used in a consistent manner and assure compatibility with the overall use of color on the flight deck. Specific colors 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., AC/AMJ 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 colors 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 AC/AMJ 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 behavior.

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

Alerting information should follow the provisions of §/JAR 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, as specified within AC 120-28D. 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 airplane 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 airplane 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 airplane 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 must 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 airplane 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.

9.4 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 airplane 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 must 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 must 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 must 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 shall be minimized. The HUD guidance symbology should not excessively interfere with pilots' forward view, ability to visually maneuver the airplane, 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 labeling (e.g., the command reference indication for "vertical speed" should be displayed in the same foot-per-minute increments and labeled with the same characters as the head-down displays);

(d) Analog 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 color, 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 intended to be 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., 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 must 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 color normally assigned to distinguish and call attention to Cautions and warnings.

For multi-color 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 must 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 maneuver is required (resolution advisory, windshear).

If a Ground Proximity Warning System (GPWS), wind shear detection system, a wind shear escape guidance system, or a 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 must 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 airplane'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 airplane's normal flight envelope.

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

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

  NOTE: In the context of this AC, "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 airplane's intended operation.

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

The FGS should perform its intended function during routine airplane 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 Flight Test Guide (AC 25-7A) and the Autopilot, Flight Director and Autothrust Systems SAE ARP 5366 may prove useful for establishing the general behavior 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 AC, "windshear" is considered a wind gradient of such a magnitude that it may cause damage to the aircraft. Airplanes intended to meet § 121.358 for windshear warning and guidance need flight director windshear guidance. The FGS may also provide suitable autopilot control during windshear. Refer to 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 (check AIM language)
- Severe or unusual types/effects of icing (e.g., airfoil contamination)

10.2.1 Icing Considerations

The FGS typically will be designed to provide acceptable performance in all standard airplane configurations. Operating an airplane in icing conditions can have significant implications on the aerodynamic characteristics of the airplane (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 airplane.

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.

10.3 Performance in Non-Normal Conditions

The FGS will occasionally be operating when the airplane transitions outside of the normal flight envelope of the airplane, when other airplane systems experience failure conditions (e.g., inoperative engine, loss of hydraulics) or when the airplane 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 (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}.

Standard stall warning and high-speed alerts are not always timely enough for the flight crew to intervene to prevent unacceptable speed excursions during FGS operation. 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 airplane 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 Airplane 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 airplanes are normally operated at or above the minimum maneuvering 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 airplane 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 airplane 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 airplane to the defined vertical path or go-around as necessary.

b) The FGS may maintain the defined vertical path as the airplane 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 airplane 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 airplane 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 airplane 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 behavior 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. This is considered consistent with criteria for Category III automatic landing systems, in JAR-AWO 107 and AC 120-28D, Appendix 3, Section 8.1 Automatic Flight Control Systems, which states that it must not be possible to change the flight path of the airplane with the automatic pilot(s) engaged, except by initiating an automatic go-around.

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 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 §/JAR 25.1329(h). The autopilot must 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

§/JAR 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 airplane 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 airplane 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., six knots), 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., six knots), 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 airplane back to within the speed range of the normal flight envelope.

11 CHARACTERISTICS OF SPECIFIC MODES

There are certain operational modes of the FGS that have been implemented in different ways in different airplanes 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 behavior 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 airplane. 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 airplane heading or track. For the situation when the airplane is in a bank when the Heading or Track Hold mode is engaged, the FGS should roll the airplane to a wings-level condition and maintain the heading or track when wings-level is achieved (typically less than five 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 airplane 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 airplane in the same direction as the sense of the selected heading change (e.g., if the pilot turns the heading select knob clockwise, the airplane should turn to the right), even if the shortest heading (or track) change is in the opposite direction. 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 airplane 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 maneuvering capability immediately after takeoff, and limits, should they exist. After takeoff or go-around, maneuvering 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 airplane. 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 airplane, 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 airplane, 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 airplane. 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 armed at all times to capture the selected altitude. Note: assuming that it is armed at all times, then 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 should 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.

(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 maneuver. 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 airplane 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., <200 feet/min) is reached. The intensity of the leveling maneuver 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 airplane 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 airplane 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 airplane 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 leveling 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), then the deviation from that path must 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 airplane. 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 35 feet 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 liftoff:

(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 airplane considering the following factors:

- Normal rate rotation of the airplane to the commanded pitch attitude, at V_R-10 knots for all engines and V_R-5 knots for engine out, should not result in a tail-strike.
- The system should provide commands that lead the airplane 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 10 knots 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 airplane 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 airplane has reached 35 feet 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 liftoff 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 airplane, or provide guidance to rotate the airplane, 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 climbout and airplane 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 maneuver 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 airplane 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 RNAV – refer to AC 120-28D, AC 120-29A, JAR-AWO and JAR-OPS 1).

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 airplane is not established on the final lateral path.

Additional guidance and criteria is contained in AC 120-29A, AC 120-28D and JAR-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 airplane. 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 the same 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 maneuver the airplane 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 maneuver the airplane 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 requirements of §/JAR 25.143(c) 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 airplane.

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

(c) It should be possible to perform all normal maneuvers 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 airplane 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 §/JAR 25.143(f), account should be taken of such adjustments to trim as may be carried out by the automatic pilot in the course of maneuvers that can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged maneuvers, 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 maneuver.

(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 airplane during manual flight. In both cases, it is the pilot who is in actual control of the flight path and speed of the airplane. 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 Advisory Circular 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 airplane 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.

- A Touch Control System (TCS) is a function that is available on many business and commuter aircraft. With a TCS system, 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 maneuver the airplane 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 airplane 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 airplane as desired using the flight deck controls without first disengaging the autopilot. When the pilot releases the controls, the autopilot reassumes control of the airplane 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 airplane 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 §/JAR 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 can not 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

§/JAR 25.1309 defines the basic safety requirements for airworthiness approval of airplane systems and AC/ACJ 25.1309 provides an acceptable means of demonstrating compliance with this rule. This section provides additional guidance and interpretive material for the application of §/JAR 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 AC/ACJ 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 AC/ACJ 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 §/JAR 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 airplane 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 airplane's flight path utilizing the airplane's aerodynamic control surfaces,
- guidance provided to the flight crew to achieve a particular desired flight path or maneuver, through information presented on a head-down or head-up display system, and
- control of the thrust applied to the airplane.

Dependent upon the functionality provided in a specific FGS, the failure conditions could potentially impact the following:

- the control of the airplane 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 airplane,
- 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 airplane.

NOTE:: The safety assessment of a FGS for use in supporting takeoff, approach and landing operations in low visibility conditions is further addressed in AC 120-29A, AC 120-28D, and JAR-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 airplane 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, airplane 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 airplane certification programs are identified. The classifications of Failure Conditions should be agreed with the authority during the §/JAR 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 §/JAR 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 §/JAR 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 airplane. 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 airplane 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 airplane to failures in an automatic flight control system could have implications on the safety of operations when the airplane is close to the ground. For the purpose of this advisory circular, close to the ground can be assumed to be less than 500 feet above the liftoff 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 AC 120-29A, AC 120-28D, and JAR AWO Subparts should be used for those additional considerations.

13.5.2.1 Takeoff

If approval is sought for engagement of the autopilot below 500 feet after liftoff, 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 airplane should be conducted. An Autopilot Minimum Engage Altitude after Takeoff will be established based, in part, on the characteristics of the airplane 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 500 feet,
- a significant increase in pitch attitude that results in the airplane 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 500 feet 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 airplane 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 airplane 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 500 feet above touchdown,
- a significant increase in pitch attitude that results in the airplane 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 centerline, 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 airplane 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 AC/ACJ 25.1309.

