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AUTOMATIC FLIGHT CONTROL SYSTEMS (CASA ATPL)

CHAPTER 5 – AUTOLAND/GO-AROUND

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INTRODUCTION

The most difficult phase of flight for flight crews is landing when visibility of the runway threshold is poor and unfavourable wind conditions are present. Various methods of airfield approach have been developed over time with each one leading the aircraft to a point at which the pilot can acquire the runway visually with enough height to make adjustments and land the aircraft safely.

The Instrument Landing System (ILS) has become the standard ICAO approach as it is accurate enough to enable very low visual acquisition heights. The height that an aircraft can descend using the ILS to become visual and land safely is governed by the following factors:

- Runway and airfield location and facilities
- Aircraft performance and equipment fitted
- Pilot training and operator approval.

Runway and Airfield Location and Facilities

Each runway at each airfield is categorised by the most demanding approach and landing that can be made. Limitations can be the surrounding terrain, obstructions close to the airfield, runway lighting and airfield infrastructure such as a back-up electricity supply. The ILS beam antennas must be protected against interference caused by vehicles or parked aircraft. In determining the category of the approach these factors are taken into account. A runway may have a different category of approach than its reciprocal.

Aircraft performance and Equipment fitted

Each type of aircraft, its performance capability and the approach and auto landing equipment fitted to it are required to be certified to an appropriate approach category. Depending on the sophistication of the equipment fitted, the pilot can:

- Use the automatic flight control system to fly the ILS approach to a point when manual takeover is required to land. This is referred to as a semi-automatic approach. Or,
- Allow the automatic flight control to conduct a fully automatic landing and rollout. This is referred to as a fully automatic approach or auto land.

Pilot training and Operator approval

The crew is required to complete training and maintain currency in certain categories of approach as well as the airline operator being approved by the relevant aviation authority.

ILS Approach Categories

Depending on the factors described above, an ILS approach can be categorised into numerous levels each with specific limits of visual acquisition of the threshold. These are named Category I, II and III.

Category III is further divided into IIIA, IIIB and IIIC. These categories will be described in greater detail later in this chapter.

AUTOLANDING SYSTEMS

Using the ILS approach, modern autopilots have the capability to land the aircraft in all weather conditions with almost no visibility achieved by the pilot and continue to maintain the runway centreline until the aircraft comes to a stop.

Basic requirements for Auto landing Systems

To certify aircraft with automatic landing capability, they must comply with the following minimum requirements:

- The safety achieved by an automatic landing must not be less than a manual landing and the risk of a fatal accident should be better than 1×10^{-7}.
- The flight crew must be able to adequately monitor the landing phase, so that if a critical malfunction occurs, the autopilot can be manually disengaged, and manual control of the aircraft taken at any time, with the minimum of skill required, keeping the aircraft under control.
- It is improbable that the landing performance is outside the following touchdown limits of 60 to 900 metres after the threshold and an outboard landing gear no more than 21 metres from the centre line assuming a runway width of 45 metres.

To automatically land the aircraft, the auto land system needs to be able to:

- Align the aircraft with the runway centreline.
- Achieve a sink rate of approx two feet per second before touchdown.
- Reduce speed from 1.3 Vs to about 1.15 Vs at threshold by reducing power.
- Level the wings before landing.
- Yaw the aircraft to remove any drift angle, known as de-crabbing or kick off.

Obviously extensive safety margins must be provided for auto land operation and this is achieved by the use of multiple autopilots and indications to the pilot of any malfunctions plus options available so that the auto land may be aborted.

Safety features for Auto landing Systems

An automatic flight control system incorporating auto land facilities must include safety features that ensure that:

- There is sufficiently rapid response to prevent deviation from the flight path in the event of environmental disturbances such as windshear and turbulence.
- The effect of a servomotor runaway must be limited, so that a safe recovery action can be made by the pilot.
- Control system failures that do not cause an immediate deviation from the flight path (passive failures) are indicated to the pilot.

Therefore, to meet the requirement for a safe approach and auto land the system must:

- Not deviate from the flight path as a result of a runaway malfunction
- Have sufficient control authority for accurate maintenance of the flight path
- Incorporate warning of passive failures
- Not prevent completion of the intended manoeuvre, following a failure.

