

Lining Up with the Correct Glide Slope



The Instrument Landing System (ILS) is accurate and reliable, but the ILS antenna design today causes secondary glide slopes to appear above the primary glide slope. Flight crews must be aware of this phenomenon to prevent unwanted aircraft behavior during an ILS glide slope capture.

This article explains the phenomenon of secondary glide slopes and their effect on aircraft systems. It provides guidance and examples that show how flight crews can prevent capturing a secondary glide slope. It also describes the protections on Airbus aircraft that limit the effect of an unintended secondary glide slope capture on the aircraft trajectory.

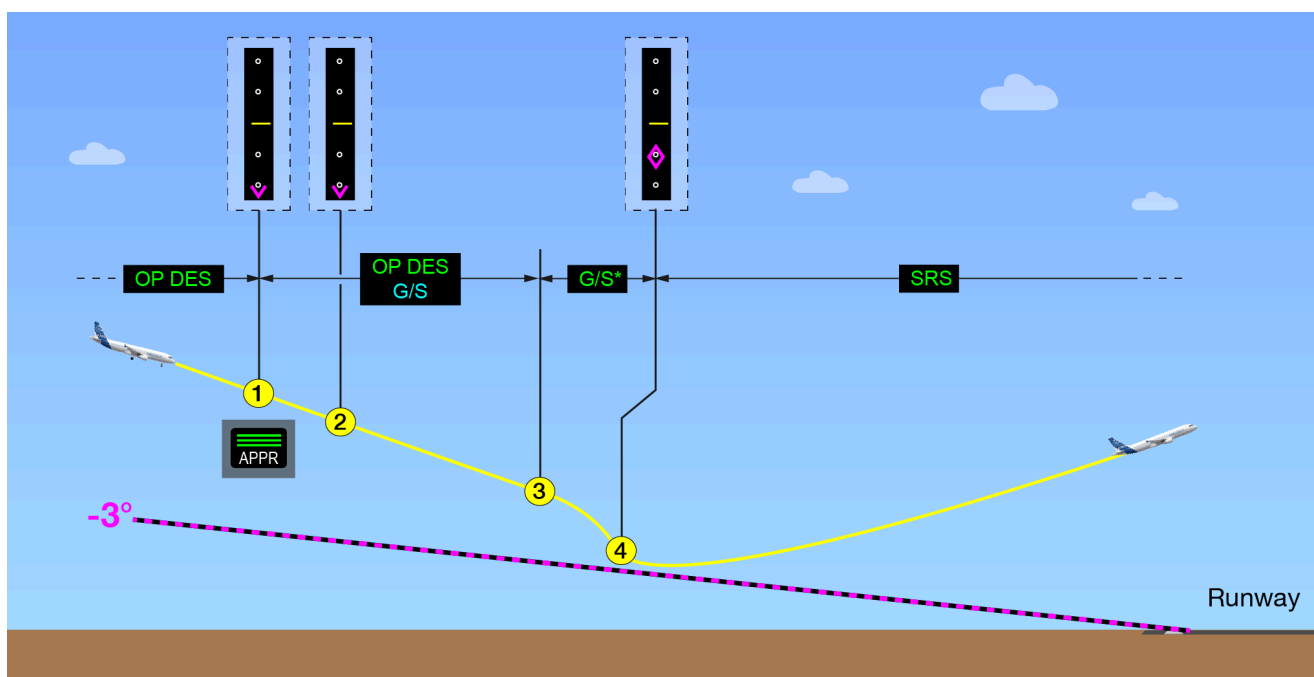
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Capturing a secondary glide slope can lead to unexpected aircraft behavior. It is important for flight crew to be aware of the phenomenon and to know how to prevent secondary glide slope capture. Some typical scenarios, based on real cases, with their associated effects on the aircraft trajectory and their prevention means are described below.

CASE 1: EXCESSIVE PITCH DOWN DURING ILS GLIDE SLOPE INTERCEPTION FROM ABOVE

The first case happens during an **ILS glide slope interception from above**. The aircraft descends in **OP DES** guidance mode (fig.1). The air traffic controller clears the flight crew for approach. ① The flight crew consequently presses the **APPR** pushbutton. ② The PFD indicates a glide slope below the aircraft, as expected by the flight crew. ③ A few seconds later, the **G/S*** mode engages and the autopilot orders a pitch down command toward the glide slope. The pitch down command continues until it reaches the 13° pitch down limit for autopilot disconnection ④. The flight crew must take over to recover the situation and perform a go-around.



(fig.1) Event of excessive pitch down during ils glide slope interception from above

A secondary glide slope capture was the cause of this event

Analysis of the data from the flight recorders enabled us to identify that this excessive pitch down order was caused by an initial capture of a secondary glide slope that caused undue early engagement of the **G/S*** guidance mode. Before explaining what happened, we need to know what the secondary glide slope phenomenon is.