The §/JAR 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 §/JAR 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 maneuvers 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 airplane 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 behavior 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, then the following criteria should be considered for applicability in developing the overall and integrated flight test and simulation requirements:

- Advisory Circular 120-29A, "Criteria for Approving Category I and II Landing Minima for FAR 121 Operators"
- Advisory Circular 120-28D, "Criteria for Approval of Category III Landing Weather Minima" need to be included in the requirements to be tested.
- JAR AWO Subparts 1, 2, 3 and 4
- JAR-OPS 1

AC 25-7A, Flight Test Guide For Certification of Transport Category Airplanes (Section 181, Automatic Pilot System), contains procedures that may be used to show compliance.

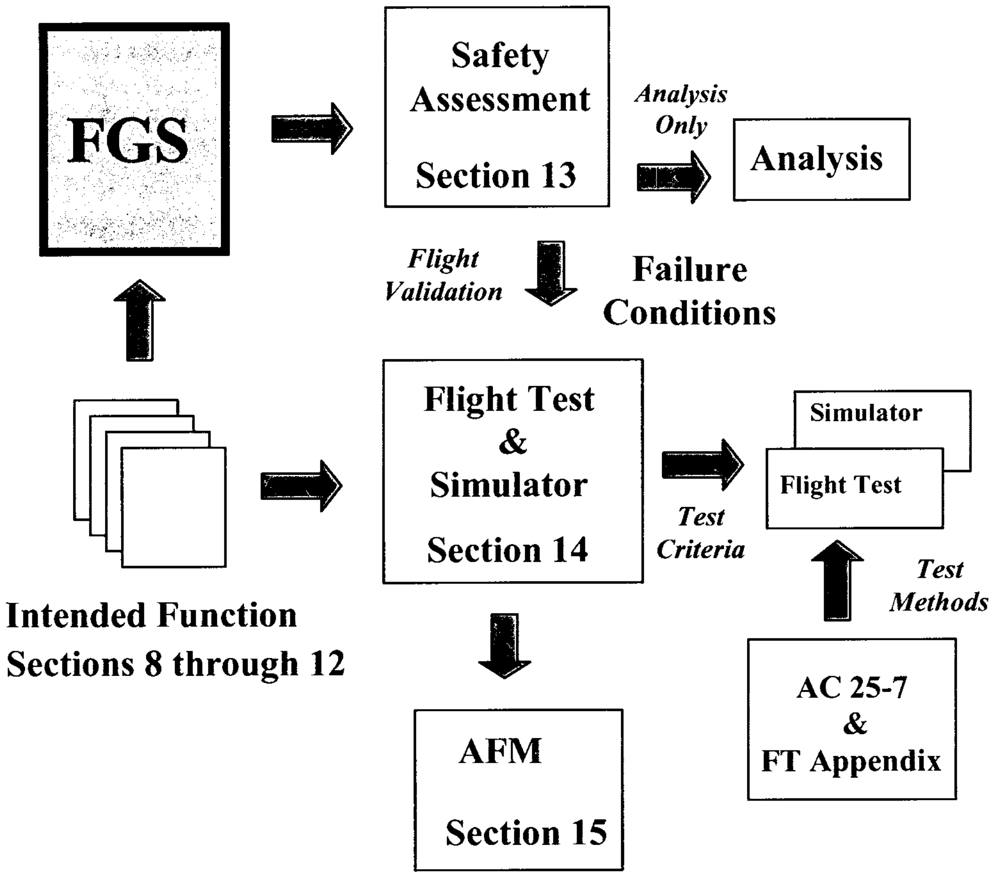

Figure 14-1

14.1 Performance Demonstration (Fault Free) – FAR/JAR 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 airplane configurations and a representative range of airplane weight, center 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 behavior of the airplane. The level of acceptable performance may vary according to airplane type and model. The FGS should be evaluated for its low and high maneuvering capability. AC 25-7A, Flight Test Guide 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 airplane'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 airplane 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, as the opportunity present itself (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 microbursts. 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 airplane wings and surfaces can progressively change the aerodynamic characteristics and stability of the airplane. 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, center 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 airplane, 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 airplane when the autopilot disengages (manual or automatic) should be determined. (Refer to Sections 8.1.2 and 9.3.3)

If the airplane is configured with a de-icing system, the autopilot should demonstrate satisfactory performance during the shedding of ice from the airplane.

Where degradation is noted which is not significant enough to require changes to the autopilot system or to deicing/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 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 airplane 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 AC 120-28, AC 120-29 and JAR AWO Subparts 2 or 3.

The flight evaluation should be conducted to assess the rotation characteristics of the airplane and the performance of the airplane 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:

- Airplane 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 airplane during the initial transition
- Speed performance during airplane 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 maneuver 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 requirements of Chapter 8 of FAA AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes, or equivalent JAA material, should be satisfied. This advisory material contains the airworthiness requirements and transition requirements for steep approaches used to support operational approvals. In addition the requirements of paragraph 6.8 AC 120-29A Appendix 2 (Cat 1)," Criteria for Approving Category I and II Landing Minima for FAR 121 Operators" should be assessed depending on the operational and low visibility requirements.

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 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 airplane 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, center 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 AC/ACJ:

- 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 can 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, 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 can 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 can 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 color, 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 behavior. 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.

NOTE: AC 120-28D, Appendix 3, Section 8 contains guidance for evaluating autopilot override for systems supporting low visibility operations.

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 airplane 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 – FAR/JAR 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.

Appendix FT – Flight Test Procedure, 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.

The flight conditions under which the failure condition is inserted should be the most critical (e.g., center 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 airplane 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 behavior of the airplane (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, 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 airplane may go unrecognized 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 §/JAR 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) Maneuvering Flight - Recovery action should not be initiated until one 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 airplane performance and will respond rapidly once the malfunction has been recognized. A reaction time of one second between recognition point and initiation of recovery is appropriate for this phase of flight.

<u>NOTE</u>:

(i). For the final phase of landing (e.g., below 80 feet), 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 airplane to its normal flight attitude under full manual control without engaging in any dangerous maneuvers during recovery and without control forces exceeding the values given in §/ JAR 25.143 (c). 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 airplane type and flight condition should be performed. This maneuver 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 maneuver.

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 airplane after takeoff and the airplane'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 made as identified in AC 120-28D and JAR 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 Appendix FT – Section 4.2.3.3.

14.2.4 Maneuvering

Where the Safety Analysis identifies a Failure Condition that has a dynamic effect on the roll control of the airplane, 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. This 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 FT Appendix – 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^{o} path starting 50 feet 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 the failure recognition and recovery are assumed to be 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 be 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 may also be considered applicable to RNAV operations

If these effects can not 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 the Flight Test Procedures Appendix FT – 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 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/MDA
- The effect of potential fuel imbalance
- Airplane System Failures (as necessary – requiring specific flight evaluation), e.g.,
  - Hydraulics
  - Electrical
  - Flight Controls
  - FGS related Sensors

The probability of failure of an FGS elements 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 be 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 airplane 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 airplane should not result in penetration of the net flight path as defined in §/ JAR 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 airplane should also be assessed. In all of the above, account should be taken of operating the airplane 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 liftoff (typically 100 feet 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 airplane 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 airplane 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 airplane 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 airplane 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 airplane 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 fifty feet. Considerations for steep approaches are provided in a subsequent section.

The vertical flight path control for a 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 extreme temperature effect should be considered in the operational authorization

The Minimum Use Height is the value identified using method identified in Appendix FT - Section 4.2.3.2 [Method 1].