These criteria can be met by the use of duplicate or triplicate systems. This ensures that a single failure within a system has an insignificant effect on the overall performance during approach and landing.

AUTOLANDING TERMINOLOGY AND DEFINITIONS

Specific standardised terms are used for autolanding systems and these are defined as follows:

Decision Height (DH)

This is the wheel height above the runway elevation by which a go-around must be initiated unless adequate visual reference has been established, and assessment of the aircraft position and approach path is satisfactory to continue the approach and the landing safely.

A Decision Height is typically used for any type of approach but when applied to autolanding from an ILS approach it will vary depending on the automatic landing system fitted to the aircraft. Decision Height is stated in feet (ft). Refer to Figure 5-1.

Note that Decision Height (DH) is not the same as Decision Altitude (DA).

DH 199 - 100 FT	1. Autopilot with an ILS coupling mode 2. Autothrottle 3. Radio altimeter 4. Excess ILS deviation warnings
DH 99 - 50 FT	1. As for previous -199 – 100 FT 2. Autopilot with autoland mode
DH below 50 FT	1. As for previous -199 – 100 FT 2. (a) Autopilot with fail operational autoland and automatic missed approach modes OR (b) Autopilot with autoland and missed approach modes and a landing guidance display
No Decision Height	1. As for previous -below 50 FT 2. (a) Autopilot with fail operational ground roll mode OR (b) Fail operational head-up ground roll guidance display OR (c) Autopilot with ground roll mode and a head-up ground roll guidance display 3. Anti-skid braking system

Figure 5-1 Decision Height Systems and Equipment

Fail Passive Landing Systems

An automatic landing system is fail passive if, in the event of a failure, there is no significant out-of-trim condition or deviation of flight path or attitude, but the landing cannot be completed automatically. A fail passive system is also known as a **Fail Soft System**.

Alert Height

The alert height is a specific radio height, based on the characteristics of the aircraft and its Fail Operational Landing System (described next). If a failure occurs above the alert height in one of the redundant operational systems the approach discontinues and a go-around executed. If a failure occurs below the alert height in one of the redundant operational systems it is ignored and the approach continues.

Fail Operational Landing System

An automatic landing system is fail operational if, in the event of failure below the alert height during the approach, flare and landing phases, the landing can still be completed by the remaining part of the automatic landing system. The fail operational system downgrades to a fail passive system to complete the automatic landing. A fail operational system is also known as a **Fail Active System**.

Runway Visual Range (RVR)

Runway visual range is defined as the maximum distance in the direction of take-off or landing at which the runway can be seen from a position on the centre line at a height of 15 ft which corresponds to the average eye level of a pilot at touchdown.

RVR is derived by instruments at the airfield and transmitted to ATC who will inform the pilot of the current visibility conditions. RVR values are normally stated in metres but can be stated in feet or statute miles.

Typically, high intensity runway lighting will be on to provide the best RVR but a runway without lights can still be assessed for an RVR.

Armed, Captured and Engaged

These are common terms used to describe the status of autopilot, flight director and autothrottle operations during auto land. A system or mode of operation that is armed is one that is ready to:

- CAPTURE a radio beam provided it is within range and has an reasonable entry angle in relation to the beam; or
- ENGAGE autopilots or autothrottle into action when triggered manually or automatically.

Modes of operation may be armed manually or automatically.

The term CAPTURED relates to the aircraft's acquisition and tracking of the radio beams.

Approach Categories

The following table is a summarised version of the approach categories applicable to a large transport aircraft landing at a fully equipped airfield. Aircraft that are not fitted with a Fail Passive or Fail Operational auto land system are limited to CAT II minima. Refer to Figure 5-2.