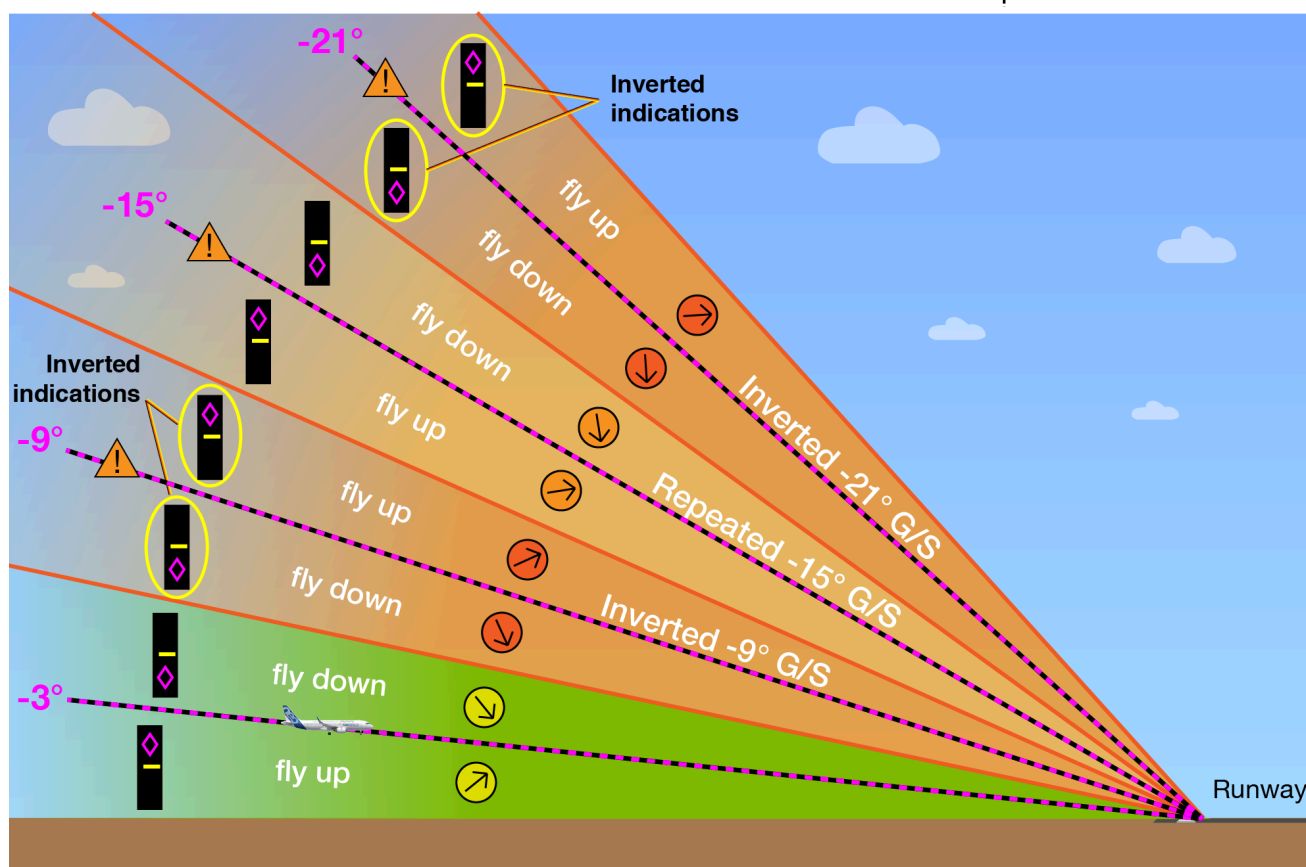
ILS Secondary Glide Slope Phenomenon

Secondary glide slopes are an inevitable characteristic due to the ILS antenna design. When an aircraft flies well above the main glide slope, the glide slope deviations displayed on the PFD will refer to the nearest glide slope, which may be a secondary glide slope instead of the primary one. This can lead both the flight crew and the autopilot to erroneously consider the secondary glide slope as the reference for the final descent.

There are several types of ILS glide slope antennas that use different technologies. They can be classified into two theoretical categories: “Inverted” glide slope and “repeated” glide slope. This considers the associated impact on the autopilot behavior and the indications observed by the flight crew.