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 a 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 airplane should be assessed.

For FGS that are failure protected (i.e., fail passive), the minimum engagement height will typically be no lower than 50 feet 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. 50 feet above runway elevation

b. Two times the Height Loss for the airplane as a result of any identified autopilot Failure Condition(s) using the method identified in Appendix FT - Section 4.2.3.3. [Method 2]

14.3.1.3 Circling Approach

For the purposes of this AC, 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 related to climb, cruise or descent are identified during the certification program.

14.3.3 Maneuvering

No specific constraints for the use of the autopilot are considered necessary for maneuvering flight unless unacceptable performance or failure characteristics are identified during the certification program. Section 14.2.4 provides assessment criteria for maneuvering flight for autopilot failures.

14.4 Automatic Disengagement of the Autopilot

The automatic disengagement characteristics of the FGS should be investigated throughout the flight envelope. Automatic disengagement of the FGS system will occur for several reasons such as system failures, sensor failures, unusual accelerations, etc. These disengagement cases should be analyzed to determine the ones that can safely be demonstrated during the test program. The use of simulation is recommended for all conditions that are expected to result in significant transients. For each disengagement, the transients, warnings, and pilot workload for recovery should be evaluated and compliance with §/JAR 25.1329 (d) and (e) should be verified.

14.5 Assessment of Human Factors Considerations

See new section 14.5

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 behavior and operation of the FGS when used by a representative range of pilots.

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. The test participants should include pilots representing the average pilot in the expected fleet.

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 cognitive task analyses;
- Mock-up evaluations and demonstrations;
- Part-task evaluations and demonstrations;
- Simulator evaluations, demonstrations, and tests; and
- Engineering flight evaluations, demonstrations, and tests.

The data from such evaluations may be useful for credit to establish FGS compliance with regulations having human factors considerations. 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 being considered:

- Full physical implementation of flight deck controls, displays, indicators and annunciators for all flight crew positions.
- Adequate emulations of equipment (hardware and software function, including failures) should be incorporated in the simulation.
- Weather simulation including gusts and turbulence.
- Representation of the operational environments, including air traffic, day/night operations, etc, to provide realistic crew workload scenarios.
- Data collection capabilities

Evaluations and tests are intended to generate objective and/or subjective data. It will not always be possible to obtain direct and objective measurements of flight crew performance, even with high fidelity flight or simulation evaluation, demonstration, or test scenarios, and with a broad range of pilots. In these cases, evaluations and tests should be based on the use of structured, subjective methods such as rating scales, questionnaires and/or interviews.

Rationale should be provided for decisions regarding new or unique features in a design. Human factors specialists, together with evaluation pilots, should confirm 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 with the HF-related considerations of the FGS with this AC.

See new section 14.5, next page

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 behavior 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 with the HF-related considerations of the FGS with this AC.

15 AIRPLANE FLIGHT MANUAL (AFM)

The following sections provide guidance on material to be provided in the Airplane Flight Manual (AFM) to ensure that the appropriate information related to FGS operation is translated into air carrier operations. For additional guidance, note that AC 25.1581-1/AMJ 25.1581 addresses requirements of the AFM for transport category aircraft and distinguishes between those aircraft that are used in air carrier operations and those not in air carrier service.

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 AC120-28D, AC 120-29A, and JAR-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 airplane model as established in the course of the type certification process, and as necessary. 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.

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 AFMs 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. 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 should contain operating information sufficient for flight crew reference. 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 1

Recommendations to the Transport Airplanes and Engines Issues Group (TAEIG) from the Flight Guidance Systems Harmonization Working Group (FGSHWG)

The FGSHWG identified a number of regulatory issues in the process of conducting its activities in response to the Terms of Reference provided by TAEIG. These issues have been developed into recommendations for additional work, or for further consideration, as the activity was considered outside of the scope of work for the FGSHWG. Some of the issues may need further coordination between the regulatory authorities and Industry to determine if, or how, to proceed. This Appendix documents those recommendations and requests that TAEIG consider the information provided in its response to the FAA and JAA is response to the ARAC tasking.

1) The FGSHWG was tasked to:

   Review recommendations that stem from recent transport aviation events and relate to crew error, cockpit automation and in particular, automatic flight control/guidance made by the NTSB, the FAA Human Factors Team, and the JAA Human Factors Steering Group.

   The Group found it necessary to limit the scope of its work and determined it was not in the Group's purview to address the human factors and potential crew confusion issues associated with flight management systems. The Group did address the FGS crew confusion and error issues relating to use of a FGS. In doing so, the FGS interface with an FMS was addressed. However, the Group agreed that a similar activity should be undertaken to address similar crew confusion and error issues associated with FMS operations.

   Recommendation – Consideration should be given to producing an AC/ACJ, or similar material, that provides guidance on human machine interface issues associated with the use of flight management systems (FMS).

2) The FGSHWG was tasked to:

   Harmonize acceptable methods of demonstrating compliance with FGS requirements and to propose relevant language for the next revision of the flight test guide AC 25-7(x).

   The JAA does not have an equivalent document to AC 25-7A. The Working Group decided to produce an Appendix to the 25.1329 AC/ACJ that documents flight test procedures related to the update to the 25.1329 rule and the associated guidance material. The JAA members have indicated a preference to make the 'Flight Test' Appendix a second ACJ or AMJ to the rule. The FAA would update AC 25-7A to include the addition material.

   Note: The Working Group has used a philosophy of the "What needs to be evaluated" material goes in the body of the AC/ACJ and the "How to evaluate" material goes in the Flight Test Guide, or ACJ/AMJ Appendix.

   Recommendation – The FAA should consider the material provided in the Flight Test Appendix of the proposed AC/ACJ 25.1329 for integration into AC 25-7A. Care should be taken to ensure that the connectivity between AC/ACJ 25.1329 and AC 25-7A is maintained during that integration. Additionally, the structure of both documents should be carefully considered such that there is little or no duplication of FGS test procedures between the two, and it is readily apparent what material resides in each document. The relative timing and implications of the issuance of AC/ACJ 25.1329 and a revision to AC 25- 7A needs to be considered.

3) The Working Group has attempted to address the overlap in criteria in current autopilot and All Weather Operations [AWO] material. The low visibility aspects have been removed from AC/ACJ 25.1329 and deferred

to the appropriate AWO material. This activity was anticipated as part of the work of the All Weather Operations Harmonization Working Group that shares a significant number of members with the FGSHWG. The effectiveness and consistency of the joint work of the two groups should be reviewed.

Recommendation - Advisory Circulars 120-28D and 120-29A should be reviewed and possibly amended such that the two ACs are consistent with new §25.1329 provisions contained in this package, and that there is no conflicting material contained in those Advisory Circulars and the proposed AC/ACJ 1329. The JAA AWOSG should be tasked to produce Category I criteria consistent JAR ACJ 25.1329 and to review and amend JAR AWO Subparts, as necessary.

4) The FGSHWG was tasked to:

   Review §25.1329/1335, JAR paragraphs 25.1329/1335 plus the material contained in NPA 25F-243 in addition to §121.579, and the associated Advisory Circulars 25.1329-1 and ACJ 25.1329. Update and harmonize the Part 25 §/paragraphs and the associated guidance material, in the light of the review of regulatory materials, current certification experience, and changes in technology and system design.

   In reviewing FAR 121.579, the Working Group found an inconsistency with current autopilot operations and the operational objectives identified by the Commercial Aviation Safety Team (CAST). This involves the calculation of the autopilot Minimum Use Height (MUH). The Working Group undertook a proposed revision to FAR 121.579 to make it compatible and consistent with all aspects of the work assigned to the Group.