CATEGORY I minima		
CAT	DH (ft)	RVR (m)
I	> 301	800
	251 - 300	650
	201 - 250	600
	200	550

CATEGORY II minima		
CAT	DH (ft)	RVR (m)
II	100 - 120	300
	121 - 140	400
	> 141	450

<table>
<tr><th colspan="6">CATEGORY III minima</th></tr>
<tr><td colspan="2" rowspan="4"></td><td colspan="4">TYPE OF AUTOLAND SYSTEM</td></tr>
<tr><td>FAIL PASSIVE</td><td colspan="3">FAIL OPERATIONAL</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">WITHOUT ROLLOUT CONTROL OR GUIDANCE SYSTEM</td><td colspan="2">WITH ROLLOUT CONTROL OR GUIDANCE SYSTEM</td></tr>
<tr><td>PASSIVE</td><td>OPERATIONAL</td></tr>
<tr><td>CAT</td><td>DH (ft)</td><td>RVR (m)</td><td>RVR (m)</td><td>RVR (m)</td><td>RVR (m)</td></tr>
<tr><td>IIIA</td><td><100</td><td>200</td><td>200</td><td>200</td><td>200</td></tr>
<tr><td rowspan="2">IIIB</td><td>< 50</td><td>Not allowed</td><td>Not allowed</td><td>125</td><td>75</td></tr>
<tr><td>No DH</td><td>Not allowed</td><td>Not allowed</td><td>Not allowed</td><td>75</td></tr>
<tr><td>IIIC</td><td>No DH</td><td>Not allowed</td><td>Not allowed</td><td>Not allowed</td><td>0</td></tr>
</table>

Figure 5-2 Summary of Approach Categories

AUTOLAND LIMITATIONS, MODES, STATUS AND FAILURE ANNUNCIATION

Limitations

Each aircraft will have wind and flap limitations restricting the use of autoland. Typical examples for Boeing aircraft are maximum wind speeds of 25 kts headwind, 15 kts tailwind and 25 kts crosswind. Flaps should be in the landing range, typically 25 or 30 degrees.

Airbus aircraft are usually 35 kts headwind, 19 kts tailwind and 20 kts crosswind with flaps also in the landing range, called configuration 3 or configuration FULL.

Mode annunciation

During the autolanding sequence a series of mode and submode changes occur with the autopilots, flight director and autothrottle. These changes occur based on Radio Altitude (RA) heights as the aircraft descends to the touchdown point. The changing modes and submodes are annunciated to the pilots as they become ARMED and ENGAGED either on the EADIs on modern aircraft or separate mode annunciators on older aircraft types.

The colour green is always used for ENGAGED or CAPTURED and the colour white or amber for ARMED. Refer to Figure 5-3.

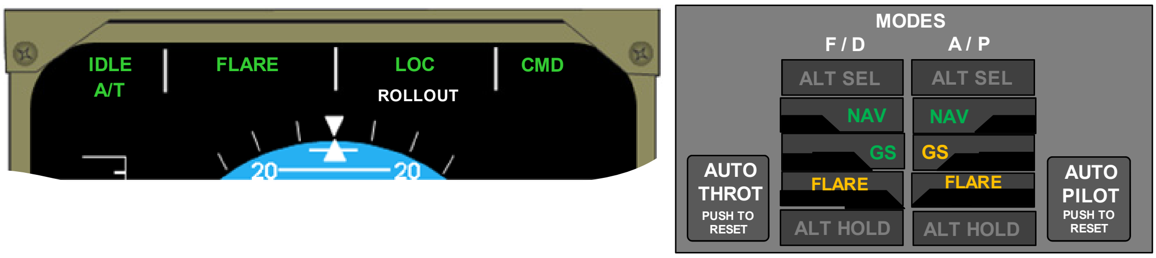
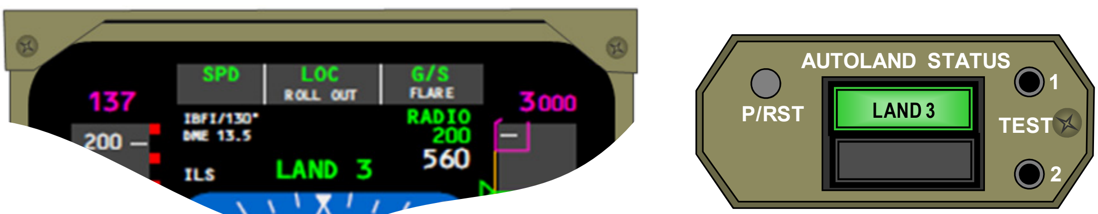


Figure 5-3 Autoland Mode Annunciation

Status annunciation

The pilots must also be made aware of the continuing serviceability of the auto land system during the auto land sequence and this will be continuously displayed on the EADIs or on a separate status annunciator. Refer to Figure 5-4.



