



The Airbus safety magazine

# Safety first

SPECIAL EDITION  
**Control Your  
Speed Series**

**AIRBUS**



#### **Safety First, Special Edition, Control your**

**Speed Series** February, 2018. Safety first is published by Airbus S.A.S. - 1, rond point Maurice Bellonte - 31707 Blagnac Cedex/France. Publisher and Editor: Yannick Malinge, Chief Product Safety Officer. Concept Design by Airbus Multi Media Support 20180245. Reference: X00D16031905 Special Edition 2. Photos by Airbus, A. Tchaikovski, S. Ramadier, P. Masclet, Lindner Fotografie, P. Pigeyre, JB. Accariez, A. Doumenjou, H. Gousse, F. Lancelot. Computer renderings by Fixion.

This brochure is printed on Stucco.

This paper is produced in factories that are accredited EMAS and certified ISO 9001-14001, PEFC and FSC CoC. It is produced using pulp that has been whitened without either chlorine or acid. The paper is entirely recyclable and is produced from trees grown in sustainable forest resources.

The printing inks use organic pigments or minerals. There is no use of basic dyes or dangerous metals from the cadmium, lead, mercury or hexavalent chromium group.

#### **Editorial Team**

**Guillaume  
ESTRAGNAT**



**Timothy  
ROACH**



**Daniel  
PERCY**



© Airbus S.A.S. 2018 – All rights reserved.  
Proprietary documents.

By taking delivery of this Brochure (hereafter "Brochure"), you accept on behalf of your company to comply with the following guidelines:

» No other intellectual property rights are granted by the delivery of this Brochure than the right to read it, for the sole purpose of information.

» This Brochure and its content shall not be modified and its illustrations and photos shall not be reproduced without prior written consent of Airbus.

» This Brochure and the materials it contains shall not, in whole or in part, be sold, rented, or licensed to any third party subject to payment.

This Brochure contains sensitive information that is correct at the time of going to press.

This information involves a number of factors that could change over time, effecting the true public representation. Airbus assumes no obligation to update any information contained in this document or with respect to the information described herein.

Airbus S.A.S. shall assume no liability for any damage in connection with the use of this Brochure and of the materials it contains, even if Airbus S.A.S. has been advised of the likelihood of such damages.

# Safety first

**The Airbus magazine contributing to the enhancement of the safety of aircraft operations by increasing knowledge and communication on safety related topics.**

Safety first is published by the Product Safety department. It is a source of specialist safety information for the use of airlines who fly and maintain Airbus aircraft. It is also distributed to other selected organizations and is available on digital devices.

Material for publication is obtained from multiple sources and includes selected information from the Airbus Flight Safety Confidential Reporting System, incident and accident investigation reports, system tests and flight tests. Material is also obtained from sources within the airline industry, studies and reports from government agencies and other aviation sources.

All articles in Safety first are presented for information only and are not intended to replace ICAO guidelines, standards or recommended practices, operator-mandated requirements or technical orders. The contents do not supersede any requirements mandated by the State of Registry of the Operator's aircraft or supersede or amend any Airbus type-specific AFM, AMM, FCOM, MMEL documentation or any other approved documentation.

Articles may be reprinted without permission, except where copyright source is indicated, but with acknowledgement to Airbus. Where Airbus is not the author, the contents of the article do not necessarily reflect the views of Airbus, neither do they indicate Company policy.

Contributions, comment and feedback are welcome. Enquiries related to this publication should be addressed to:

#### **Airbus**

#### **Product Safety department (GS)**

1, rond point Maurice Bellonte  
31707 Blagnac Cedex - France  
Fax: +33(0)5 61 93 44 29

[safetycommunication@airbus.com](mailto:safetycommunication@airbus.com)