   Recommendation – TAEIG should recommend that FAA Flight Standards revise FAR 121.579 as identified in Appendix 5: Additionally, similar changes should be considered for FAR 135.93 for Commuter and On-Demand airplanes. The Working Group feels it vitally important that this rule be updated in lockstep with the final release of the revisions to FAR 25.1329 and AC/ACJ 25.1329. Unless this is done, the operational rule FAR 121.579 will be inconsistent with the material developed by the FGSHWG, as both the operational rule (FAR 121.579) and AC/ACJ 25.1329, discuss how to calculate the autopilot Minimum Use Height (MUH). This could lead to significant confusion for both an applicant and the certifying authority if this material is used without the operational rule being updated. The FGSHWG also recommends that the JAA consider an Operational Rule similar to FAR 121.579, as proposed, to ensure a similar level of consistency.

5) During the course of the proposed rulemaking activity and the writing of the advisory material, it became apparent to the Working Group that there are many operational aspects of a flight guidance system that are not well understood by the flight crew. There was discussion within the Group on the level of information necessary, and the means, to make the information available to the flight crew. The role of the Airplane Flight Manual was discussed (i.e., regulated) along with various other documents such as Flight Crew Operations Manuals and Flight Crew Training Manuals. The Group believes that improvements are necessary in the material made available to the flight crew if improvements are to be made in reducing crew confusion and error.

   The type of information that the Working Group feels should be made available to pilots include:

   <u>Overall flight deck design/operating philosophy</u>. This would include such things as any high level concepts, such as a "quiet dark cockpit", or overall philosophy which drove the design of flight deck controls, displays, aural warnings, etc. In other words, an equal emphasis should be given to "Why" it is designed the way it is, in addition to "How" it is operated.

   <u>The Flight Guidance System Human/Machine Interface (HMI) design philosophy</u>. Examples include:

   The functionality of controls (e.g., the MD-11 Glareshield Control Panel controls "Pull to Engage, Push to Hold" concept).

   The use of color or shapes for target bugs on the displays.

   <u>Additional information regarding the operation and behavior of the autoflight system, over and above the normal "system description"</u>. An area that causes confusion is the divergence of the pilot's expectations of how the system is going to operate vs. the actual system response. Examples include:

- Detailed operation of the various flight modes (such as how does the Altitude Capture function work when a new altitude is dialed in when the flight guidance system is already in the process of capturing the old altitude, how the engaged flight guidance systems (both autopilot and autothrust) respond when they are in a Go Around mode and what must the pilot do to exit from that mode, any specific automatic mode reversions that may take the pilot by surprise).
- The response of not only the flight guidance system but also the basic airplane when a pilot manually overrides an engaged autopilot or autothrust system without first disengaging it.

<u>(Possibly complex) interactions between systems</u>. The interactions of such systems as flight director and autopilot, autopilot and autothrust, and autopilot and the flight management system are a source of pilot confusion. Examples include:

- A description of when the airplane speed is being controlled by thrust vs. when it is being controlled by pitch control.
- What autopilot mode will become active when it is engaged if a flight director has already been selected on.
- How the flight management system modes are integrated with the autopilot modes.

<u>System response to and recovery from unusual flight conditions</u>. Examples include:

- How the system will respond if the airplane exceeds the normal limits of FGS operation (e.g., 35 degrees bank, inverted flight) while the FGS system is engaged.
- How the system will respond if the pilot attempts to be engaged the system when the airplane is already outside the normal limits of operation (e.g., will the FGS system attempt to return the airplane to a normal attitude, will it disconnect immediately).

<u>Speed/Envelope Protection</u>. A detailed explanation should be provided of how speed protection (both high and low speed) and envelope protection (if provided) will operate. Examples include:

- How the system will respond with and without an operational autothrust system.
- Will the aircraft divert altitude to protect speed in all operational modes vs. only specific modes.
- Will the system disconnect at any time beyond the speed protection limits vs. always staying engaged and attempt to return the airplane within the normal operational limits.
- When the system will take active control vs. when the system relies on the pilot taking appropriate action based on a flight deck alert.
- Will the autothrust system automatically engage if not already engaged and speed protection is required.

Recommendation - This issue should be highlighted to the FAA Aircraft Evaluation Group (AEG) and JAA Operations communities with a recommendation that work should be undertaken with Industry to determine how to standardize the type and scope of material necessary to improve the flight crew's understanding of modern highly automated flight decks.

(*Note*: This type of recommendation has been made previously in the FAA Human Factors Team Report titled "The Interfaces Between Flightcrews and Modern Flight Deck Systems".)

6) The FAA developed autopilot interim policy to address many of the issues in the Working Group's Terms of Reference.

   Recommendation - FAA interim Autopilot policy ANM-99-01 should be canceled upon publication of §25.1329 and AC/ACJ 25.1329.

7) The Working Group is aware that tasking is in work to update AC/AMJ 25-11 on display systems. The Working Group has developed generic Heads Up Display (HUD) criteria that should be considered in the

update to this AC/AMJ. Generic HUD criteria is contained in Appendix 4 of this Working Group Report. This material is currently contained in a generic FAA HUD Issue Paper, which is then applied to every certification program that involve a HUD. By placing this material in a published AC, the need for applying the generic Issue Paper to all HUD certification programs would be removed.

Recommendation - The general HUD criteria of Appendix 4 should be made available to the Avionics Harmonization Working Group tasked with updating the AC/AMJ 25-11.

8) The Working Group has defined "Flight Guidance Systems" as being the sum of the autopilot, flight director, and autothrust systems in both the proposed FAR/JAR 25.1329 and proposed accompanying advisory material. The autothrust function is the new addition, as it has not been treated as part of autopilot systems in the past. Nothing in the current AC 25.1329-1A or ACJ 25.1329 addresses any aspect of the autothrust system. However, the autothrust system interfaces with Propulsion Systems. FAR?JAR 25.901 regulates aspects of the autothrust system not covered by the proposed FAR/JAR 25.1329, as do other FAR's, JAR's, Advisory Circulars, FAA notices, and published policy statements. The Working Group concluded that the autothrust system has never been treated as a system and that the current published material governing its design and certification is scattered, not of the same type (e.g., Advisory Circular, rule, policy statement), and has not been rigorously examined for potential areas of confusion, overlap, and conflict.

Recommendation - Consideration should be given to performing a detailed study of the rules, advisory material, notices, policy, etc. that govern the certification of an autothrust system with the intent of:

- Determining what currently published material deals with the autothrust system.
- Determining that the currently published material adequately covers all aspects of the autothrust system.
- Determining if there are any overlaps in coverage, or more importantly, any conflicts in the currently published material.
- If necessary, produce additional Advisory Circular material to cover all aspects of the autothrust system that are currently not covered by the FGS Advisory Circular, specifically those aspects that are currently covered only by FAR's, notices, and policy statements. The ultimate goal should be to have all aspects of the autothrust system covered in Advisory Circulars, so that there is no need to depend on notices and policy statements.

  Note: Theconcern is that an applicant, when looking at the proposed AC/ACJ 25-1329, may not understand that there is additional material that must be considered when designing and certifying an autothrust system, or where it may be found.
- Ensuring that there is sufficient cross-referencing between Advisory Circulars so that an applicant understands, without undue difficulty, where additional advisory material may be found concerning autothrust systems.

Appendix 2
Graphical Representation – Tracing Between Existing and Proposed § 25.1329 Paragraphs

Existing Paragraphs

(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 airplane.**

(b) Unless there is automatic synchronization, 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.