ILS with “inverted” secondary glide slopes

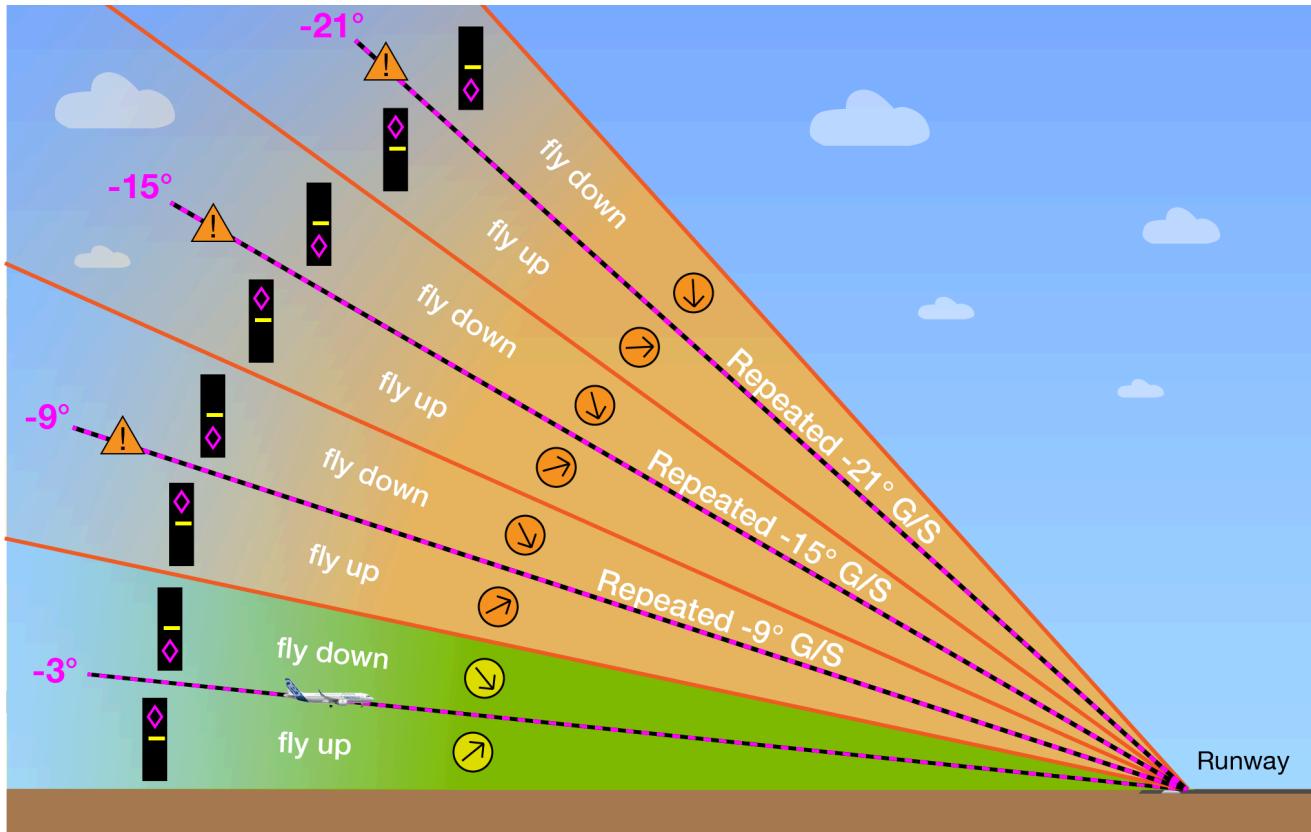
This category of glide slope antennas inverts the orientation of the glide slope at every other glide slope. For example, in the case of a -3° glide slope, secondary glide slopes exist at -9° , -15° , -21° and every other 6° , but the glide slopes at -9° , -21° and every other 12° are inverted. The PFD glide slope deviations are inverted for these glide slopes, i.e. the aircraft is seen above the glide slope when it is below and vice versa (fig.2).



(fig.2) Theoretical representation of a main -3° ILS glide slope and its inverted secondary glide slopes (only the secondary glide slopes at -9° , -15° , and -21° are represented for clarity and the angles are represented at twice their actual size)

ILS with only “repeated” secondary glide slopes

This category of antennas has only repeated glide slopes above the main glide slope (**fig.3**). For example, in the case of a -3° glide slope, repeated secondary glide slopes exist at -9° , -15° , -21° and every other 6° .



(**fig.3**) Theoretical representation of a main -3° ILS glide slope and its repeated secondary glide slopes (only the secondary glide slopes at -9° , -15° , and -21° are represented for clarity and the angles are represented at twice their actual size)



NOTE

There is no way for flight crews to know which category of ILS antenna (either with “inverted” or “only repeated”) is used at their destination airport.

Note that no cases of unexpected behavior due to ILS with “only repeated” glide slopes were reported to Airbus, therefore the examples shown only describe scenarios of ILS with inverted glide slopes.

Variable measured signal characteristics at the boundary between two glide slopes

Test flights performed to analyze the secondary glide slope structures showed that the real characteristics of the glide slopes may differ from the above theory, in particular in the boundary region between two glide slopes (shown as amber lines in **fig.2** and **fig.3**). Therefore, it is difficult to predict the behavior of the autopilot in these zones.

