

## **SAFETY NOTICE**

**SUBJECT: Unstable Approaches – Air Traffic Control Considerations**

**GENERAL:** Safety Notices (SNs) are issued by the Civil Aviation Authority – Macao, China to convey advisory information to Macao aviation entities to enhance safety. SNs contain safety-related recommendations, guidance and/or industrial best practices to specific subjects which may or may not have been addressed by established requirements and regulations.

**RELATED REGULATIONS:** AC/ATS/006 Manual of Standards – Air Traffic Management

**APPLICABILITY:** This SN applies to Macao Air Traffic Service Provider.

**CANCELLATION:** This SN is the first SN issued on this subject.

**REFERENCES:** The following material was referred to for the development of this SN:

- ICAO Regional Aviation Safety Group – Asia and Pacific Regions (RASG-APAC) endorsed safety tools – Guidance material on Unstablished Approach

### **1. Introduction**

- 1.1 This safety notice is issued to increase the knowledge of air traffic controllers about stabilized approaches and their awareness of the part that ATC can have in contributing towards an approach becoming unstable.

### **2. Background**

- 2.1 The ICAO Regional Aviation Safety Group – Asia and Pacific Regions (RASG-APAC) endorsed a safety tool which provide information to increase the ATC staff's ability to recognize and identify the possible risks in order to avoid / reduce the risk of unstable approaches.
- 2.2 It is recognized that many factors contribute towards unstable approaches and that the flight crew are ultimately in control of the aircraft; however, this document predominately focuses on the proposed ATC contribution towards an unstable approach. A list of causal factors, some without any ATC involvement, are included so that ATC staff have an awareness of the additional factors that could be occurring during an approach, some of which could lead to an unstable and/or missed approach.

### **3. *Guidance Material (Unstable Approaches – Air Traffic Control Considerations)***

- 3.1 This guidance was developed by Civil Air Navigation Services Organisation (CANSO) and has been endorsed by ICAO RASG-APAC. Appendix 1 to this SN contains material available to assist air traffic controller to bring the attention of the additional factors that could be occurring during an approach, some of which could lead to an unstable and/or missed approach. A copy of the original CANSO document is also available at the following ICAO RASG-APAC Safety Tools page <https://www.icao.int/APAC/RASG/eDocs/Guidance%20material%20on%20Unstablished%20Approach.pdf>

### **4. *Recommended Actions***

- 4.1 Air Traffic Service Provider is encouraged to note the information contained in this Safety Notice and to review its policies, procedures and training to reflect the safety issues contained in this SN.

- End -

# **APPENDIX 1**

## Unstable Approaches: Air Traffic Control Considerations

# Unstable Approaches: Air Traffic Control Considerations

<b>1_ Introduction_p3</b>	
1.1_Objectives_p4	
1.2_Limitations_p4	
<b>2_ ATC Involvement in Unstable Approaches_p4</b>	
2.1_Distance (Time) Provision_p4	
2.1.1_Descent Planning and ATC Routing_p4	
2.1.2_Approaches_p6	
2.1.2.1_Change of Runway_p6	
2.1.2.2_Change of Approach – Precision/ Non-precision_p7	
2.1.2.3_Visual Approaches_p8	
2.1.2.4_Vectoring for Approach_p8	
2.1.3_Descent Planning Requirements_p10	
2.1.3.1_Adherence to the Flight Plan Route and Approach Procedure_p11	
2.1.3.2_Local Knowledge_p11	
2.1.3.3_Track Distance Information From Approach Controller_p11	
2.2_Speed Instructions_p12	
2.2.1_Speed Instructions During Descent_p12	
2.2.1.1_Descent at Higher Speeds_p12	
2.2.1.2_Descent at Lower Speeds_p12	
2.2.2_Speed Instructions on Approach_p13	
<b>3_ Conclusions_p13</b>	
<b>Appendix A_p15</b>	
<b>Appendix B_p16</b>	
<b>Appendix C_p17</b>	
<b>Appendix D_p18</b>	
<b>Appendix E_p19</b>	

## Unstable Approaches

### Air Traffic Control Considerations

#### 1 Introduction

An aircraft must meet certain criteria on approach to be able to land safely. This is because an aircraft in flight, and in particular a large aircraft, possesses a great deal of energy that must be dissipated appropriately during descent, landing and rollout. Managing an aircraft during the descent and approach phases essentially becomes a task of managing energy, which is provided by aircraft speed and level.

Landing long or a landing at excessive speeds can result in an overrun. Excessive sink rates on approach whilst attempting to capture a glide path from above changes the energy state of the aircraft which is difficult for pilots to manage with the possible consequence of a hard landing or even a Controlled Flight into Terrain (CFIT).

The criteria for continuing an approach generally relates to the aircraft's position, height, speed and configuration and should be outlined in an airline's operations manual. For each performance criterion, such as speed, rate of descent, etc., the aircraft must be within a certain tolerable 'window' in order for it to be classified as 'stabilised' and continue to land. These criteria are assessed at 'gates' that tend to be established, depending on individual airline Standard Operating Procedures (SOPs) and flight conditions, between 1,500ft and

500ft above ground level. (Descriptions of typical 'window' criteria can be found in Appendix A).

Should the aircraft not meet these criteria, it is considered to be unstable, and a pilot should be expected to execute a go-around. If an aircraft does not meet the conditions of the gate criteria and proceeds beyond the gate altitude, then the occurrence is, in some operators, automatically logged by the aircraft's on-board information monitoring system (Flight Data Recorder) and the airline operator informed. Although the approach's stability is only officially 'measured' (against the criteria) when the aircraft passes through the above gates, an unstable approach is usually the result of a series of causal factors (weather, tailwind, fatigue, pressure, workload, poor planning, pilot error, Air Traffic Control (ATC) interaction, procedures etc.), which can occur at any stage of the approach, even as far back as the cruise phase.

The diagram below (Fig. 1) represents a typical approach divided into stages, with key events shown. Within each of these stages, the aircraft can be subject to adverse interactions that could result in the approach becoming unstable. (A suggested list of the possible causal factors which could affect the flight during any of the stages can be found in Appendix B.)