Proposed Paragraphs

(a) **Quick disengagement controls for the autopilot and <u>autothrust</u> functions must be provided for each pilot.** The autopilot quick disengagement controls must be located on both control wheels (or equivalent). The <u>autothrust</u> 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.**

Autothrust requirements are new.

(b) The effects of a failure of the system to disengage the autopilot or autothrust functions when manually commanded by the pilot shall be assessed in accordance with the requirements of § 25.1309.

NEW

(c) thru (e), below, introduce NEW requirements related to <u>transients</u>. These are somewhat related to the intent of the current 25.1329(b)

(c) Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a significant transient response affecting the control of flight patch of the airplane.

(d) Under normal conditions, disengagement of automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path.

(e) Under other than normal conditions, transients affecting the control or flight path of the airplane resulting from the disengagement of any automatic control functions of a Flight Guidance System shall not require exceptional piloting skill or strength to remain within, or recover to, the normal flight envelope.

(e) Attitude controls must operate in the plane and sense of motion specified in Sec. 25.777 (b) and Sec. 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 airplane, 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) If the automatic pilot system can be coupled to airborne navigation equipment, means must be provided to indicate to the flight crew the current mode of operation. Selector switch position is not acceptable as a means of indication.

JAR 25.1329(l)
[(i) A warning must be provided to each pilot in the event of automatic or manual disengagement of the automatic pilot. (See JAR 25.1322 and its AMJ.)]

(f) Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §§ 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be 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 airplane (in accordance with § 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 shall 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.

NEW

(i) The FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.

(j) Following disengagement of the autopilot, a visual and aural warning 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.
NEW

(l) The autopilot must not create an unsafe condition when the flight crew applies an <u>override</u> force to the flight controls.
NEW

(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.
NEW

Appendix 3

Airbus

FGSHWG Minority Opinion

The Flight Guidance Harmonization Working Group [FGSHWG] was chartered to produce proposed revisions to FAR/JAR 25.1329 and the associated AC/ACJs. The FGSHWG has made a best effort attempt to reach consensus on all issues. This document identifies a Minority Opinion that has been expressed following the consensus building process.

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Summary of Issue:

New standard for FGS emphasizes the need for a warning in case of Autopilot volunteer disengagement by the crew. It also states that this warning should only be canceled after a second crew action.

The need for a warning to cover Autopilot disengagement not triggered by the crew (Autopilot internal monitoring, failures, ...) is commonly agreed. But the recommendation to activate the very same warning at each Autopilot volunteer disengagement does not seem commensurate with the need.

Rule or AC/ACJ Reference(s):

AC/ACJ 25.1329 § 8.2.2.1

Discussion:

The new standard offers some advantages from a pure engineering point of view: a simple and single implementation can cover all cases of AP disengagement. So the issue here is not driven by feasibility or development considerations. The issue that we foresee is from the cockpit perspective and its every day operational use:

The aural alert associated to AP failure should be an aggressive sound. Its activation at each volunteer Autopilot disengagement will contribute to a noisier cockpit, and can generate a burden, typically in approach when coming in the middle of Radio Altitude call-outs or Air Traffic Control landing clearances.

The nuisance rate, i.e. the ratio between warnings triggered by volunteer and conscious disengagement in every day flight, and warnings triggered by undue activation of the Instinctive Disconnect Pushbutton will be very high. There is a risk to train the crew with the reflex action to click or double-click on the Autopilot Instinctive Disconnect just to kill the warning thus compromising crew awareness and warning efficiency the day it will be needed. The fact is that in case of Autopilot volunteer disengagement this warning is unique: All the aircraft systems are healthy!

It is understood that the need is :

- to alert the crew of an undue activation of the Autopilot instinctive disconnect
- to ensure Pilot Not Flying awareness of Pilot Flying action.

One can imagine future design responding to these needs without the activation of a warning.

Recommendation:

It is suggested to adopt a more flexible wording for JAR/FAR 25.1329 and AC/ACJ 25.1329 § 8.2.2.1, to describe the need and the safety concern rather than to prescribe a solution, in order to allow crew awareness of AP volunteer disengagement by alternate means to an aural warning:

- JAR/FAR 25.1329

(j) Following disengagement of the autopilot, a visual and**/or** aural ~~warning~~ **alert** must be provided to each pilot and be timely and distinct from all other cockpit ~~warnings~~ **alerts**.

- AC/ACJ 25.1329

8.1.2.1 Autopilot Disengagement Alerts

Since it is necessary for a pilot to immediately assume manual control following **automatic** disengagement of the autopilot ~~(whether manual or automatic)~~, a visual and aural warning must be given. This warning must be given without delay, and must be distinct from all other cockpit warnings. 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 must 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.

Manual disengagement of the autopilot should cause an alert to be issued to ensure PNF awareness. This alert may be a caution, or a warning if the applicant chooses to implement a common design for both manual and automatic disengagement.

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.

APPENDIX 4

General HUD Material

Background

This material was assembled by the FGSHWG in the conduct of its work developing criteria relating to the guidance aspects of Head Up Displays [HUD]. The following material is considered 'generic HUD criteria, not guidance, and is more appropriately addressed in AC/AMJ 25-11. The FGSHWG is providing this information to TAEIG with the request that it be forwarded to the working group that will work on an update to AC/AMJ 25-11 for consideration in their work.

HUD Characteristics

Restrictions on view

When installed, whether in use or not, the HUD equipment must not create additional obstructions to the pilot's required external field of vision (see JAR 25.773 (a)(1)). The equipment must not restrict the pilot's view of any controls, indicators or other flight instruments.

Restrictions on movement

The HUD equipment must not hinder the movement of the pilots whilst carrying out their normal tasks and emergency procedures, entering or leaving the cockpit, or during emergency egress.

Additional hazards

The HUD equipment must not increase significantly the likely-hood of injury to the pilots in the event of an accident (see JAR 25.785c(2)). It must not present dangers under normal operating conditions or abnormal conditions (e.g. dazzle, high voltage, implosion, projection, un-pressurized flight, presence of smoke).

External lighting levels

The display must be visible in expected operational light levels and against expected operational external scenes. Manually selectable and automatically maintained brightness control suitable for day and night operation must be provided.

Field of view

The binocular instantaneous field of view (IFOV) must not be unduly sensitive to the position of the pilot's head in the wind and turbulence conditions. In the event of a total loss of the display as a result of head movement, the pilot must be able to regain the display symbology rapidly and without difficulty.

From the Eye Reference Point (ERP), the azimuth Instantaneous Field Of View (IFOV) must be sufficient to allow the display to be used without display limitations at the crosswind certified for approach operations in combination with the critical engine inoperative when the airplane is trimmed out.

Optical performance

The HUD combiner and the windshield together must not cause significant optical degradation or distortion of the pilot's view of the outside world.

Symbology design

The designed symbol set (size and font) must be clear and uncluttered and enable easy assimilation of the displayed information. It must have no features that might lead to confusion or to an error by the pilot.

The display format must contain features minimizing the possibility of pilot fixation on the symbology when the aircraft is near the ground.

There must be clear and unambiguous indication to the pilot of pitch and bank. If non-conformal positioning of normally conformal display elements occurs (e.g. horizon line and flight path vector), this must be clearly indicated.

Symbology hierarchy

A symbology hierarchy must be established such that higher priority symbology clearly and unambiguously overwrites lower priority symbology.

Outside world view

As far as practicable the display must not degrade, distort or detract from the pilot's view of the runway or of other aircraft. If an artificial runway or other external ground references are provided they must correlate with the real world as seen by the pilot.

