ACJ 25.1329
Automatic-pilot System (Acceptable Means of Compliance)
See JAR 25.1329

1 ***General***
1.1 For the purpose of this ACJ the automatic-pilot system should be considered to include the various sensors, computers, power supplies, controllers, instruments, servo motors/actuators, and associated wiring.

1.2 Adequate precautions should be taken to prevent the incorrect adjustment of parts of the automaticpilot if such errors would hazard the aeroplane (e.g. torque clutches or limit switches with so great a range of adjustment that maladjustment could be catastrophic).

1.3 The automatic pilot should comply with JAR 25.671(a) and in making the safety analysis, failures of the engines, control systems and trim systems should be taken into account.

2 *Malfunction Tests* (see also 5)

2.1 *Climb, Cruise and Descent Flight Regimes*

2.1.1 The more critical of the following should be induced into the automatic-pilot system. If auto-throttles are installed, they should be operating.
a. A signal about any axis equivalent to the cumulative effect of the most critical of those failures, including a failure of autotrim, if installed, which are not shown to be Extremely Remote or Extremely Improbable.
b. The combined signals about all affected axes, if multiple axis failures can result from a failure which is not shown to be Extremely Remote or Extremely Improbable.

2.1.2 Corrective action should not be initiated until three seconds after the pilot has become aware, through either the behaviour of the aircraft or a reliable failure warning system, that a malfunction has occurred. The simulated failure and the subsequent corrective action should not cause:—
a. the imposition on any part of the aeroplane structure of a load greater than its proof strength,
b. an exceedance of $V_{MO} + ½ (V_{DF} — V_{MO})$ or $M_{MO} + ½ (M_{DF} — M_{MO})$,
c. an exceedance of the maximum demonstrated lift coefficient or a stall,
d. a normal acceleration outside the range 0 to 2g,
e. a bank angle of more than 60º en-route or more than 30º during the final approach,
f. dangerous degradation of the handling qualities of the aeroplane.

2.1.3 The power or thrust for climb should be the most critical of:—
a. that used in the performance climb demonstrations,
b. that used in the longitudinal stability tests, or
c. that actually used for operational climb speeds. The altitude loss should be measured.

2.2 *Manoeuvring Flight.*

Malfunctions should also be induced into the automatic-pilot system similar to 2.1. When corrective action is taken one second after the result of the malfunction has alerted the pilot, the resultant loads and speeds should not exceed the values in 2.1. Manoeuvring flight tests should include turns with the malfunction induced when maximum bank angles for normal operation of the system have been established and in the critical aeroplane configuration and/or stages of flight likely to be encountered when using the automatic-pilot. The altitude loss should be measured.

2.3 *Oscillatory Tests*

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

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

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

3 *Recovery of Flight Control.*

Recovery should be demonstrated either by overpowering or by manual use of an emergency quick disconnect device after the appropriate delay. The pilot should be able to return the aeroplane to its normal flight attitude under full manual control without exceeding the loads or speed limits defined in this paragraph and without engaging in any dangerous manoeuvres during recovery, or the use of exceptional skill. If an emergency quick disconnect button is not installed on the control wheel, it should be possible to overpower servo forces plus resultant airloads in all configurations and attitudes of flight demonstrated, including maximum speed for which approval is sought and without exceeding the following transient control forces measured at the pilot's controls; pitch 50 pounds; roll 30 pounds (force applied at rim); yaw 150 pounds. The maximum servo forces used for these tests should not exceed those values shown to be within the structural limits for which the aeroplane was designed. The maximum altitude loss experienced during these tests should be measured.