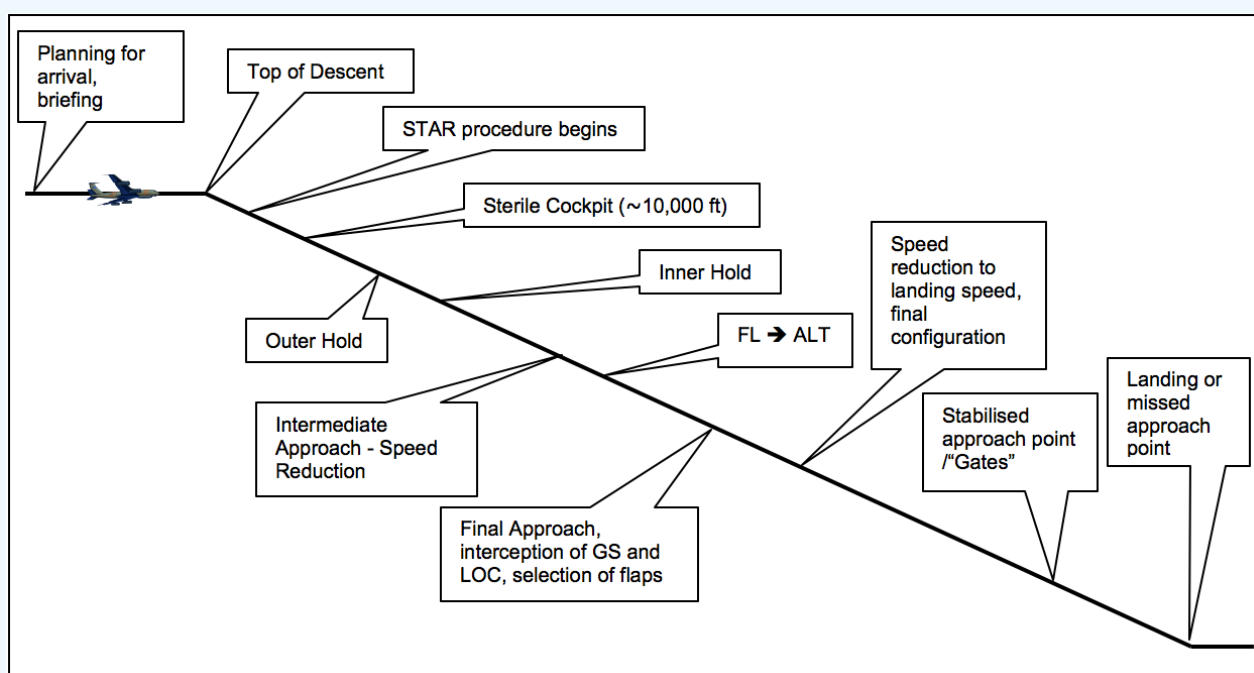


Figure 1: Approach Stages and Key Events

Pilots are under pressure to achieve a stabilised approach for a number of reasons:

- **Safety:** Unstable approaches have either directly or indirectly been the cause of several incidents and accidents, including runway excursions.
- **Economic:** A missed approach can essentially nullify all profit from a flight. Due to fuel constraints, it may also result in a diversion to an alternate aerodrome<sup>1</sup>.
- **Legal:** Recent changes in legislation (within Europe, European Union Operations (EU Ops) have replaced JAR OPS 1, which now trumps any national law) stipulate that stabilised approaches are mandated.

Ultimately, it remains the responsibility of the Pilot in Command to decide not to continue an approach if, in his or her opinion, the approach is becoming unstable. This decision can be made at any point during the approach and not just at the stabilised approach decision point. Nevertheless, in the chain of events that can lead to an unstable approach, ATC can play a role.

### 1.1 Objectives

The purpose of this booklet is to increase the knowledge of air traffic controllers about stabilised approaches and to increase their awareness of the part that ATC can have in contributing towards an approach becoming unstable.

### 1.2 Limitations

It is recognised that many factors contribute towards unstable approaches and that the flight crew are ultimately in control of the aircraft; however, this document predominately focuses on the proposed ATC contribution towards an unstable approach. Flight crew issues such as competence, training and Crew Resource

Management (CRM) are not covered herein. A list of causal factors, some without any ATC involvement, are included (see Appendix B) so that ATC staff have an awareness of the additional factors that could be occurring during an approach, some of which could lead to an unstable and/or missed approach.

In this assessment, the contributory causes towards unstable approaches have been considered from a generic perspective, but with an emphasis on turbojet/turbofan aircraft. The principles provided in this paper may not apply to all aircraft and airline operating procedures.

## 2 ATC Involvement in Unstable Approaches

This section considers the role that ATC can play in contributing to unstable approaches and discusses potential solutions from an ATC perspective. The premise of this assessment is that ATCOs can contribute towards unstable approaches through their involvement in and understanding of the following basic factors:

- Distance (time) provision
- Speed instructions

For both of the above factors, two-way communication between ATC and the flight-deck plays a very important role. With good communication from both sides, the risk of an unstable approach occurring can be significantly reduced.

### 2.1 Distance (Time) Provision

#### 2.1.1 Descent Planning and ATC Routing

When operating piston and light turboprop aircraft, descent planning is relatively straightforward, as these aircraft operate at lower speeds and altitudes and use propellers, which can be manipulated to increase drag.

<sup>1</sup> An aircraft must typically carry sufficient fuel to fly to the primary (planned) destination, and then to an alternate destination. If the aircraft does not land at the primary destination (unstable approach, bad weather, blocked runway, etc.), this may result in the primary fuel being used, leaving nothing but the diversion fuel in the tanks. In this case, a diversion is mandatory. The only exception to this, under EU rules, is an option for the crew to remain at destination if certain criteria are met and to burn off the diversion fuel (in this case the crew should inform ATC that they are using their diversion fuel). In the latter case, if the aircraft reaches, or is anticipated to reach, its final reserve fuel, then a Mayday call is mandatory.

Jet aircraft (and larger turbo prop aircraft) have a ‘clean’ design that offers minimal drag in order to achieve high cruising speeds. Therefore, jet aircraft have a tendency to be ‘slippery’, i.e., require a large distance to descend and/or slow down. Further, jet aircraft operate at higher altitudes, making the descent longer, which can compound any errors. The situation is exacerbated by the use of modern, high-bypass, turbofan engines, which produce a significantly higher residual thrust at flight-idle than older, low-bypass or pure turbojet engines fitted to the previous generation of jet aircraft.

Large aircraft are often fitted with a Flight Management System (FMS) that performs the descent calculations. Based on the planned route, the FMS continuously calculates and updates a vertical profile and a speed profile, collectively referred to as a descent profile in this assessment. The vertical profile relates to the aircraft’s planned level at any given point during the descent, and the speed profile relates to the target speeds for each segment of the descent. The speed profile is calculated by a number of factors such as speed limits, wind and Cost Index<sup>2</sup>.

With the necessary involvement of ATC instructions, the FMS-calculated descent profile

is not often flown. It is therefore important that the flight crew keep a mental model (situational awareness) of the profile, as the constantly changing environment can quickly alter the remaining track mileage.

Descent planning for jet aircraft (including business jets, see Reference 4) is often based on a ‘three times’ rule of thumb, or a variant thereof (depending on aircraft size and altitude—see below). As an example, with 100 nautical track miles remaining, the aircraft should be at approximately 30,000ft on its descent profile. Extra distance is then added for deceleration. At high altitudes descent profiles are generally calculated as 3 times the height plus 20 or 30nm, or 4 times the height until required to slow below 250kts. With larger aircraft such as the B747 or A380, momentum plays a bigger role; hence, a longer distance for deceleration is required. Other factors may also play a role during manual descent planning, such as speed instructions from ATC, wind and turbulence.

A simplified example is shown in Figure 2 below. Note that the numbers used are for illustration purposes only and will vary depending on aircraft type.

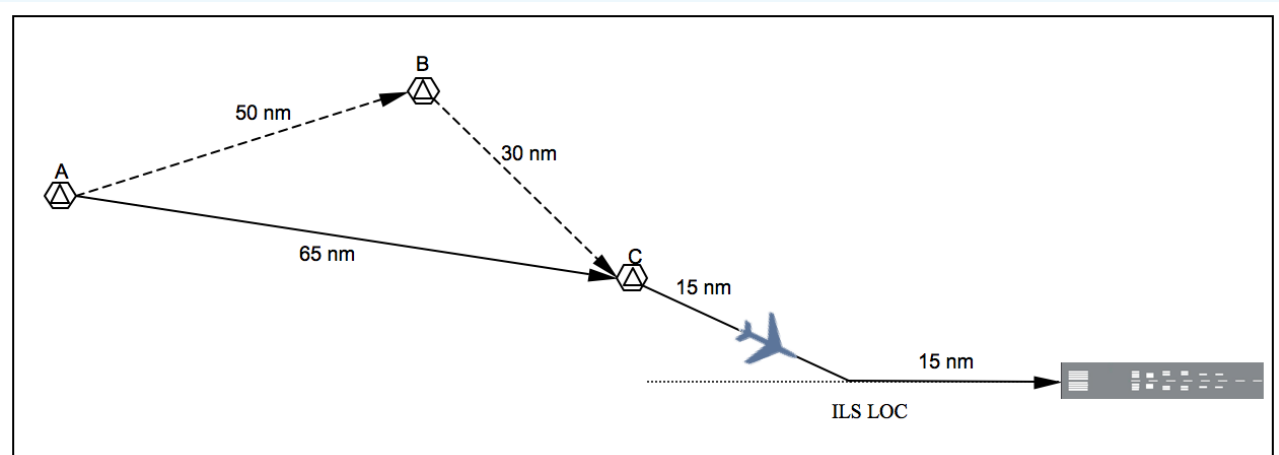


Figure 2: Descent Planning Example (Plan View)