Brightness Variation

The brightness of the outside visual scene may be considered to range from 100 to 8000 foot lamberts over a time period of 5 seconds and from 5 to 1000 foot-lamberts over a similar time period. Manual control of the HUD brightness level should be available to provide compensation beyond this range and to provide the means to set a reference level for automatic brightness control.

Color HUD

As for any color HUD, care must be taken that the interaction of the HUD colors and the background (i.e., out the window) color of lights and terrain does not create confusion for the pilot. Real world color shift should not be misleading.

APPENDIX 5

Proposed Revision to FAR 121.579

Original Text ***as of Amdt. 121-265, 62 FR 27922, May 21, 1997***

§ 121.579 Minimum altitudes for use of autopilot.

(a) Enroute operations. Except as provided in paragraphs (b), (c), and (d) of this section, no person may use an autopilot enroute, including climb and descent, at an altitude above the terrain that is less than twice the maximum altitude loss specified in the Airplane Flight Manual for a malfunction of the autopilot under cruise conditions, or less than 500 feet, whichever is higher.
(b) Approaches. When using an instrument approach facility, no person may use an autopilot at an altitude above the terrain that is less than twice the maximum altitude loss specified in the Airplane Flight Manual for a malfunction of the autopilot under approach conditions, or less than 50 feet below the approved minimum descent altitude or decision height for the facility, whichever is higher, except -
(1) When reported weather conditions are less than the basic VFR weather conditions in § 91.155 of this chapter, no person may use an autopilot with an approach coupler for ILS approaches at an altitude above the terrain that is less than 50 feet higher than the maximum altitude loss specified in the Airplane Flight Manual for the malfunction of the autopilot with approach coupler under approach conditions; and
(2) When reported weather conditions are equal to or better than the basic VFR minimums in § 91.155 of this chapter, no person may use an autopilot with an approach coupler for ILS approaches at an altitude above the terrain that is less than the maximum altitude loss specified in the Airplane Flight Manual for the malfunction of the autopilot with approach coupler under approach conditions, or 50 feet, whichever is higher.
(c) Notwithstanding paragraph (a) or (b) of this section, the Administrator issues operations specifications to allow the use, to touchdown, of an approved flight control guidance system with automatic capability, in any case in which -
(1) The system does not contain any altitude loss (above zero) specified in the Airplane Flight Manual for malfunction of the autopilot with approach coupler; and
(2) He finds that the use of the system to touchdown will not otherwise affect the safety standards required by this section.
(d) Takeoffs. Notwithstanding paragraph (a) of this section, the Administrator issues operations specifications to allow the use of an approved autopilot system with automatic capability below the altitude specified in paragraph (a) of this section during the takeoff and initial climb phase of flight provided:
(1) The Airplane Flight Manual specifies a minimum altitude engagement certification restriction;
(2) The system is not engaged prior to the minimum engagement certification restriction specified in the Airplane Flight Manual or an altitude specified by the Administrator, whichever is higher; and
(3) The Administrator finds that the use of the system will not otherwise affect the safety standards required by this section.

[Doc. No. 6258, 29 FR 19219, Dec. 31, 1964, as amended by Amdt. 121-13, 30 FR 14781, Nov. 30, 1965; Amdt. 121-33, 32 FR 13912, Oct. 6, 1967; Amdt. 121-130, 41 FR 47229, Oct. 28, 1976; Amdt. 121-206, 54 FR 34331, Aug. 18, 1989; Amdt. 121-265, 62 FR 27922, May 21, 1997]

Proposed Revised Text

§ 121.579 Minimum heights for use of autopilot.

Unless otherwise approved by the administrator, an autopilot may not be used lower than the applicable heights specified below. Enroute altitudes or heights are considered to be above terrain as applicable to the route flown. For takeoff, approach, or landing, the heights are above the runway touchdown zone elevation, runway elevation, or airport elevation, as applicable.

(a) Takeoff and initial climb.

An autopilot may not be used for takeoff or initial climb below the following height:

(1) Below the value specified in the approved AFM for takeoff, or

(2) If a minimum engagement height is not specified by the AFM, an autopilot may not be used below 500'above the departure airport elevation.

Not withstanding (1) or (2) above, the Administrator may determine that an autopilot engagement height lower than 500 feet above airport elevation, or an engagement height different than that specified by the AFM may be used by issuing operations specifications authorizing an alternate minimum engagement height.

(b) Enroute.

(1) For autopilots certificated in accordance with AC 25.1329 (dated ....), as amended, the autopilot may not be used during cruise at a height less than twice the demonstrated height loss, or 500 feet above applicable terrain, which ever is higher. For autopilots that do not specify a height loss or specify a negligible height loss, the autopilot may not be used during cruise at a height less than 500 feet above applicable terrain.

(2) For autopilots not certificated in accordance with paragraph (1) above, the autopilot may not be used during cruise at a height less than twice the demonstrated height loss, or 500 feet above applicable terrain, which ever is higher. For autopilots that do not specify a height loss, the autopilot may not be used during cruise at a height less than 750 feet above applicable terrain.

(c) Approach.

Except in accordance with section (d) below, no person may use an autopilot during approach at a height that is less than the following, as applicable:

(1) The minimum height specified in the AFM for autopilot approach for the mode(s) used, or

(2) Not lower than a height equal to twice the maximum height loss specified in the Airplane Flight Manual for a malfunction of the autopilot under applicable approach conditions, or less than 50 feet above the landing runway touchdown zone, whichever is higher, or

(3) For systems that are demonstrated to have negligible or zero height loss (below the intended descent flight path) for applicable failure conditions, the autopilot may not be used below 50 feet above the landing runway touchdown zone, runway elevation or airport elevation; or

(4) For systems where a minimum use height, or height loss for approach is not specified in the AFM, an autopilot may not be used at any altitude less than 50 feet below the lowest applicable DA(H) or MDA(H) for the instrument procedure being used, except as follows:

(i) If the pilot determines that suitable visual reference, as specified in § 91.175 of this chapter, has been established during an instrument approach, and can reasonably be expected to be maintained, or

(ii) If weather conditions do not require use of an approved instrument approach procedure, an autopilot may be used for approach no lower than the greatest of the applicable minimum use height specified in the AFM, or twice the applicable height loss, or 50 feet above the landing runway touchdown zone elevation, runway elevation, or airport elevation, as applicable, or

(iii) If an approved and appropriately functioning autoland capability is used in accordance with section (d) below, or

(iv) If the Administrator issues operations specifications authorizing use of a lower autopilot minimum use height, but not less than 50 feet above the landing runway touchdown zone elevation, runway elevation, or airport elevation, as applicable. Issuance of operations specifications based on this provision requires that the certificate holding office determine that a lower minimum use height can be safely used by that operator, for that operators type(s) of aircraft, authorized airport(s), underlying approach terrain, instrument procedures used, applicable DA(H) or MDA(H), and flight crew procedures, or

(v) If executing an autopilot coupled go-around or missed approach, using an appropriately certificated and functioning autopilot with go-around capability.

(d) Landing.

Notwithstanding paragraph (c) of this section, autopilot minimum use height provisions do not apply to autopilot operations when an approved automatic landing system mode is used. Automatic landing systems may not be used except in accordance with approved operations specifications.

(e) Go-Around.

Following a go-around, unless an automatic go-around is accomplished, an autopilot may not be engaged below the minimum height specified in section (a) above for takeoff or initial climb. For an automatic go-around initiated with an autopilot already engaged, an autopilot minimum use height does not apply. Use of automatic go-around capability must not adversely affect safe obstacle clearance.