(G) 3 Recovery of Flight Control (United Kingdom). *Recovery should be demonstrated either by overpowering or by manual use of an emergency quick disconnect device after the appropriate delay. The pilot should be able to return the aeroplane to its normal flight attitude under full manual control without exceeding the loads or speed limits defined in this paragraph and without engaging in any dangerous manoeuvres during recovery, or without the use of unusual skill. It should be possible to overpower servo forces plus resultant airloads in all configurations and attitudes of flight demonstrated, including maximum speed for which approval is sought and without exceeding the following transient control forces measured at the pilot's controls; pitch 50 pounds; roll 30 pounds (force applied at rim); yaw 150 pounds. The maximum servo forces used for these tests should not exceed those values shown to be within the structural limits for which the aeroplane was designed. The maximum altitude loss experienced during these tests should be measured.*

4 Performance of Function. The automatic pilot system should be demonstrated to perform its intended function in all configurations in which the auto-pilot may be used throughout all appropriate manoeuvres and environmental conditions, including turbuIence, unless an appropriate operating limitation or informational statement is included in the aeroplane flight manual. All such manoeuvres should be accomplished smoothly and without subjecting the aeroplane to loads greater than those described in 2.1.1.

5 *Automatic-pilot Instrument Approach Approval*

5.1 Throughout an approach, no signal or combination of signals simulating the cumulative effect of any single failure or malfunction in the automatic-pilot system should provide hazardous deviations from flight path or any degree of loss of control if corrective action is initiated one second after the pilot has become alerted to the malfunction.

5.2 The aircraft should be flown down the ILS in the configuration and at the approach speed specified by the applicant for approach. Simulated automatic-pilot malfunctions should be induced at critical points along the ILS, taking into consideration all possible variations in automatic-pilot sensitivity and authority. The malfunctions should be induced in each axis. While the pilot may know the purpose of the flight, he should not be informed when a malfunction is to be or has been applied except through aeroplane action, control movement, or other acceptable warning devices.

5.3 An engine failure during an automatic ILS approach should not cause a lateral deviation of the aeroplane from the flight path at a rate greater than three degrees per second or produce hazardous attitudes.

5.4 If approval is sought for ILS approaches initiated with one-engine inoperative, the automatic-pilot should be capable of conducting the approach. The deviation from the ILS course following the failure of a second critical engine should not be greater than three degrees per second.

5.5 The minimum engagement height should be determined. Either of the following methods is acceptable for uncoupled ILS approaches. If approval is being sought for coupled ILS approaches, however, the method given in 5.5.2 should be used.

5.5.1 *Altitude Loss Method.*

Recoveries should be initiated one second after the pilot recognizes the failure. The altitude loss shall be measured as the vertical distance between the glide slope path and the lowest point in the recovery manoeuvre.

5.5.2 *Deviation Profile Method*

a. The aeroplane should be so instrumented that the following information is recorded:
i the path of the aeroplane with respect to the normal glidepath;
ii the point along the glidepath when the simulated malfunction is induced;
iii point where the pilot indicates recognition of the malfunction; and
iv the point along the path of the aeroplane where recovery action is initiated. Data obtained from the point of the indicated malfunction to the point where the aeroplane has either again intersected the glide slope or is in level flight will define the deviation profile. When changes to the aeroplane automatic pilot configuration are made during the approach and these changes alter the deviation profile, additional data should be obtained to define each of the applicable deviation profiles. An example of a deviation profile may be found in Figure 1.
b. Recoveries from malfunctions should simulate under-the-hood instrument conditions with a one-second time delay between pilot recognition of the fault and initiation of the recovery at all altitudes down to 80 percent of the minimum decision altitude for which the applicant requests approval.
c. Recoveries from malfunctions at altitudes between 80 percent of the minimum decision altitude for which the applicant requests approval and the minimum altitude for which the applicant requests approval to operate the automatic-pilot may be visual with no time delay between pilot recognition of fault and initiation of recovery.
[(G)(c) (United Kingdom) *Paragraph deleted*] **]**

NOTE: Point of change of aeroplane configuration may be more than one point. For instance:

1. Gain changes along the glide path.
2. The 200 ft or middle marker transition.
3. Flap changes affecting automatic-pilot authority, etc