Possible inappropriate engagement of **G/S*** when crossing the boundary between two glide slopes

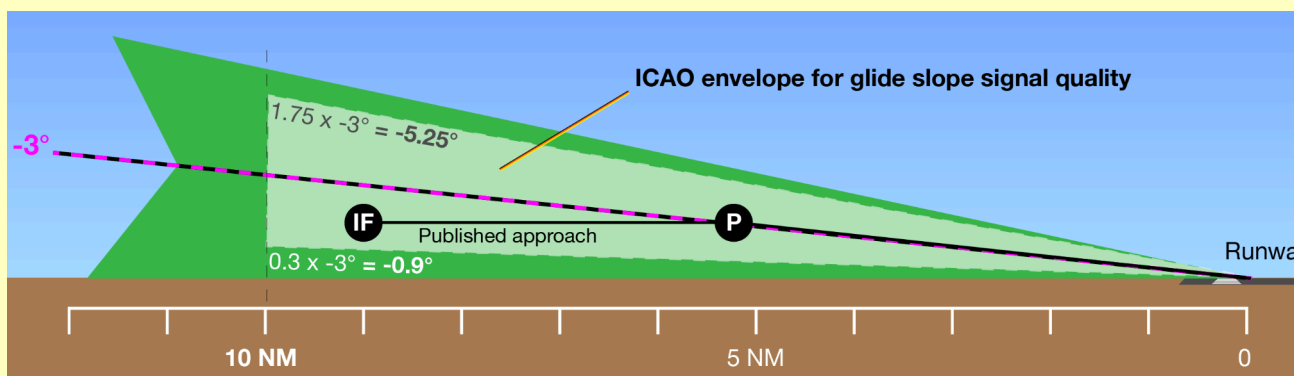
When an aircraft crosses the boundary between two glide slopes (at approximately -6° , -12° , -18° , etc...), temporary deviation “jumps” and/or a false deviation value of zero can trigger inappropriate engagement of the **G/S*** capture mode. This can happen when the approach guidance modes are armed, meaning that the **APPR** (LAND for A300-600/A310) pushbutton was previously pressed. The physical characteristics of the glide slope or the speed and angle at which the aircraft crosses the boundary, will influence if engagement occurs. Note that this phenomenon is possible for both the “repeated” and “inverted” types of secondary glide slope. Therefore, it is difficult to anticipate the autopilot behavior when crossing the boundary between two glide slopes. ■

The ICAO envelope for glide slope signal quality

ICAO guidelines provide recommendations for ensuring the quality of the ILS glide slope signal. Periodic checks on all ILS equipped runways ensure that **the ILS signal quality is at the required level inside a defined envelope**.

Capturing the ILS glide slope within this envelope ensures that the aircraft is within the area of influence for the primary glide slope. It also ensures that the ILS signal is of sufficient quality to ensure a normal ILS glide slope capture. The ICAO envelope (**fig.4**) is within:

- **10 NM** from the runway threshold
- **$\pm 8^\circ$ laterally** from the runway centerline
- **$0.3 \times \Theta$ up to $1.75 \times \Theta$** (Θ , being the nominal glide path angle).