[Doc. No. 6258, 29 FR 19219, Dec. 31, 1964, as amended by Amdt. 121-13, 30 FR 14781, Nov. 30, 1965; Amdt. 121-33, 32 FR 13912, Oct. 6, 1967; Amdt. 121-130, 41 FR 47229, Oct. 28, 1976; Amdt. 121-206, 54 FR 34331, Aug. 18, 1989; Amdt. 121-265, 62 FR 27922, May 21, 1997; Amdt. 121-xxx, YY FR ZZZZZ, June xx, 2002]

§/JAR 25.1329 Flight Guidance System
[See AC/ACJ 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 requirements of §/JAR 25.1309.

(c) Engagement or switching of the flight guidance system, a mode, or a sensor must not produce a significant transient response affecting the control or flight path of the airplane.

(d) Under normal conditions, the disengagement of any automatic control functions of a flight guidance system must not produce any significant transient response affecting the control or flight path of the airplane, nor require a significant force to be applied by the pilot to maintain the desired flight path.

(e) Under other than normal conditions, transients affecting the control or flight path of the airplane resulting from the disengagement of any automatic control functions of a flight guidance system must not require exceptional piloting skill or strength to remain within, or recover to, the normal flight envelope.

(f) Command reference controls (e.g., heading select, vertical speed) must operate consistently with the criteria specified in §/JAR 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be 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 airplane (in accordance with §/JAR 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 FGS functions, controls, indications, and alerts must be designed to minimize flight crew errors and confusion concerning the behavior 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.

(j) Following disengagement of the autopilot, a visual and aural warning 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.

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 AC/ACJ 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 airplane 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 airplane 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 airplane;
- 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 airplane certification programs. The specific number and type of Failure Condition may vary with airplane type, airplane 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 airplane certification programs:

- A load on any part of the primary structure sufficient to cause a structural failure preventing safe flight and landing (Refer to §/JAR 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 §/JAR 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 airplane certification programs:

- Exceedance of an 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 1000 ft. (304.8 m above an applicable airport elevation);
- Degradation of the flying qualities of the airplane that excessively increases flight crew workload;
- Failure that could result in a RTO and high speed overrun (e.g., 60 knots)
- A flight path deviation that requires a severe maneuver to prevent contact with obstacle, terrain or other aircraft.

  NOTE: Severe maneuver 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 airplane certification programs:

- A flight path deviation, a required recovery maneuver, 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 airplane or be serving or consuming hot drinks).
- Degradation of the flying qualities of the airplane that significantly increase flight crew workload.

APPENDIX FT - FLIGHT TEST PROCEDURES

NOTE: This Appendix contains Flight Test procedures that can be used to validate the operation of an FGS consistent with the update to AC/ACJ 1329. The expectation is that the FAA would integrate this material in an update to AC 25-7 – Flight Test Guide.

The JAA will include this material as an AMJ Number 2 to JAR 25.1329.

FT.1 General

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 will need to be assessed.

Some aspects of the design may be validated by laboratory test and/or simulator evaluation. It is recommended that an applicant provide a certification flight demonstration plan to the authorities at a timely point in development program.

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 airplane type and configuration.

The modes of the FGS should be demonstrated in representative airplane configurations and under a representative range of flight conditions.

The following are specific test procedure that can assist in that demonstration program.

FT.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.

FT2.1 Low Speed Protection

The low speed protection feature in an FGS is intended to prevent loss of speed to an unsafe condition [Refer to AC/ACJ 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. <u>High Altitude Cruise Evaluation</u>.

   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 behavior 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 3000 feet MSL and 250 knots, 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 8000 feet MSL.

d) Make a flight level change to 8000 feet with a 250 knots 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 airplane trajectory and behavior.

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 airplane to decelerate at about 1 knot per second.

c) As the airspeed decreases, observe the airplane trajectory and behavior.

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} + 40 knots) with the thrust at idle power until low speed protection activates.

d) As the airspeed decreases, observe the airplane trajectory and behavior.

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 must 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.

FT.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 AC/ACJ 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 an acceleration beyond V_{MO}/M_{MO}

   d) As the airspeed increases, observe the behavior 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 V_{MO}/M_{MO}, or other appropriate speed.

2. High Altitude Level Flight Evaluation without Autothrust function

   a) Select a thrust value that will result in acceleration beyond V_{MO}/M_{MO} .

   b) As the airspeed increases, observe the basic airplane overspeed warning activate between V_{MO} + 1 and V_{MO} + 6 knots.

   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 airplane depart the selected altitude.

   e) After sufficient time has elapsed to verify and record FGS behavior has elapsed, reduce the thrust as necessary to cause the airplane to begin a descent.

   f) Observe the FGS behavior 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 V_{MO}/M_{MO} with the FGS engaged in altitude hold

   b) Select vertical speed mode that will result in acceleration beyond V_{MO}/M_{MO}

   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 must 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

FT.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.

FT.3.1 Icing

The accumulation of ice on the airplane wings and airframe can have an effect on airplane characteristics and FGS performance. FGS operations may mask the onset of an airplane 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 airplane evaluation with 'ice shapes'.

The following conditions should be considered for evaluating FGS performance under 'icing conditions':

(a) "Holding ice" as defined by JAR/FAR 25 Appendix C (Note - subject of future NPA/NPRM action)

(b) Medium to light weight, symmetric fuel loading

(1) High lift devices retracted configuration:

Slow down at 1 knot/sec 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 airplane 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 airplane accretes or sheds ice asymmetrically it should be possible to disengage the autopilot at any time without unacceptable out of trim forces.

(4) General maneuverability 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.

FT.4 Failure Conditions

This section contains criteria relating to airplane system Failure Conditions identified for validation by a system Safety Assessment.

FT.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 airplane (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 airplane 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.

FT.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 airplane 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 airplane. 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.

FT.4.2.1 Takeoff

This material addresses the use of a FGS after rotation for takeoff.

Section 13 identified the key considerations for this phase of flight to be the effect on the net flight path and the speed control after liftoff. Automatic control is not typically provided for the takeoff roll. It may however be selected soon after liftoff. Failure Conditions may be introduced with this engagement.

For the initial liftoff through flap retraction, it can be assumed that the flight crew is closely monitoring the airplane movements and a maximum crew response time after recognition would be one second.

FT.4.2.2 Climb, Cruise, Descent and Holding and Maneuvering

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.

FT.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

FT.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 one 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..

FT.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 15 feet above the threshold. The method of determination maybe by 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.

FT.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.