<sup>2</sup>The Cost Index (CI) is entered into the FMS and provides a time-to-money ratio. The CI usually ranges from 0 – 200. As an example, inputting a CI of 0 will yield the most economic flight, but at the lowest speeds. A CI of 200 would result in highest speeds, but also at the highest financial cost. The CI is calculated by the AO Ops department and input into the FMS before the flight departs.



- Should the aircraft follow the planned route (A - B - C - Airport), the total track distance would be 110 miles. Assuming no wind, the aircraft should aim to use perhaps 10 miles for decelerating and the remaining 100 miles for descending, meaning that the aircraft should aim to be at approximately 30,000ft at point A, according to the 'three times' rule (at 30,000ft larger aircraft using the 4x rule calculation would need 100nm plus 20nm for the deceleration).
- Should ATC give the aircraft a shorter route at Point A (A - C - Airport), the total track distance would reduce to 95 track miles. Assuming no wind, the aircraft should aim to again use 10 miles for decelerating and the remaining 85 miles for descending, meaning that the aircraft should aim to be at approximately 25,000ft at point A, according to the 'three times' rule. This means the aircraft would suddenly be 5,000ft high on the 'new' descent profile.

Ideally, descents usually take place with little or no thrust, hence immediate measures that are available to 'catch' the profile are speed brakes and increased speed (the effect of speed is discussed in further detail in Section 2.2). Speed limits tend to apply at lower levels (e.g. 250 knots below FL100) and speed brakes often become less effective as the aircraft decelerates, although even at lower speeds, speed brakes are capable of doubling the normal rate of descent. Towards the latter stages of the descent, drag may be increased further by early deployment of gear and flaps. However these aircraft configuration changes are not preferred due to increased system wear (even though flaps and gear have defined maximum operating speeds). Another disadvantage comes with the fact that medium and large aircraft have landing gear "cycle" limitations thereby limiting the frequency of retraction or extension by the crew. After the landing gear and flaps are selected down, they are not retracted until after landing or during the execution of a missed approach or go-around. Therefore when

the additional drag caused by the deployed flaps and gear is not required anymore, an increase in thrust is required to counteract the drag, therefore negatively affecting fuel consumption and noise levels. Although the FMS will automatically try to adjust the descent profile for alterations, a point can be reached where the aircraft simply does not have sufficient distance to descend and decelerate. An aircraft falling behind the descent profile and unable to continue the approach can be caused by both a variation and combination of factors. A common contributing factor arises from the inability of the crew to anticipate all ATC instructions, or irregular instructions. Such situations may occur when wind velocity and direction significantly differ from that which is forecast. Another possible reason for approach instability may be due to high workload which does not allow the crew to appropriately focus on energy management during the approach. Should this occur early in the approach the crew may request additional track miles to provide the time and distance to regain the desired profile. Later in the approach, adjustments to regain the profile become more problematic until such a point where the crew must decide to execute a missed approach or request new vectors for final approach.

One of the most critical elements is to ensure that the crew receive regular and accurate updates of the distance from touchdown (DFT) and are informed at the earliest opportunity of a change in routing; vectoring will significantly alter the track miles. This is especially important for planning purposes if the track miles are being reduced.

## 2.1.2\_ Approaches

### 2.1.2.1\_ Change of Runway

Prior to arrival a number of tasks must be accomplished on the flight-deck. As an example, the flight-deck must be configured for the approach, including setting frequencies, minima, levels, speeds, routings etc. Following this a briefing is required. Briefings are a component of Crew Resource Management (CRM) to assure 'transparency'; i.e. crew are working to the same plan for both normal and abnormal events. Briefings will always include details of the Missed

Approach Procedures (MAP) for the planned arrival runway. The crew will also fly the approach expecting to “go-around” until reaching the decision height or missed approach point at which time the decision to continue to land must be made. However, a go-around can still be initiated at any point in the approach, even after the aircraft has touched down but before the reverse thrusters have been deployed.

Prior to the approach, the setup and briefing tend to be conducted reasonably early, usually well before top of descent. A late runway change may not only imply a different routing for the aircraft, but also necessitate that the flight deck must be set up for a different approach on a different runway. This will require a new briefing and the Flight Management Computer (FMC) to be reprogrammed. In VMC, many airlines are now advocating against acceptance of a late runway change. Late changes should only be accepted by the crew if the change is based on a visual approach where the aircraft can be kept stabilised AND the missed approach will be a visual missed approach not requiring the FMC to be re-programmed. Late runway changes tend to increase the flight deck workload significantly during an already busy flight phase. This also applies to any changes to the standard MAP which, if not as published, should be communicated to the flight crew as early as possible. It is reasonable to assume that errors are more likely to occur as the workload increases.

Runway changes that result in more track miles remaining are generally easier to cope with, as they provide additional time for the setup and briefing. With more track miles suddenly remaining, the aircraft will be low on the ‘new’ profile which can be compensated for by reducing the rate of descent. Further, a late change to a parallel runway with the same type of approach tends to be easier to cope with, as the descent profile remains virtually the same.

The most difficult runway change involves a change to a runway that results in less track miles remaining. As an example, a late change from 09 to 27 for an aircraft coming from the east will probably result in a rushed setup and

an abbreviated briefing, and will, assuming the aircraft was on profile in the first place, suddenly put the aircraft high on the ‘new’ profile. In these instances, additional track miles will probably be required.

#### 2.1.2.2\_ Change of Approach – Precision/Non-precision

There are fundamental differences in how different types of approaches are flown. The ILS is the most common approach used at large airports. An ILS approach is usually flown at 3° and allows most aircraft to fly a large part of the approach on autopilot. It also requires relatively little manipulation of the autopilot during the approach; it is primarily controlled speed reduction that permits flaps and gear to be deployed. During an ILS approach the aircraft will continue to slow and configure after becoming established on both the localiser and the glide slope. This means that the aircraft can maintain a relatively high speed until late in the approach, such as 160knots until four miles. However, it is very difficult for a larger aircraft (A330, B-737-800, etc) to descend on the glide slope and slow down simultaneously, therefore the controller must allow for deceleration to final approach speed when the aircraft is approaching the glide slope interception point. Flight crew requests for a slower airspeed during the final portion of the approach should be approved to the maximum extent possible.

Non-precision approaches<sup>3</sup> result in a much higher workload, as in many cases, the crew must manually and continuously monitor and control the rate of descent or altitude. Although it can be flown on autopilot, more manipulation of the autopilot is required, as the crew must continuously adjust the rate of descent. The rate of descent for non-precision approaches can also be steeper in the final approach segment than for precision approaches. The autopilot is usually disconnected earlier compared to a precision approach, as the decision point (decision altitude) is higher. Non-precision approaches may be offset from the runway, which requires an element of manual handling late in the approach, and as they are not usually flown and practiced as frequently as precision approaches, it can result in

<sup>3</sup>ICAO assembly resolution A37-11 underpins the higher safety risks with non-precision operations and aims at having the availability of approach procedures with vertical guidance to all runways.

the crew being less proficient.