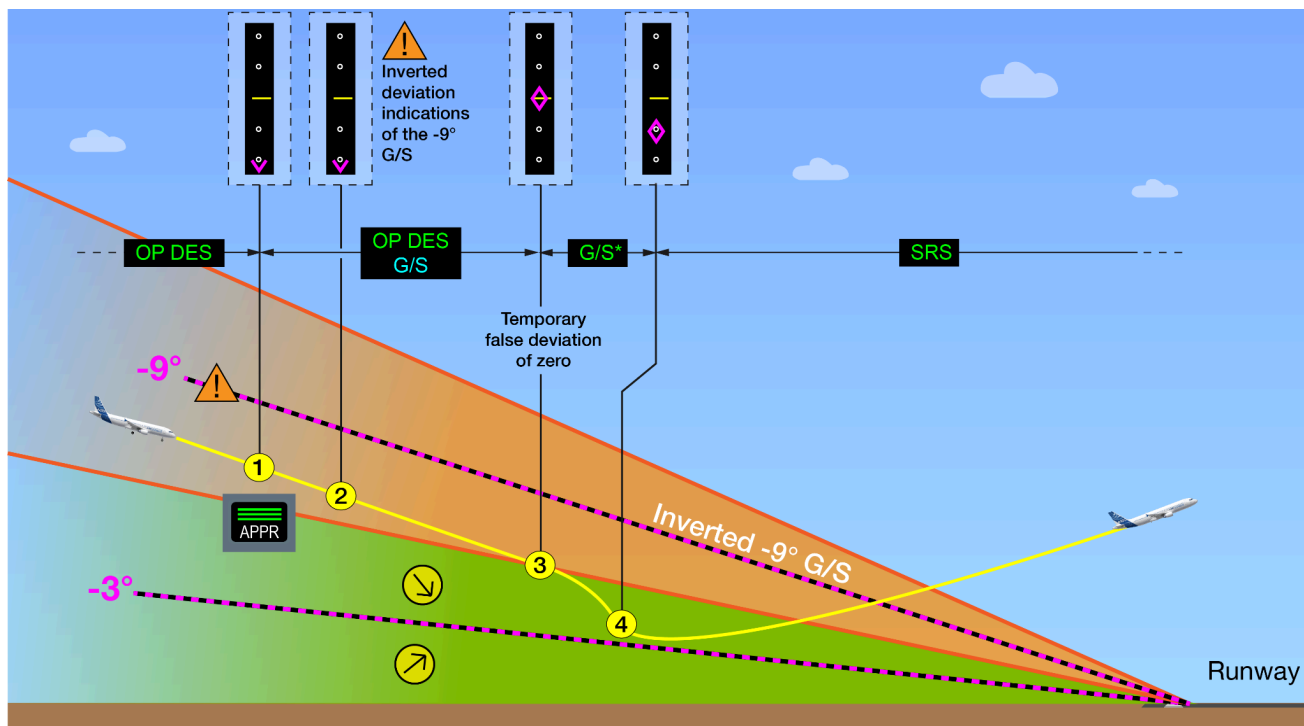
(fig.4) Example of the ICAO envelope for an ILS with a -3° glide slope

Analysis of the excessive pitch down event

With the secondary glide slope theory in mind, we can review the scenario of the event to better understand what happened.

The aircraft is in **OP DES** (LVL/CH for A300-600/A310) mode (**fig.5**). ① The flight crew presses the **APPR** (LAND for A300-600/A310) pushbutton well above the -3° glide slope, within the -9° zone of influence. The aircraft is nearer to the -9° secondary glide slope but far enough from it so that the **G/S** mode is armed but not engaged. ② The inverted glide slope deviations mean the flight crew cannot detect that their aircraft is in the zone of influence of an inverted secondary glide slope. The glide slope indicated below the aircraft is as expected

by the flight crew. ③ When the aircraft crosses the -6° boundary between the -3° and -9° glide slopes, a temporary false deviation value of zero received by the MMR triggers the undue engagement of the **G/S*** mode. Therefore, the autopilot orders a pitch down command toward the -3° glide slope. As the aircraft is flying high above the -3°, there is sufficient time for the pitch to reach the 13° pitch down limit for autopilot disconnection ④. In manual flight, the flight crew must take over to recover the situation and perform a go-around.

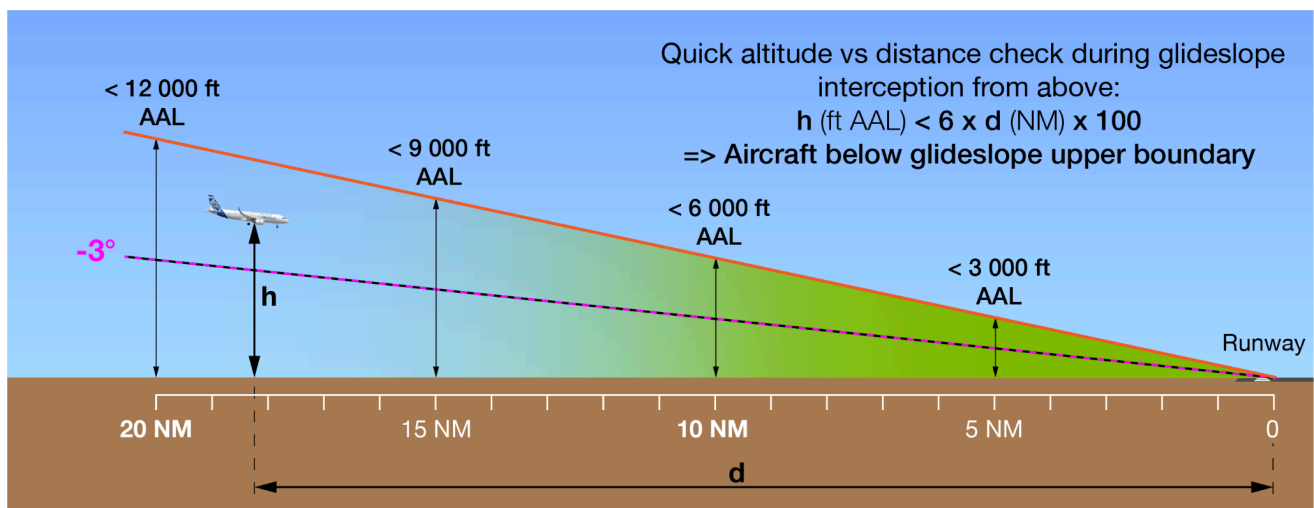


(fig.5) Excessive pitch down due to undue G/S* activation during ILS glide slope interception from above