AUTOLAND STATUS ANNUNCIATOR (ASA)

Figure 5-4 Autoland Status Indication

Failure annunciation

Failures occurring at any time are annunciated on annunciator panels, EFIS displays and EICAS/ECAM primary displays. Typically these are accompanied by aural warnings. Failures occurring during autolanding will obviously change the autoland status. Refer to Figure 5-5.

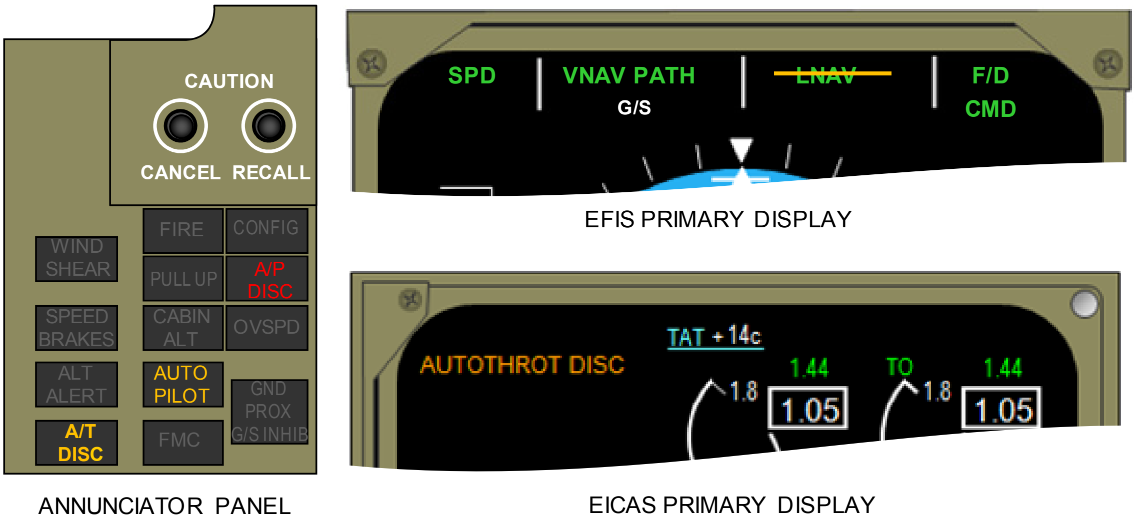


Figure 5-5 Failure Annunciation

AUTOLAND PROFILE

Introduction

The intended profile of an autolanding system using the ILS is to capture, turn on and track the localiser at a level altitude well above 1500 ft radio altitude until the aircraft captures the glideslope at which time it will descend on glideslope. Approaching the threshold the aircraft will flare, touchdown and rollout maintaining the runway centreline until the aircraft comes to a stop. Refer to Figure 5-7.