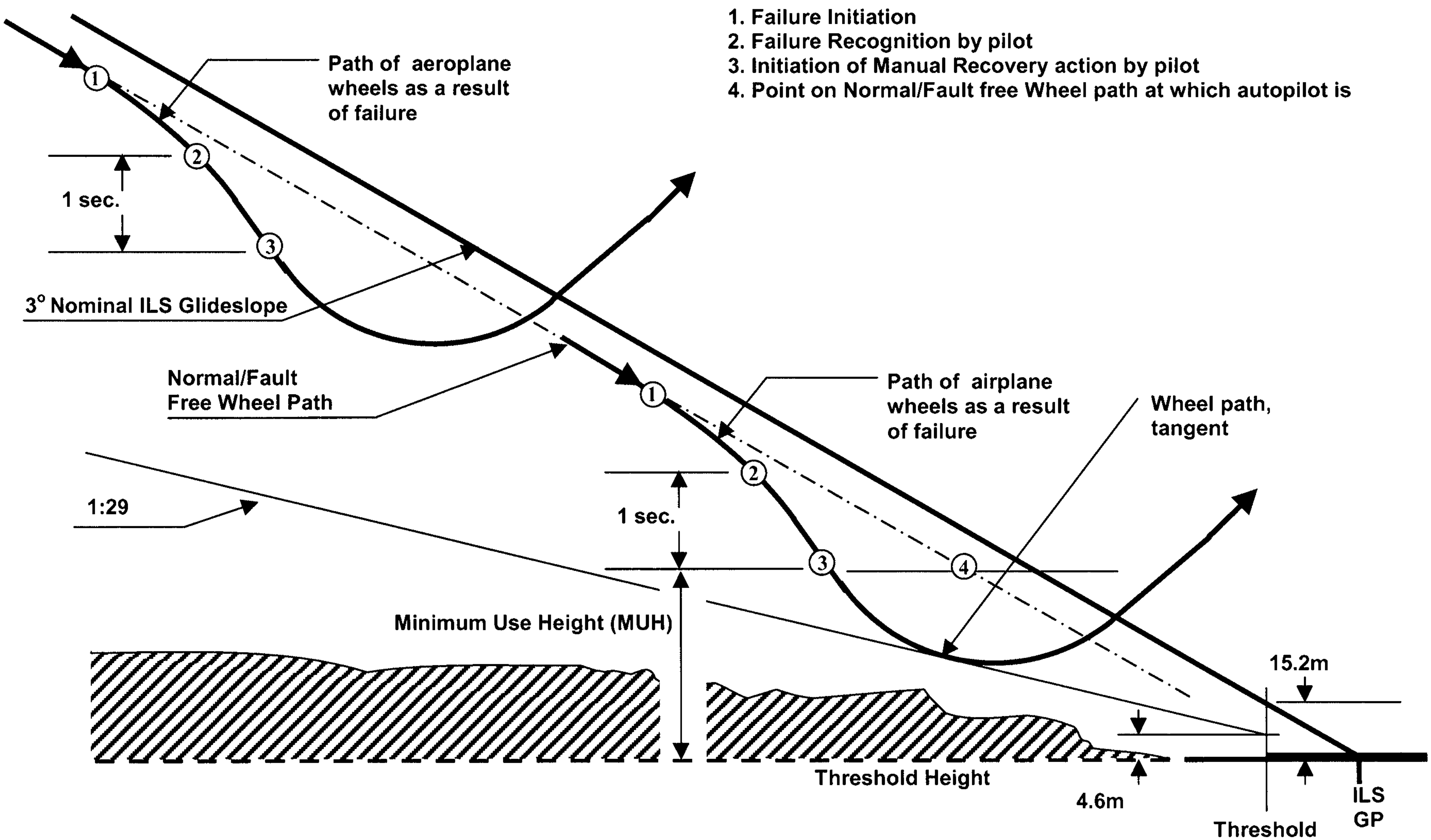

Figure FT – 1 Deviation Profile Method

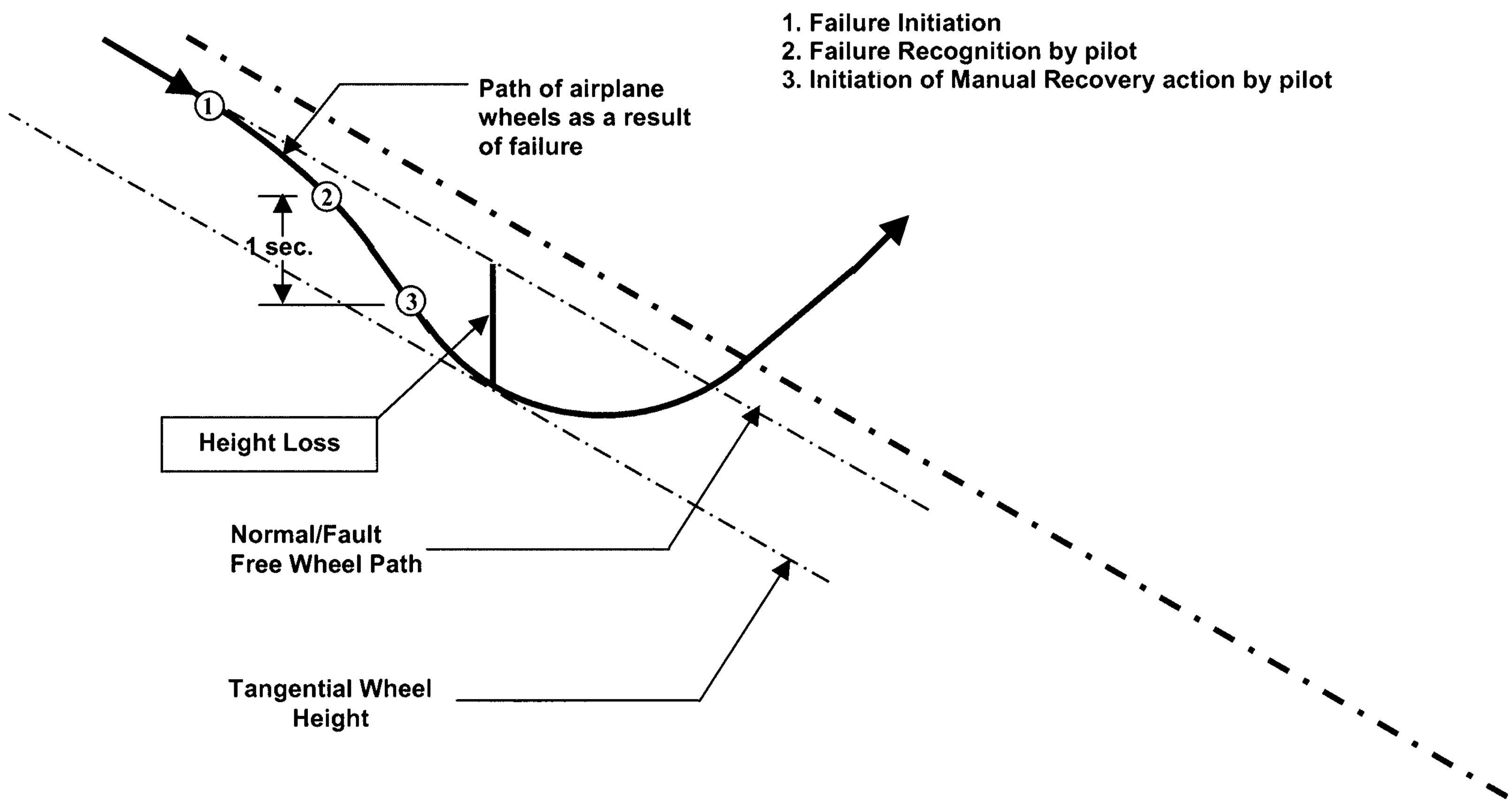

Figure FT – 2 Height Loss Method

FT.4.3 Autopilot Override

The initial tests to demonstrate compliance should be accomplished at an intermediate altitude and airspeed e.g. 15000 feet MSL and 250 knots. With the autopilot engaged in altitude hold, the pilot should apply a low force 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 airplane. Verify that the transient response is in compliance with Section 8.4.

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 airplane.

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 airplane and verify that the transient response is in compliance with Section 8.4.

> **NOTE**:: During hardover testing as described in Chapter 6 of AC 25-7A there will be several opportunities throughout the flight envelope to conduct these tests. The evaluation of the manual disconnects would include the forces required for an autopilot disengage, (not too light, but not too high,), the transients characteristics associated with each one (i.e., what type of motion and "g's" that are produced), and the warnings that are generated.

After the initial tests have been successfully completed, the above tests should be repeated at higher altitudes and airspeeds until reaching M_{MO} at high cruise altitudes.