Prevention: Quick check of the aircraft position before pressing the APPR pushbutton when intercepting a glide slope from above

When intercepting the glide slope from above, the flight crew should ensure that the aircraft is below the upper boundary of the main glide slope before they press the **APPR** (LAND for A300-600/A310) pushbutton. This boundary is located at approximately twice the value of the primary glide slope angle (approximately -6° in our example). This ensures that the capture will be done on the correct glide slope. As a rule of thumb, a quick altitude vs. distance check can be done to ensure that the aircraft is below the upper boundary of the main glide slope. The aircraft altitude above airport elevation (in ft) should be less than 6 times the distance to runway (in NM) multiplied by 100 (fig.6):

$$h(\text{ft AAL}) < 6 \times d (\text{NM}) \times 100$$



(fig.6) For ILS glide slope interception from above, a quick altitude vs. distance check ensures that the aircraft is below the upper boundary of the primary glide slope before pressing the APPR (LAND for A300-600/A310) pushbutton

Check of the glide slope in standard glide slope interception (from below)

Similarly to the above quick check, the flight crew can estimate if they are intercepting the correct glide slope during a standard glide slope interception from below using the formula: $h(\text{ft AAL}) = 3 \times d(\text{NM}) \times 100$

FCOM procedure: guidance mode for glide interception from above

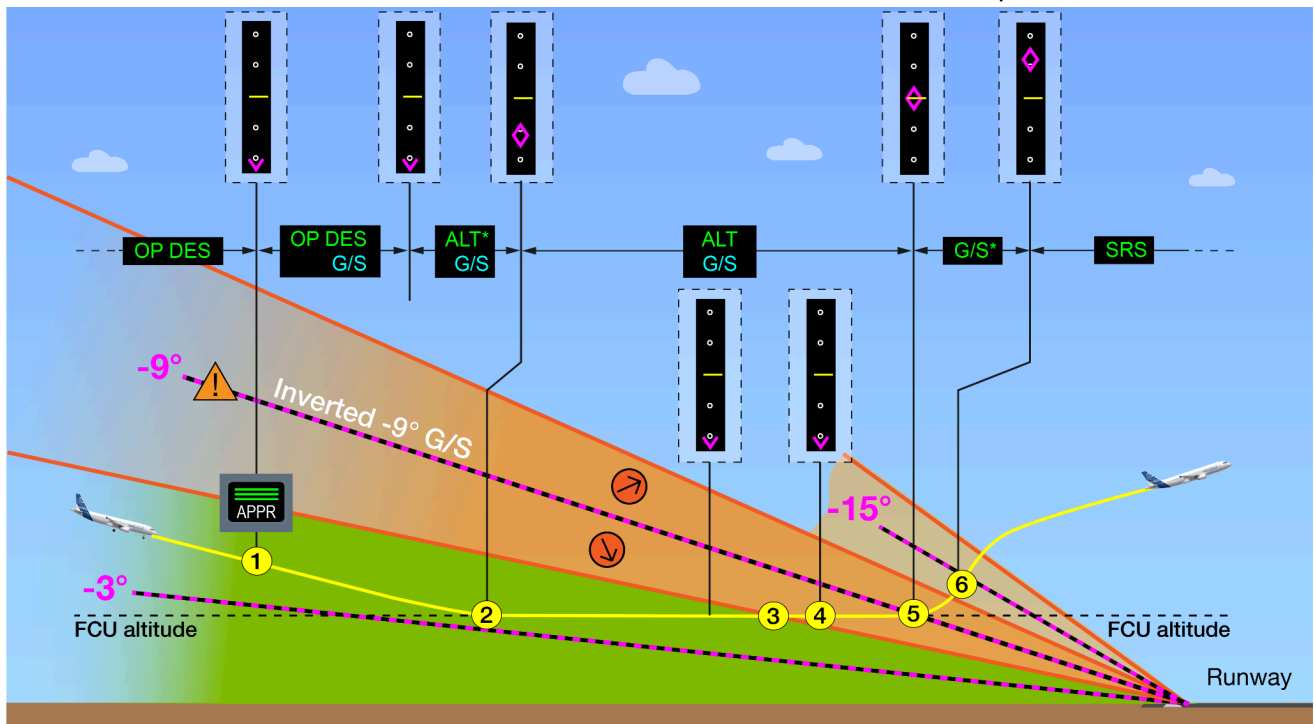
In the described event and in the next one, the flight crew uses the **OP DES** guidance mode to intercept the glide slope from above. This is not recommended in the FCOM. As per the FCOM "Glide interception from above" procedure and the FCTM, after the aircraft is established on the localizer, the flight crew should press the **APPR** pushbutton, set the FCU altitude above the aircraft altitude, and then select the **V/S** mode to intercept the glide slope. ■



CASE 2: EXCESSIVE PITCH UP DURING ILS GLIDE SLOPE INTERCEPTION FROM ABOVE

In this second case, an aircraft also intercepts the glide slope from above (fig.7).