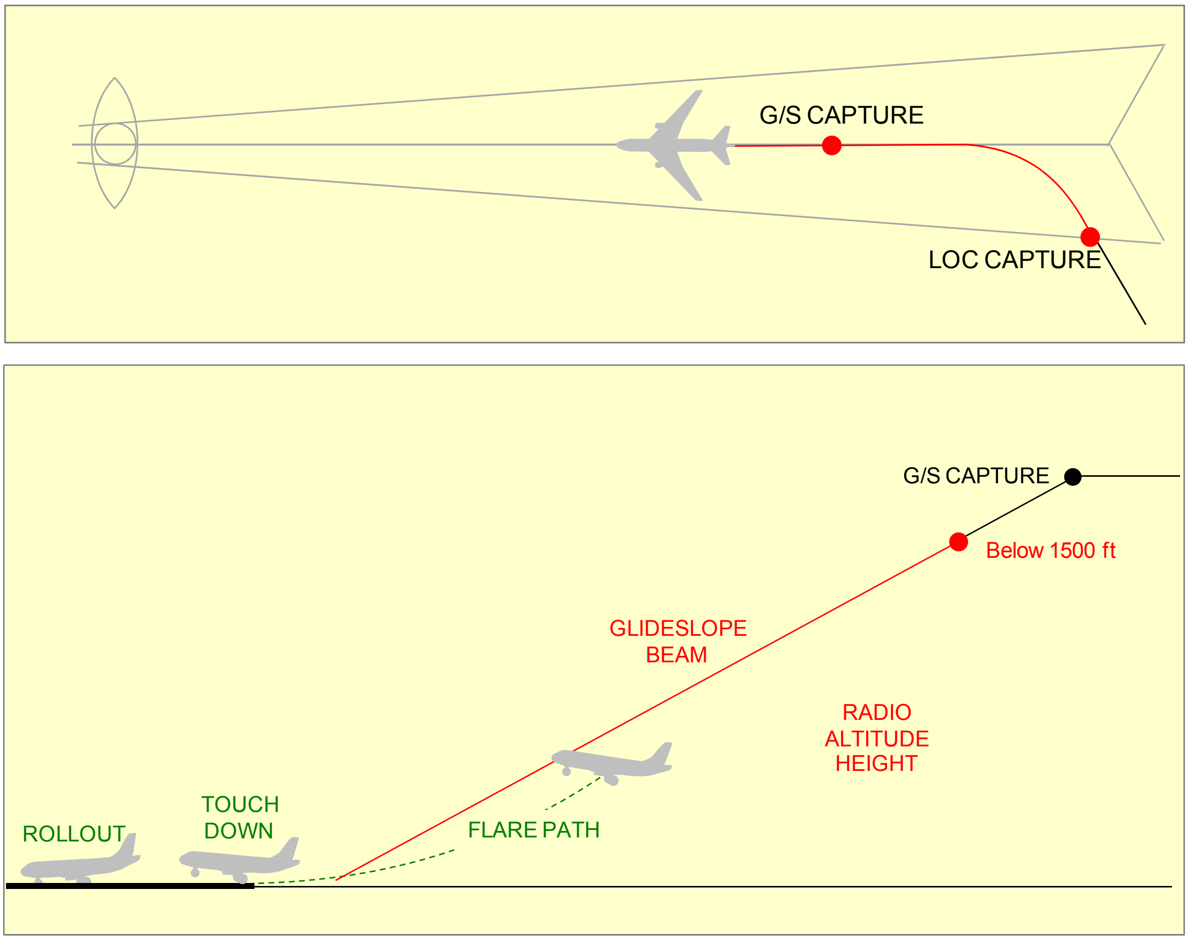


Figure 5-7 Autoland Profile

The auto land profile and the sequence of mode and submode changes are slightly different between aircraft types and manufacturers; however, there are some standard terms and functions common to all autolanding systems.

To conduct an auto land the following will be required:

- Radio altimeters
- Multiple autopilots
- Autothrottle
- Localiser and glideslope capture.

The Radio Altimeters, which are an essential part of the auto land sequence, will typically automatically become operational at approximately 2500 ft RA.

In modern aircraft pressing a switch called “approach” (APP) switch ARMS the remaining disengaged autopilots (channels). The other “off line” autopilots are now continuously supplied with outer loop control signals and they operate on a comparative monitoring basis.

Most large transport aircraft have an autothrottle system working in conjunction with the autopilot and flight director and this will be ENGAGED for the auto land. Note however that an auto land may be conducted without autothrottle.

The same approach (APP) switch previously mentioned, typically ARMS the localiser and glideslope modes of the autopilot and flight director ready for CAPTURE of the ILS beams. Typically the localiser will CAPTURE first, followed by the glideslope. At glideslope CAPTURE the aircraft will begin the descent to land.

Below 1,500 FT Radio Altitude – Auto land sequence begins

On most aircraft the auto land sequence begins when the aircraft has descended below 1500 ft Radio Altitude with localiser and glideslope beams CAPTURED. At this point the:

- Remaining autopilots become ENGAGED automatically;
- The yaw axis of the autopilot becomes active and controls the rudder; and
- The next sub-modes in the auto land sequence (flare and rollout) are ARMED.

An auto land status is indicated to the pilot confirming the ability of the aircraft to conduct an auto land. It will indicate Fail Operational configuration, Fail Passive configuration or NO auto land configuration.