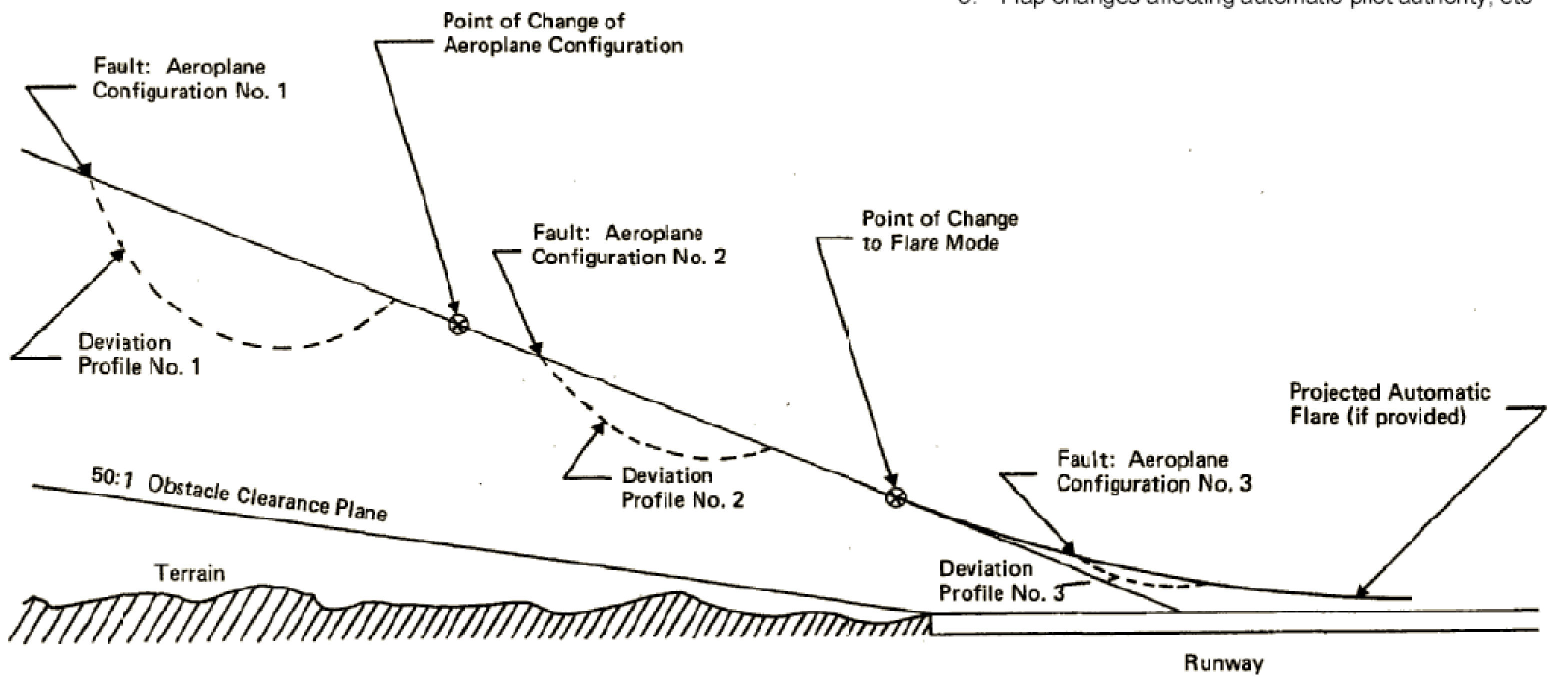

FIGURE 1 EXAMPLE DEVIATION PROFILE]