① The flight crew presses the **APPR** (LAND for A300-600/A310) pushbutton but does not set the FCU altitude target above the aircraft altitude, because it is usually requested by the SOP for an ILS approach. The aircraft converges toward the -3° glide slope, but reaches the target altitude before the **G/S*** can engage. ② The aircraft levels off and starts to diverge from the -3° glide slope and to converge with the -9° secondary glide slope. ③ When crossing the -6° boundary between the -3° and -9° glide slopes, the MMR receives a temporary false deviation value of zero, but it is not sufficient to engage the **G/S*** mode. ④ The -9° glide slope is inverted, and as a result, the glide slope deviation indications show the glide slope below the aircraft. ⑤ When the aircraft crosses the -9° secondary glide slope, the **G/S*** guidance mode engages. The autopilot then commands a pitch up when the aircraft crosses the -9° glide slope, due to its inversion. In this case, the flight crew has no choice but to perform a go-around ⑥.



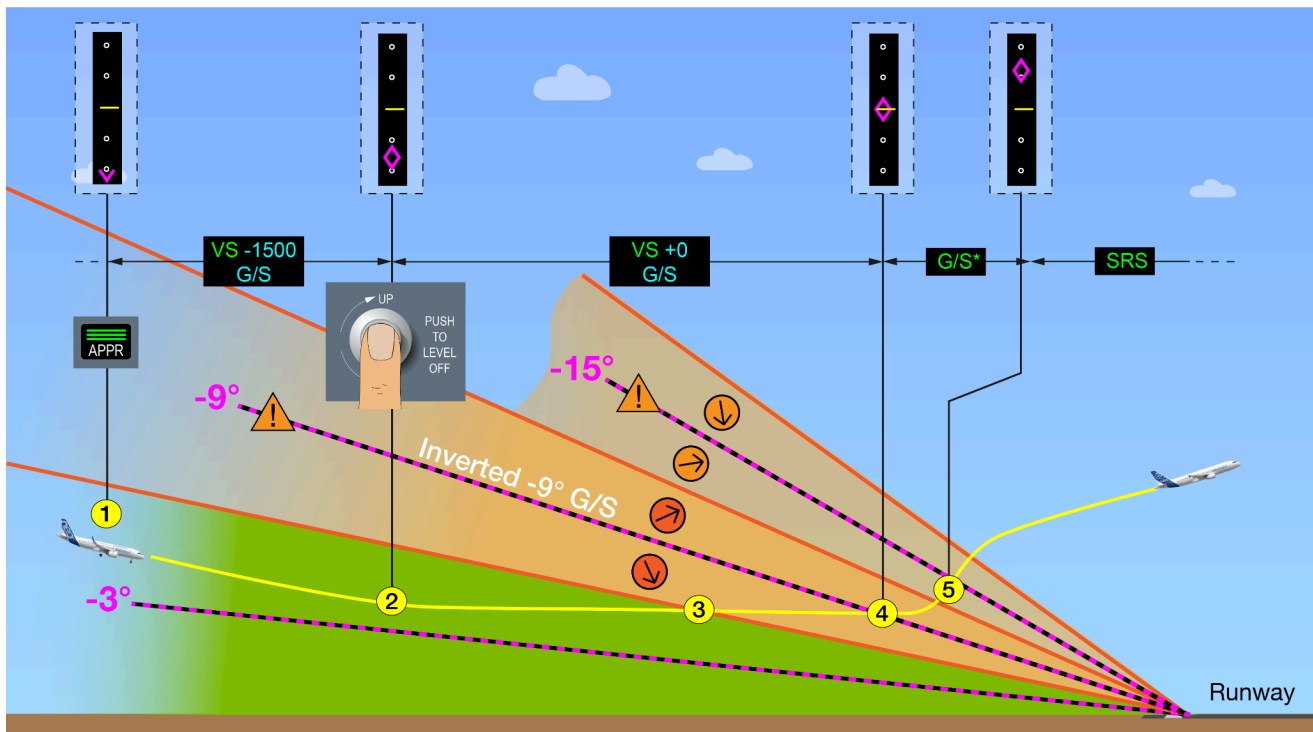
(fig.7) Excessive pitch up command due to inverted secondary glide slope capture