Controllers should be aware of the increased workload and constraints for the aircrew when flying a non-precision approach (see 2.1.2.4), and should aim to position the aircraft on finals at a distance greater than normal to allow the crew time to appropriately set up their configuration.

Note: The International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services – Air Traffic Management (PANS ATM) does not differentiate on how a controller is expected to radar vector an aircraft to the final approach course; the same procedure applies (30 degrees or less, two nautical miles prior to glide slope intercept) for precision or non-precision approaches. However, an awareness of flight crew workload can prevent overloading the flight deck, which could lead to a loss of situational awareness and create a situation with a high potential for an incident/accident.

Based on these challenges, non-precision approaches tend to be carefully briefed. A fundamental difference compared to a precision approach is speed management. As the speed decreases, the pilot must, with reference to instruments adjust the rate of descent in order to remain on the correct glide-path. As the aircraft is slowed, the initial calculated rate of descent will need to be reduced otherwise the aircraft will descend below the glide-path. These changes, along with aircraft configuration inputs, may significantly increase the cockpit workload and have been direct causal factors in many CFIT events. If the speed is stable however, the rate of descent can also be stabilised, reducing cockpit workload and allowing greater monitoring of the approach. Non-precision approaches can also be steeper than precision approaches; hence the aircraft must be slowed down and configured earlier. Therefore it would be unreasonable to provide the pilots with any form of speed instructions after the Final Approach Fix (FAF).[1] In fact, many airlines train their crews to fly a non-precision approach at the final approach speed and therefore most crews would elect to slow down much earlier than when on an ILS.

Considering the above, a late change from

a precision approach to a non-precision approach can be significant from a pilot perspective, and may not always be feasible unless additional track miles are granted. Some operators do not allow the crew to fly any approach unless it was previously briefed, and for this, the crew requires extra time. The main fundamental difference as compared to a precision approach, is the management of speed and rate of descent.

#### 2.1.2.3\_ Visual Approaches

A visual approach is usually flown manually and is mainly based on pilot judgement. Visual approaches follow a standard traffic pattern, or variations thereof. Pilots sometimes request visual approaches at smaller airfields even if an instrument approach is available, as they can be made shorter and therefore be quicker. A visual approach requires no instrument guidance; however, the flight crew will often use on-board navigation systems (if available) for reference.

Visual approaches are more judgement-based with less guidance available and can be associated with more pilot errors (including performing unstable approaches) than instrument approaches. Offering an aircraft a visual approach with short notice to expedite traffic flows will again result in a higher workload on the flight-deck, as a new briefing and strategy will be required and may be refused by the crew if they do not have sufficient time to brief. Airline flight crews may be less proficient with visual approaches, as they tend to be performed less frequently, so, contrary to belief, offering a visual approach is not necessarily the aircrew's preferred option.

#### 2.1.2.4\_ Vectoring for Approach

Both lateral and vertical guidance must be provided for any type of approach. The lateral guidance can be determined by obtaining distance and bearing from a radio beacon of some sort (NDB, ILS, VOR, DME, LOC, etc.), or space based (GNSS) navigation aids.

For an ILS precision approach, the vertical guidance is based on the glide slope signal which is emitted from the side of the runway. Non-precision approaches do not provide a glide slope signal, hence the vertical guidance is based on

height/distance calculations using the DME, timing from a fix or by the FMS during a VNAV approach. In this case it is often the Pilot Monitoring (PM) that provides the vertical guidance to the Pilot Flying (PF) by calling out the appropriate levels for each point in the approach. This represents a significant increase in flight-deck workload and controllers should be aware of this and vector the aircraft onto finals at a greater distance than they would for a precision approach.

An aircraft can either self-position for an approach or be vectored. Before leaving the Initial Approach Altitude<sup>4</sup> (also known as Platform Altitude), the aircraft must be lined up with the runway, if carrying out a precision approach and be at an appropriate distance. If the aircraft is not in the correct position, the final descent cannot be commenced, as the aircraft may be outside of the protected area and terrain separation cannot be assured. A descent at this point would be dangerous, particularly if in Instrument Meteorological Conditions.

Vectoring by ATC plays an important role in positioning an aircraft for an approach. The following examples show one scenario during which an aircraft is correctly vectored for a precision approach and one scenario where unrealistic vectoring results in the aircraft performing a missed approach and/or becoming unstable.

In the correctly executed scenario in Figure 3 below, the aircraft at Point A is vectored in for an approach and is likely to intercept the localiser before the glide slope, or at least at the same time as the glide slope (Point B). In this case, the aircraft will intercept the glide slope from below, which is preferred.<sup>5</sup> Provided that the aircraft has been cleared for the approach, it can safely descend on the glide slope, as it has both lateral and vertical guidance.

Basic aircraft instruments are shown, with the vertical bar on the dial showing the localiser, and the horizontal bar showing the glide-slope.

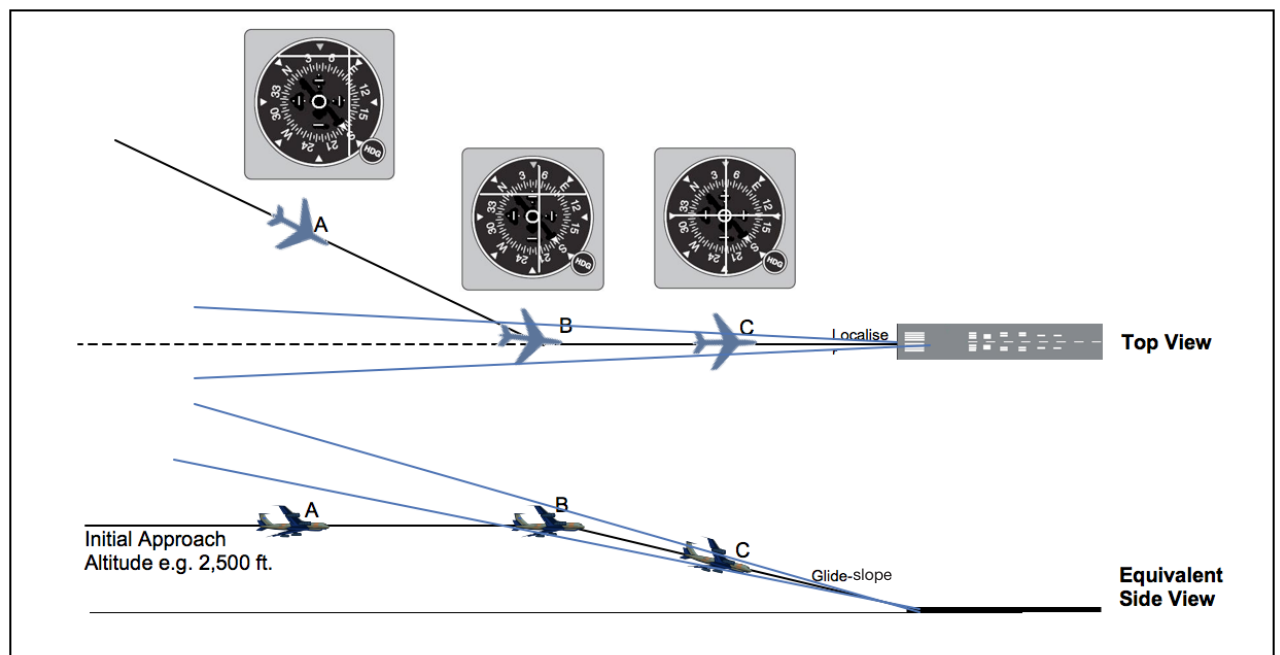


Figure 3: Approach Vectoring (Reference Scenario)

<sup>4</sup> At many airports, a form of Continuous Descent Operations (CDO) is used. ICAO has adopted the term CDO to 'embrace the different techniques being applied to maximise operational efficiency while still addressing local airspace requirements and constraints. These operations have been variously known as continuous descent arrivals, continuous descent approaches, optimized profile descent, tailored arrivals and 3D/4D path arrival management forming part of the business trajectory concept'. In these cases, the aircraft would descend onto the localiser and glide slope without leveling off. Refer to ICAO Doc 9931, Continuous Descent Operations Manual, for more information.