Flare

At an aircraft specific radio altitude point on the glideslope the flare sub-mode ENGAGES and manoeuvres the aircraft onto a new descent path referred to as the **flare path**. The flare engage height can range from 25 ft to 50 ft depending on aircraft size.

During the flare manoeuvre the following occurs:

- A reduced rate of descent is established on a flare path
- The autothrottle reduces thrust to idle
- The rollout mode becomes ENGAGED
- Touchdown.

Rollout

In the flare manoeuvre at a specific radio altitude the rollout sub-mode ENGAGES. The radio height is typically around 5 ft.

During the rollout manoeuvre the following occurs:

- The localiser centreline is maintained by rudder and nose wheel steering.
- The flare mode becomes DISENGAGED.
- Autothrottle becomes DISENGAGED automatically when reverse thrust is selected.
- The rollout mode becomes DISENGAGED when the aircraft comes to a full stop.

GO-AROUND PROFILE

Introduction

Depending on the weather conditions and the aircraft's auto land configuration a missed approach procedure may be necessary when decision height is reached. Additionally, the sudden onset of windshear at the threshold may demand a go-around procedure.

A fully automatic go-around is available from any point in the auto land sequence once multiple autopilots are engaged (below 1,500 ft) and until the aircraft is established on the runway. However, a partially automatic single autopilot or a flight director only go-around can be made also.

The intended profile of the automatic go-around is to climb the aircraft straight ahead at approximately 2,000 feet per minute to the missed approach altitude and then level off automatically. The AFDS controls pitch and roll while the autothrottle increases thrust as required to establish the climb rate. The pilot is responsible for gear and flap retraction. Refer to Figure 5-8.

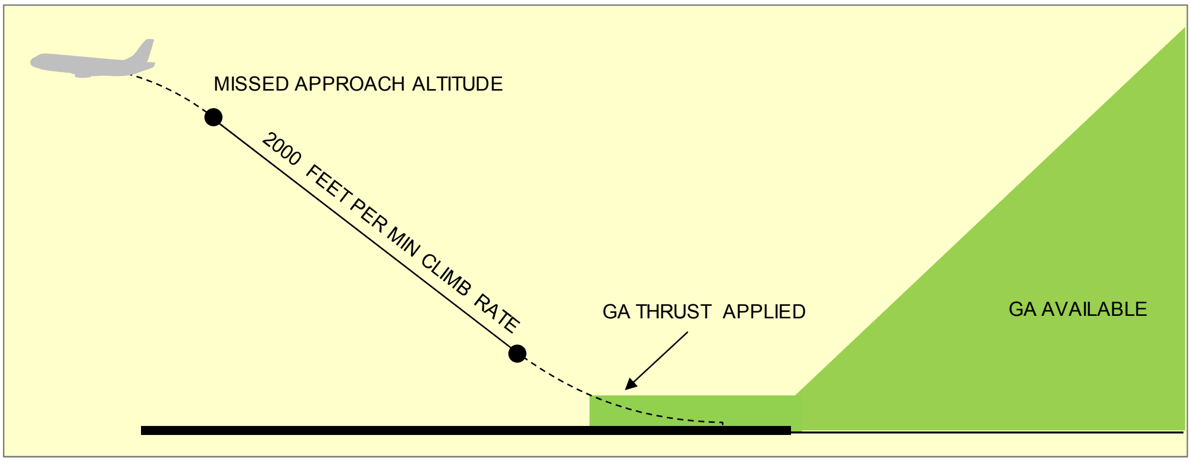


Figure 5-8 Go-around Profile

The pilot may terminate the automatic go-around when safe to do so before the aircraft reaches the missed approach altitude.

Go-around

A fully automatic go-around can only be engaged (activated) if it is ARMED.

The go-around mode is ARMED when the glideslope is captured OR anytime the flaps are not UP.

It is ENGAGED by the pilot pressing either of two go-around switches typically located at the thrust levers.

During the go-around manoeuvre the following occurs:

- Go-around thrust becomes available for use by the autothrottle
- A safe speed is maintained
- A climb rate (approximately 2000 fpm) is established
- Aircraft maintains existing track
- The aircraft levels off automatically.

Go-around is DISENGAGED by the pilot selecting other AFDS modes.