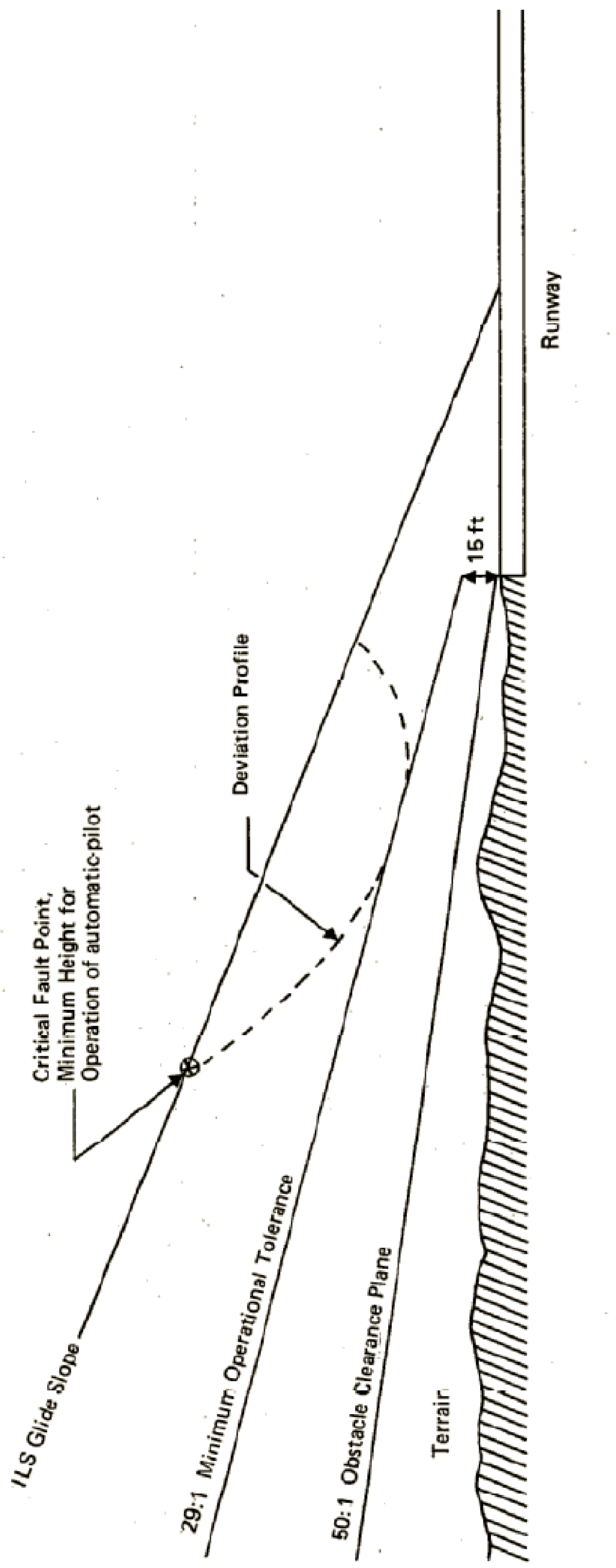

FIGURE 2 EXAMPLE OPERATING LIMITATION]

d. The minimum altitude at which the autopilot may be used should be determined as the altitude which results in the critical deviation profile becoming tangent with a minimum operational tolerance line. An example of this may be found in Figure 2. The 29:1 slope of the minimum operational tolerance line provides a one percent gradient factor of safety over the 50:1 obstacle clearance line. An additional factor of safety is provided by measuring the 29:1 slope from the horizontal at a point 15 feet above the runway threshold. It is recognized that this minimum altitude will vary with glide slope angle. Information regarding these variations should be obtained and presented.

5.6 A malfunction of the automatic-pilot during a coupled ILS approach should not place the aeroplane in an attitude which would preclude conducting a satisfactory go-around, or landing.

6 *Servo Stall Forces.*

The automatic-pilot system should be so installed and adjusted that the system tolerances established during certification tests can be maintained in normal operation. This may be assured by conducting flight tests at the extremes of the tolerances. Those tests conducted to determine that the automatic pilot system will adequately control the aeroplane should establish the lower limit; and those tests to determine that the automatic-pilot will not impose dangerous loads or deviation from the flight path should be conducted at the upper limit. Appropriate aeroplane loadings to produce the critical results should be used.

7 Operating Procedures.

Operating procedures for use at the automatic pilot should be established.
(See ACJ 25.1585(a).)

8 *Malfunction Tests.*

In malfunction tests described in 2.1.1, 2 1.2, 2.2 and 5.1, the recognition point should be that at which a pilot in service operation may be expected to recognise the need to take action and not that at which a test pilot engaged in flight trials might do so.

(G) 8 Malfunction Tests (United Kingdom). In malfunction tests described in 2.1.1, 2.1.2, 2.2 and 5.1 the recognition point should be that at which a pilot in service operation may be expected to recognize the need to take action and not that at which a test pilot engaged in flight trials might do so. It should not in any case be less than one second after the occurrence of the failure.