<sup>5</sup> Catching the glide slope from above is considered poor practice, as a glide slope may emit a 'false' glide slope above the actual glide slope. The 'false' glide slope is steeper than the actual glide-slope and is not reliable.

The scenario shown in Figure 4 depicts the use of unrealistic vectors that result in the aircraft becoming unstable, causing it to either execute a missed approach or incorrectly continue the approach.

The aircraft at Point D has been cut in short by ATC and has not yet arrived at the localiser. However, it is picking up the glide slope signal since it is within range. As the aircraft moves closer to the runway, the glide slope indicator tells it to descend in accordance with the glide slope even if the aircraft has not arrived at the localiser and therefore has no lateral guidance. The pilot must ignore this indication, as descending would be unsafe. Therefore, the aircraft continues in level flight.

As the aircraft reaches Point E, it finally picks up the localiser and now has both lateral and vertical guidance, but is at this point very high on the glide slope and is unable to descend sufficiently to regain the glide slope. As the aircraft is already descending and probably also decelerating, increasing the rate of descent is difficult. The aircraft should therefore execute a missed approach.

Vectoring an aircraft in too short (as illustrated in Figure 4 below) should be avoided, as it will likely lead to a missed approach or excessive sink rates as the flight crew attempt to catch the glide slope from above. An approach with excessive sink rates is, by definition, an unstable approach (see Appendix A).

### 2.1.3\_ Descent Planning Requirements

For the crew to be able to adequately perform descent planning, at least one of the following is required:

- Adherence to the flight plan route and approach procedure;
- Local knowledge of potential deviations;
- Track distance information from the approach controller.

To expect aircraft to always adhere to the planned route and approach procedure is impractical for ATC. Also, not all pilots will have experience with local ATC procedures. Therefore, the option that provides the most flexibility is provision of track distance information from

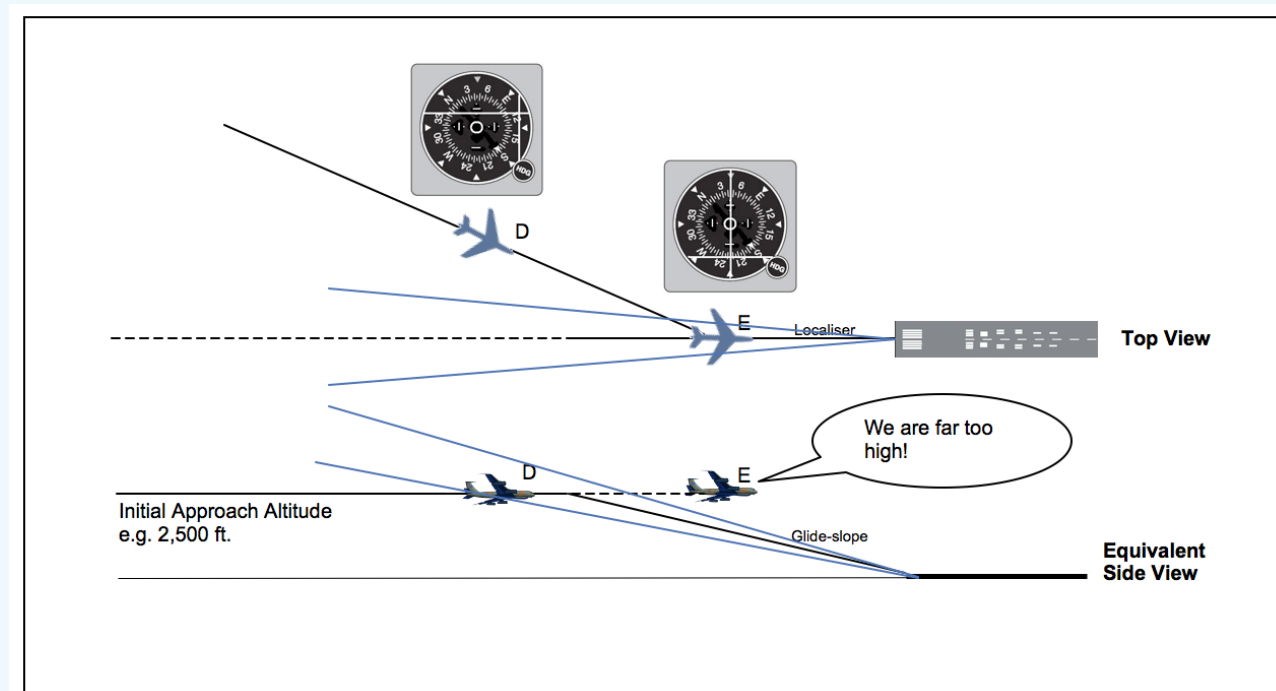


Figure 4: Approach Vectoring (Unrealistic Vectors)



the approach controller any time the aircraft is deviated from the planned route and approach procedure.

These are discussed in further detail below.

#### 2.1.3.1\_ Adherence to the Flight Plan Route and Approach Procedure

Based on the flight plan route, a descent profile can be calculated by the FMS. If the aircraft adheres to the planned route, it should also adhere reasonably to the descent profile. Whenever ATC modifies the route, some form of compensation will be required, such as a speed change or even speed brake deployment.

For ATC to keep all aircraft on their planned routes and descent profiles may not be practical in most traffic situations. Adjustments to speed, headings and levels are usually required to control traffic flow at busy times. Despite the aforementioned concerns regarding shortcuts and track mileage, some flight crew may deem that the shortcut is achievable and accept the shorter route to save time and fuel and to keep their place in the flow of traffic.

If ATC has to keep an aircraft above profile for operational reasons, it may be appropriate to adjust the aircraft speed (e.g., assign a reduced speed) prior to commencement of descent in order to compensate for the 'high' profile. Most FMS programs keep the aircraft at the maximum altitude for as long as possible, using a profile with thrust at or near idle. As a consequence, there is little to no additional descent capability for the aircraft when descent is delayed significantly beyond the computed 'top of descent point', unless the flight crew uses increased descent speed, a longer flight path or speed brakes.

Controllers should also be aware of the effect that icing has on the operation of the aircraft during the descent. Most modern aircraft require a power setting above 'flight idle' whilst descending in known icing conditions. While planning the sequence of arrival or vectoring aircraft, controllers should be aware of this additional constraint and should be careful not to position aircraft above the descent profile, as the 'recovery' to regain the profile will be much more difficult based on the additional thrust provided by the engines.

If an aircraft is held high for any reason, it is likely to end up above the required descent profile. Once the descent is granted, it will again have to compensate by increasing its descent rate, which makes it impossible to reasonably decelerate.