Prevention: Correct FCU altitude setting during glide interception from above

The "glide interception from above" FCOM procedure requests the flight crew to select the FCU altitude above aircraft altitude. This should be done after the flight crew presses the **APPR** (LAND for A300-600/A310) pushbutton to prevent unwanted **ALT*** engagement and possible level-off that can lead to the capture of a secondary glide slope as shown in this example. This important step of the procedure can prevent such an occurrence. ■

CASE 3: UNEXPECTED PITCH UP DURING A DISCONTINUED APPROACH

① The flight crew needs to interrupt their glide slope interception from above at the request of ATC, due to unavailability of the runway (fig.8). ② The flight crew presses the **VS/FPA** knob-selector to level off but does not press the **APPR** pushbutton to disarm the **G/S** guidance mode, which is usually expected during a discontinued approach. The aircraft levels off as expected. This now follows the same scenario as described in case 2: ③ When the aircraft crosses the -6° boundary between the -3° and -9° glide slope, the duration of the temporary false deviation value of zero is short enough not to engage the **G/S*** mode. ④ When the aircraft crosses the -9° glide slope, the **G/S*** mode engages and commands a pitch up due to the inversion of the secondary glide slope. ⑤ The flight crew must take over and perform a go-around.



(fig.8) Unexpected pitch up during a discontinued approach

Prevention: Disarming of the approach guidance mode during discontinued approach procedure

After the flight crew announces "CANCEL APPROACH", they must remember to press the **APPR** pushbutton to disarm the **G/S** guidance mode as per the "discontinued approach" SOP. This will prevent engagement of the **G/S*** and **G/S** modes on a secondary ILS glide slope. ■

AVAILABLE PROTECTIONS

Airbus developed some protections to limit the Flight Path Angle (FPA) in the case of a secondary glide slope capture by doing some modification on the autopilot flight guidance laws. These are available on A330, A340, A350, and A380 aircraft and limit the maximum Flight Path Angle (FPA) between 0° and -6° in **G/S*** mode. A320neo family aircraft have FPA protection in both **G/S*** and **G/S** modes.

The protections referred to above are not available on A220, A300, A310, and A320ceo aircraft at the time of publishing. The same protections will be introduced on A320ceo, and the protections that are already available on A330, A350, and A380 aircraft will be updated with the next Flight Guidance computer standard update to make these protections available in both **G/S*** and **G/S** modes. A similar protection will be added in the **GS** guidance mode of A220 aircraft at the opportunity of a future avionics build. ■

Aircraft	Current Design		Future Design		
	Protected Modes -6° < FPA < 0°	Minimum Flight Guidance Standard	Protected Modes -6° < FPA < 0°	Minimum Flight Guidance Standard	Availability Date
A300, A310	None	Not applicable	None	Not applicable	Not applicable
A220	None	Not applicable	GS	Under definition	Not yet planned
A320ceo	None	Not applicable	G/S* and G/S	I16 or C15 PI19 or PC21	Q4 2024 Q1 2025/2026
A320neo	G/S* and G/S	Basic	G/S* and G/S	Basic	Available
A330 & A330neo	G/S*	HJ1 or G1	G/S* and G/S	H7	Q4 2022
A340	G/S*	F3	None	Not applicable	Not applicable
A350	G/S*	Basic	G/S* and G/S	PRIM P13	Q4 2021
A380	G/S*	P8	G/S* and G/S	PRIM P13.5	Q2 2022

Table 1: Availability of protections in **G/S*** and **G/S** guidance modes to prevent excessive pitch if a capture of a secondary glide slope occurs. Note: Data correct at time of publication in December 2021.

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Secondary glide slopes are inevitable characteristics of ILS approaches. Flight crews must be aware of secondary glide slopes and their possible effect on the display of the glide slope deviations and on the aircraft trajectory. This will ensure that they react correctly in the case of a secondary glide slope capture.

Flight crews can prevent a secondary glide slope capture by following the applicable FCOM SOP.

To intercept an ILS glide slope from above, the aircraft should be below the boundary between the primary glide slope and the first secondary glide slope (6° for a 3° glide slope). The flight crew should then press the **APPR** (LAND for A300-600/A310) pushbutton and ensure that the FCU altitude is set above the aircraft altitude.

In the case of a discontinued approach, after the “CANCEL APPROACH” callout, the flight crew should press the **APPR** (ALT. HLD for A300-600/A310) pushbutton to disarm the **G/S** guidance mode as per the SOP.

Airbus developed protections for the **G/S*** and **G/S** guidance modes to limit the flight path angle of the aircraft between 0° and -6° . This will prevent an excessive pitch command if an unwanted capture of a secondary glide slope occurs. These protections are available on many Airbus aircraft in **G/S*** guidance modes and will be made available for most of the Airbus fly-by-wire aircraft in both **G/S*** and **G/S** guidance modes on future flight guidance computer standards.

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