#### 2.1.3.2\_ Local Knowledge

'Local knowledge' refers to the flight crew's experience with a particular area, allowing them to anticipate the ATC instructions associated with that area. As an example, certain airports publish arrival procedures that are seldom adhered to; instead, an unofficial vectored route is provided which may be longer or shorter. Pilots familiar with the approach will most likely position themselves high or low on the descent/approach in anticipation of the route change. Most major airlines use "Airport Briefing" notes to try to provide some local knowledge to crews. This information comes from either pilot or ATC feedback and from previous incidents or hazard reports.

Although the flight crew may be experienced, they may not be experienced with the arrival in question and will therefore be unable to anticipate ATC instructions.

#### 2.1.3.3\_ Track Distance Information from Approach Controller

In cases where aircraft are being vectored for an approach, provision of a regular and accurate distance to touchdown from the approach controller allows the flight crew to calculate their descent profile. This is particularly important during CDO (see Appendix C), as the room for correction is smaller. This information must be provided reasonably early during the approach to enable adjustments to be made. Should the remaining track miles be provided/updated late in the profile, it will be more difficult for the flight crew to make any necessary compensations.

Should the flight crew determine that the track miles proposed by the controller are inadequate, they may request additional track miles to enable them to comply with their criteria restrictions for maintaining a stabilised approach. If the extra miles are not available, and the crew continue with the approach, there is an increased

risk that the approach may become unstable.

The ATC belief that reducing the remaining track distance will help the flight crew is not always true; it can significantly increase the flight-deck workload, as the crew must attempt to catch the 'new' descent profile whilst trying to maintain a stabilised approach, which increases the associated risks.

## 2.2\_ Speed Instructions

### 2.2.1\_Speed Instructions during Descent

Speed instructions (e.g., maintain 280 knots) are necessary, but they remove some of the flight crew's options for managing the descent. As mentioned earlier, descent planning is a matter of managing energy, which is done effectively by altering drag. As shown by Figure 5, altering an aircraft's speed is a way of altering drag.

A few significant points can be extracted from Figure 5. These are detailed in the following sections.

#### 2.2.1.1 \_ Descent at Higher Speeds

An aircraft descending at higher speeds<sup>6</sup> (e.g., above 250 knots) will descend quicker, as the total drag is higher. Going faster therefore increases the descent rate, which can be used as a means of keeping the aircraft on the vertical profile.

If no speed instruction is given to an aircraft, it will probably descend at the optimum speed for the prevailing conditions as calculated by the FMS, and will probably descend at idle power. Should ATC instruct an aircraft to decelerate to a lower speed, the rate of descent will decrease and the aircraft will drift above the descent profile. At this point, the only option is to use spoilers and/or to request more track miles.

An instruction to maintain a higher-than-normal speed is usually not problematic, as the aircraft can simply add power to keep the aircraft on the descent profile.<sup>7</sup>

An aircraft simultaneously descending and decelerating is dissipating both its kinetic and gravitational energy, which would require a longer distance than an aircraft only decelerating or only descending. As the aircraft decelerates, less drag is available to dissipate energy, which further increases the distance.

#### 2.2.1.2\_ Descent at Lower Speeds

An aircraft descending at lower speeds will descend quicker as total drag increases. This is the likely scenario during final approach when the aircraft is configured for landing. From an ATC perspective, this is not of concern, as the aircraft would add power as necessary; hence, this will not be discussed in further detail.

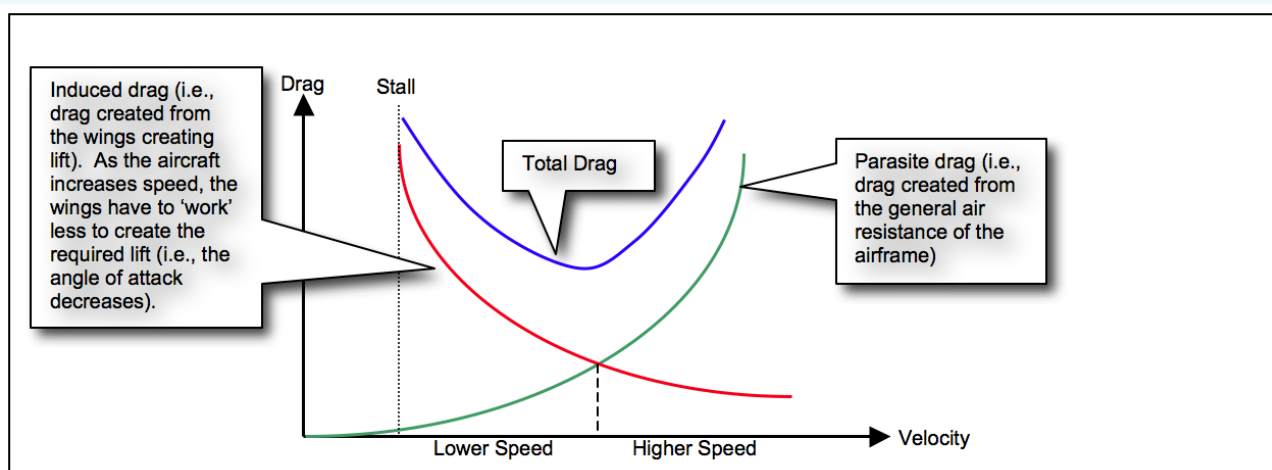


Figure 5: Drag and Speed

<sup>6</sup> With regards to the drag curve in Figure 5, 'higher speeds' usually means speeds above 'clean speed'. The actual speeds vary with aircraft type.

<sup>7</sup> Fuel burn will increase any time the aircraft is not descending at its optimum speed.

### 2.2.2\_ Speed Instructions on Approach

Higher speeds, on the other hand, can create problems as the aircraft gets closer to the airfield, as it requires a certain distance to decelerate and configure for landing. This is illustrated in the example below (Fig. 6) based on a standard three-degree ILS.

It is not uncommon for the last segment of an approach to be flown at 160 knots until four nautical miles, which effectively puts the aircraft at just under 1,300ft above the runway at four nautical miles. A common height for requiring an approach to be stabilised, as the aircraft passes through the 'gates', is 1,000ft above the runway (although, depending on airline SOPs and flight conditions, this can vary between 1,500ft and 500ft).

A speed of 160 knots is too fast for most aircraft to land at; hence, the aircraft must be slowed and configured for landing. This is probably not achievable in the approximate mile that it would take to descend from 1,300 to 1,000ft; hence, the aircraft would have to be slowed and configured before the aircraft reaches the four-mile point. If this is required, then the pilot should inform ATC that he or she cannot comply with the allocated speed restriction. The earlier in the approach this is communicated, the better, allowing ATC more time to adjust their plans and compensate.

## 3 Conclusions

This booklet has considered stable approaches from an ATC perspective only and has not covered flight-deck specifics associated with unstable approaches.

The following bullets provide the main conclusions of this assessment:

- The events that lead to an unstable approach can already begin to transpire during the initial descent (i.e., long before glide slope intercept).
- Unstabilised approaches increase risk of an unsuccessful approach and/or landing. Excessive sink rates on approach while attempting to capture a glide path can result in a hard landing or even a CFIT. An unstabilised approach can also result in landing long or at an excessive speed, which can result in an overrun.
- Any time the route is modified or speed instructions are provided, the aircraft may need to compensate for the change by adjusting power, drag, etc. Larger route modifications require larger aircraft adjustments. Similarly, if an aircraft is held high, it will end up above its descent profile and will again have to compensate.

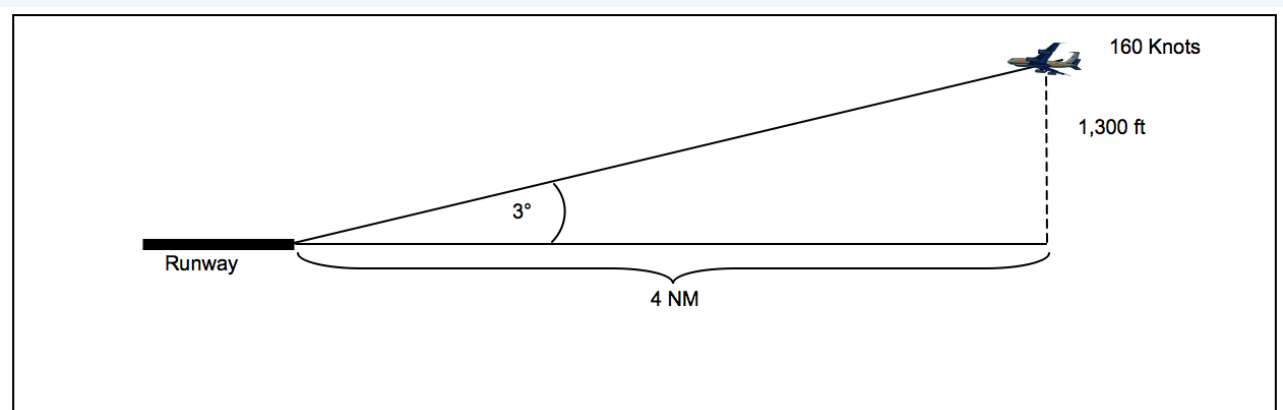


Figure 6: Speed Instruction on Approach (Side View)



- If significant shortcuts are provided during the descent, a point can be reached where the aircraft requires additional track miles to lose altitude and configure for approach and landing.
- Rather than help the flight crew, reducing the remaining track distance can significantly increase the flight-deck workload, as the crew must attempt to catch the 'new' descent profile while trying to maintain a stabilised approach.
- An aircraft requires a significantly longer distance to simultaneously descend and decelerate compared to only descending or only decelerating.
- When providing aircraft with vectors for approach, early, regular and accurate track distance information from the approach controller increases the crew's ability to calculate an accurate, achievable descent profile and reduce the chances of an unstable approach occurring.
- A late runway change significantly increases flight crew workload and increases the potential for error, which could result in an unstable approach. If the change results in a shorter route compared to the original route, more track miles could be required.
- Flight crews usually find non-precision approaches more complex, as they include more elements and are not performed as often as precision approaches. Speed instructions to aircraft that are inside the Final Approach Fix are not recommended. Due to the associated increase in cockpit workload, the aircraft should be vectored for longer finals for a non-precision approach than for a precision approach.
- Visual approaches and circling approaches are more error-prone than full instrument approaches; if ATC does not offer these types of approaches, the pilots will probably execute the approach that they have briefed and are prepared for, thus reducing the risk of an unstable approach occurring.
- Instructing an aircraft to reduce speed during the upper parts of the descent will usually cause it to drift above its descent profile. If it is expected and inserted into the FMS before top of descent, then the top of descent will shift further from the aerodrome, and it will be easier for the crew to follow the recalculated profile. The earlier the crew gets the information, the better.
- Instructing an aircraft to maintain a higher-than-normal speed during the upper parts of the descent will generally not result in problems with regards to maintaining the descent profile, as power can be added.
- Requesting that an aircraft maintain a certain speed during final approach may conflict with the requirements for a stable approach.
- Controllers should be aware that the FMS and ILS equipment are designed so that the localiser is captured first, then the glide slope. If the glide slope is captured before the localiser, the aircraft may not be able to continue the approach without becoming unstable, and the associated risk of a CFIT increases.
- It is better for pilots and ATC to acknowledge that the approach is unstable and abandon the approach early, rather than assuming that they will have the approach stabilised by the minima (e.g., 1,000/500ft), only to go around at the stabilised approach point or, worse, continue to land.
- Controllers should be wary of offering what they might consider to be favourable alternatives (e.g., cutting the aircraft in early, offering the option of a visual approach, etc.). This may lead the flight crew into accepting a situation where there is a significantly increased risk of the flight/approach becoming unstable.

## APPENDIX A

### Criteria for Stable Approach

Although flying a stabilised approach is mandatory (European Commission law), the actual criteria for a stable approach are not mandated by law, but are instead established by each airline to suit their operations and then included in the airline's operations manual. Therefore, the criteria for continuing an approach tend to vary.

The following criteria are those defined by Flight Safety Foundation (Reference 2) and have been included for illustration purposes only. Although these criteria should be viewed as 'ballpark' figures, most criteria used by the airlines tend to be reasonably close to the following:

- The aircraft must be on the correct flight path (ILS: within 1 dot GS/LOC; Visual approach: wings level at 500ft radio; circling approach: wings level at 300ft);
- Only small heading and pitch changes required to maintain path;
- Speed must not deviate more than VRef+20kts/-0kts;
- The aircraft to be in proper landing configuration;
- A sink rate of max 1,000fpm (unless briefed otherwise);
- A power setting appropriate for aircraft configuration and not below the minimum power for an approach as defined in the Aircraft Operations Manual;
- All briefings and checklists must be complete.

The above criteria tend to be applied at the following altitudes:

- IMC - stable by 1,000ft AAL;
- VMC - stable by 500ft AAL. (The aircraft should aim to be stable by 1,000ft even in visual meteorological conditions. If the crew do not achieve this, then the 'gate' can be reset to 500ft, but only if the crew anticipate that the aircraft will be stable by 500ft; if not, a missed approach must be executed.)

Note: The altitude at which the 'gates' are set and by which the approach is judged to be stable varies depending on airline SOPs and can range from 1,500ft to 500ft (300ft for circling approaches).

European Commission law now states: 'Without Visual Ground Reference: It is recommended that stabilisation be achieved at the latest when passing 1,000ft above runway threshold elevation. If ATC procedures require higher speeds and is allowed in the [operations manual], the above gate may not be met, in this case stabilisation should be achieved by 500ft.'

With Visual Ground Reference: Stabilisation should be achieved by 500ft (however it is still recommended that pilots use the 1,000ft gate as above).'

If the above gates are not met, pilots should consider initiating a go-around manoeuvre. Additionally, note the use of the words 'recommended' and 'should'.

## APPENDIX B

### Potential Causal Factors of Unstable Approaches

The following list suggests general causal factors of unstable approaches. Many of these are unrelated to ATC.

- Weather (e.g., turbulence, head/tail winds, avoidance, un-forecast);
- Aircraft technical issues;
- Late or incorrect crew briefings;
- Pilot mismanagement of aircraft energy (e.g., speed, altitude, power);
- Other traffic (e.g., held high to avoid, sequencing to airport, high traffic density);
- Unclear communication: ATC-ATC, ATC-Pilot, Pilot-ATC;
- Air Traffic Information Service (ATIS) (e.g., frequency of ATIS update, equipment to access ATIS [voice, ACARS], length of ATIS message [a requirement for short ATIS with only weather and runway has been expressed], lack of standardisation of format, lack of ATIS or shared ATIS frequencies causing garbling);
- Overloading of human (controller/pilot) due to workload;
- RT loading/congestion (held high beyond planned top of descent);
- Airspace constraints not fit for purpose (e.g., airspace size, complexity of procedures);
- Early speed control (e.g., go down/slow down, unrealistic energy management expectations);
- Vectoring (including intercepting glide slope from above, tight intercepts for the ILS);
- ATC change in routings (e.g., shortcuts/changes to distance from touchdown);
- Speed control restrictions versus aircraft configuration requirements;
- Outside CAS (e.g., no speed/variable intentions/interpretations);
- Late notice of runway change/type of approach;
- Little/inaccurate distance from touchdown information.

## APPENDIX C

### Continuous Descent Operations (CDO)

The term CDO is used to describe the various methods being used around the world to maximise operational efficiency during arrivals, whilst taking into account any localised issues such as airspace constraints or procedures.

CDO is a technique available to ANSPs and aircraft operators that helps to increase both safety (Reference 3) (through increased flight stability) and airspace capacity (through flight predictability), whilst reducing noise, fuel burn, emissions and pilot-controller communications.

An ideal CDO starts from the top of descent (TOD) point in the cruise phase of flight, allowing the aircraft a continuous descent profile, with minimum engine thrust settings, in (where possible) a low drag configuration, with minimum periods of level flight to the final approach fix/ point or where it commences the published instrument approach procedure (Reference 8).

A CDO is shown in Figure 7 below:

The noise 'footprint' is reduced because the aircraft remains higher for longer and the engines remain at lower thrust (i.e., no need to spool up to level off). Due to the lower thrust settings, the CDO also results in reduced fuel burn and less greenhouse gas emissions.

If the aircraft is being vectored, it is essential that the flight crew receive timely and accurate distance from touchdown information from ATC so that they can calculate their required rate of descent. If the aircraft is following a published arrival procedure, the FMS provides an optimum descent path and also deviation information; however, good airmanship calls for the flight crew to still maintain a mental picture of the descent profile, as the FMS is not always accurate.

ATC operational requirements for separation and/or traffic sequencing purposes may mean that it is not always possible to provide the optimal CDO; it may be necessary for ATC to stop a descent and direct level flight for portions of the arrival. However, the aim should be to minimise level offs and maximise CDO to the greatest extent possible, whilst not adversely affecting safety and/or capacity (Reference 8).

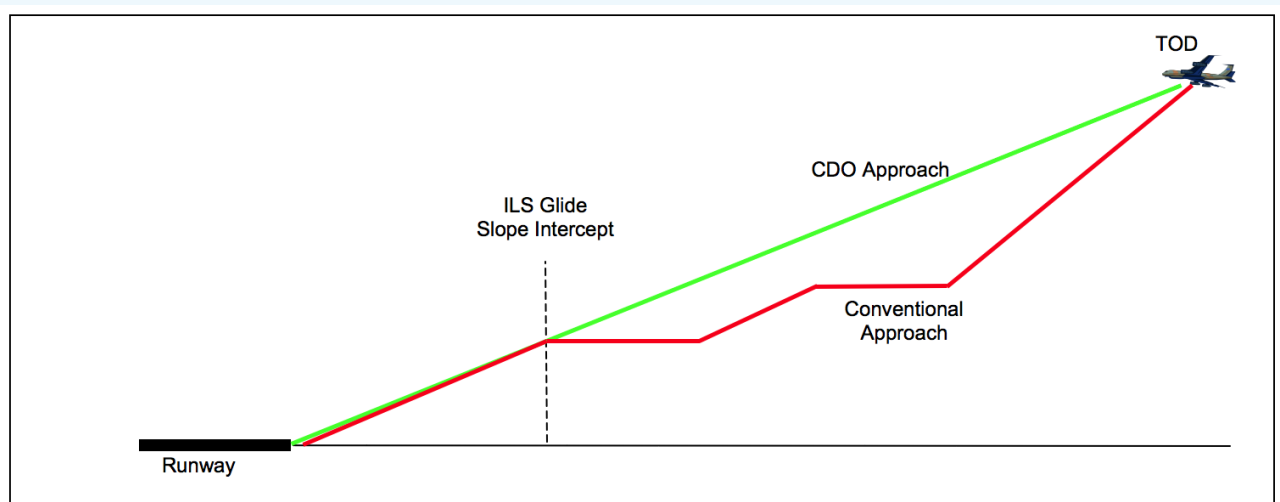


Figure 7: Continuous Descent Operations

## APPENDIX D

### Reference Documents

Ref	Document	Details
1	NATS Safety Management Manual (DOC 39)	Amendment 30, June 2009
2	FSF ALAR 7.1 Briefing Note – 7.1 Stabilised Approach	Flight Safety Foundation, Flight Safety Digest, August-November 2000
3	Instrument Procedures Handbook	US Department of Transportation, Federal Aviation Administration, FAA-H-8261-1A, 2007
4	Business Jet Operations – Consideration of Specific Hazards	HF/RPT/09, April 2009
5	DGAC Surveillance Authority	Unstable Approaches – Good Practice Guide
6	Callback from NASA’s Aviation Safety Reporting System – The Case of the Unstable Approach	Number 284, May 2003
7	The Myth of the Unstable Approach	Dr. Ed. Wischmeyer, Embry-Riddle Aeronautical University, USA. 2004.
8	Continuous Descent Operations (Manual)	ICAO Doc 9931

## **APPENDIX E**

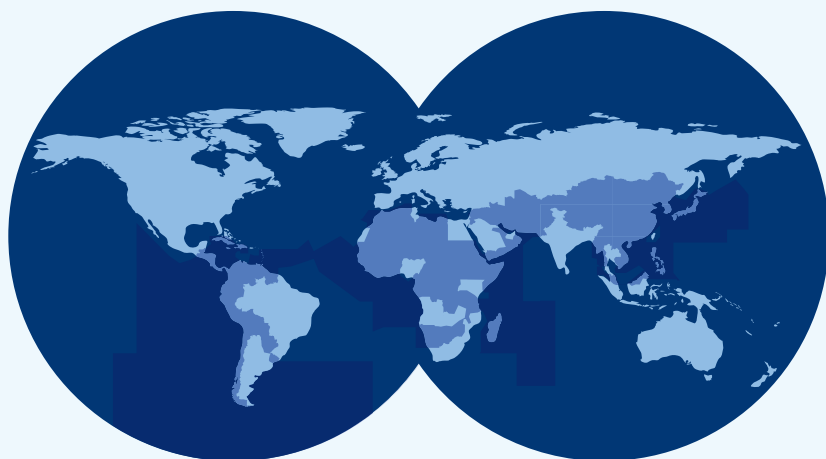
### **Abbreviations**

Ref	Document
ATC	Air Traffic Control
ATIS	Air Traffic Information Service
CANSO	Civil Air Navigation Services Organisation
CDO	Continuous Descent Operations
CFIT	Controlled Flight into Terrain
CI	Cost Index
CRM	Crew Resource Management
DME	Distance Measuring Equipment
EU	European Union
FMS	Flight Management System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
LOC	Localiser
MAP	Missed Approach Procedures
SOP	Standard Operating Procedures

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- Civil Aviation Regulatory Commission (CARC)
- Department of Airspace Control (DECEA)
- Department of Civil Aviation, Republic of Cyprus
- DFS Deutsche Flugsicherung GmbH (DFS)
- Dirección General de Control de Tránsito Aéreo (DGCTA)
- DSNF France
- Dutch Caribbean Air Navigation Service Provider (DC-ANSP)
- ENANA-EP ANGOLA
- ENAV S.p.A: Società Nazionale per l'Assistenza al Volo
- Entidad Pública Aeropuertos Españoles y Navegación Aérea (Aena)
- Estonian Air Navigation Services (EANS)
- Federal Aviation Administration (FAA)
- Finavia Corporation
- GCAA United Arab Emirates
- General Authority of Civil Aviation (GACA)
- Hellenic Civil Aviation Authority (HCAA)
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- Iran Airports Co
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