**Safety first app available here**



# Safety first

SPECIAL EDITION

## PROCEDURES

P04 

Control your Speed... at take off

---

P16 

Control your Speed... during climb

---

P24 

Control your Speed... in cruise

---

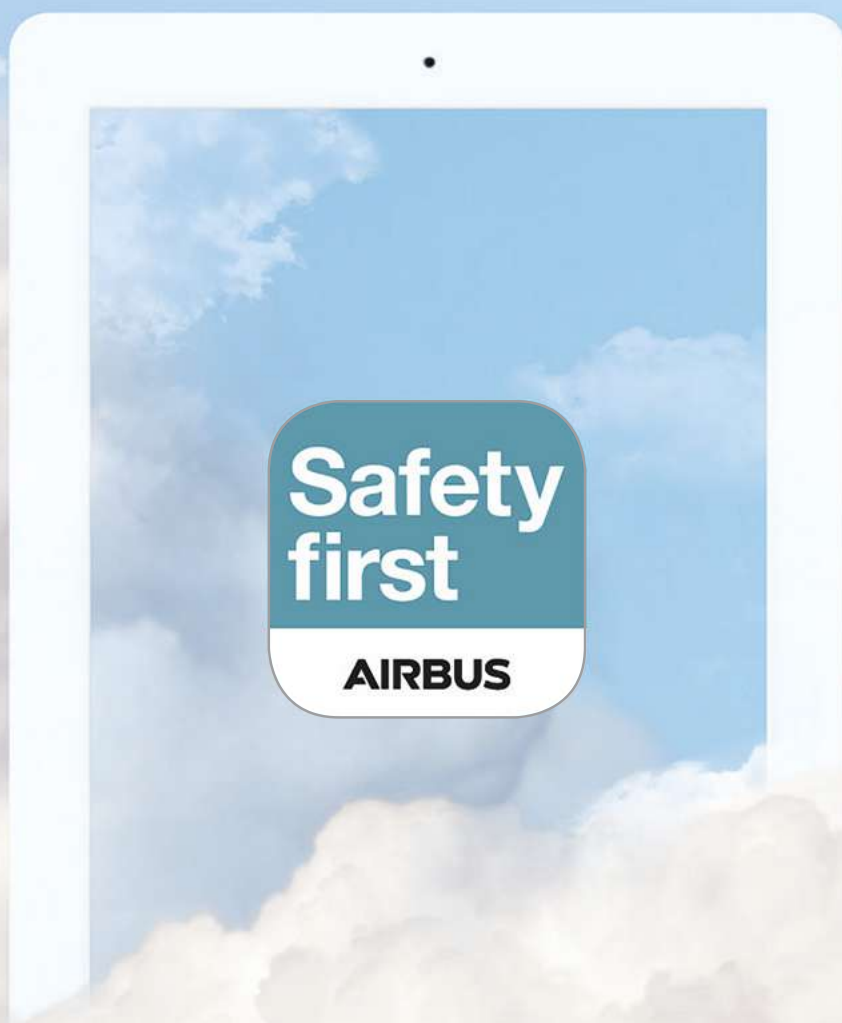
P40 

Control your Speed... during  
Descent, Approach and Landing



Flight operations

NOW AVAILABLE  
ON TABLETS AND  
SMARTPHONES



On iOS and Android



**AIRBUS**

# Foreword

In these articles, we detail everything that flight crews always wanted to know about speeds, but were afraid to ask.

Our objective is to highlight the design and operational considerations underlying all of the recommendations already published in Airbus documentation.

We aim to provide some reminders about how the various speeds are elaborated from the certification requirements to the flight test validation, and how they can be implemented in daily operations.

For all phases of flight we look at the following:

- > What are the speeds that should be monitored?
- > What do these speeds mean?
- > Where do these speeds come from?
- > What happens if these speeds are exceeded?

Flight crews need to constantly monitor their speed, regardless of how they decide to best optimize their flight.

Fly safe and be ahead of your aircraft.



**LORRAINE  
DE BAUDUS**

Flight Operations Standards  
& Safety management



**PHILIPPE  
CASTAIGNS**

Experimental Test Pilot



# Control your speed... at take-off

One of the most critical decisions that every line pilot may potentially encounter during every take-off is to continue or abort the procedure; hence the essential need to properly monitor the airspeed during this phase.

Overlooking the airspeed during take-off or conducting a take-off with an inappropriate speed are directly associated to the following main risks: a lateral or longitudinal runway excursion, maximum brake energy exceedance resulting in a brake fire, tail strike, lack of lateral control once the aircraft is airborne, or obstacle clearance trespassing.

This article aims at providing some reminders on the ways the various take-off characteristic and limit speeds are elaborated from the certification requirements to the flight test validation, and how they can be implemented in daily operations.

We will offer a series of articles on this topic, in the present and future issues of our magazine, aiming to detail everything you always wanted to know about speeds... but were afraid to ask. The lines that follow are focusing on the take-off phase.

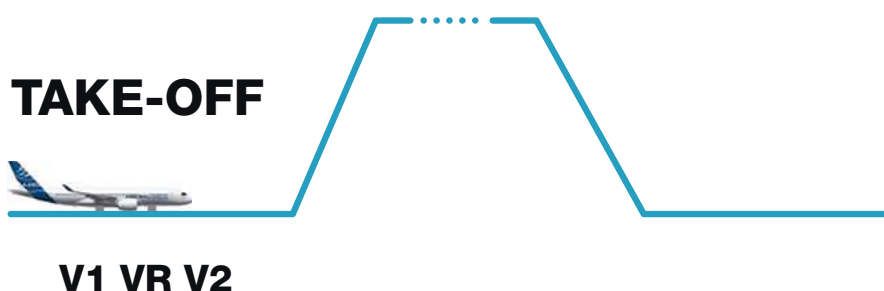
## SECURING YOUR TAKE-OFF: UNDERSTANDING SPEEDS

**Characteristic speeds are intended to provide reference points that can be used by pilots as a guide in making judgement in a very dynamic situation. In this respect, they need close supervision. What speeds exactly should be monitored? What do these speeds mean and where do they come from? What happens if such speeds are exceeded?**

Our objective is to highlight the design and operational considerations underlying all recommendations Airbus has issued to flight crews regarding speed monitoring during take-off.

Take-off operating speeds V1, VR and V2 very precisely frame the aircraft take-off performance limits and the margins that exist in the event of a failure **(fig.1)**.

For every aircraft type, V1, VR and V2 are computed by Airbus on the basis of design speeds and evidence collected during the certification testing of the airplane.



“ For every aircraft type, V1, VR and V2 are computed by Airbus on the basis of design speeds and evidence collected during the certification testing of the airplane. ”

**(fig.1)**

V1: Decision speed  
VR: Rotation speed  
V2: Take-off safety speed



## PROCEDURES

Control your speed... at take-off

### V1: Decision speed

#### » Definition

V1 is the maximum speed at which a rejected take-off can be initiated in the event of an emergency.

V1 is also the minimum speed at which a pilot can continue take-off following an engine failure.

This speed is entered by the crew in the MCDU during flight preparation, and it is represented by a "1" on the speed scale of the PFD during take-off acceleration **(fig.2)**.

#### » How is V1 determined?

If take-off is aborted at V1, the aircraft must be able to be stopped before the end of the runway, without exceeding the maximum energy the brakes can absorb.

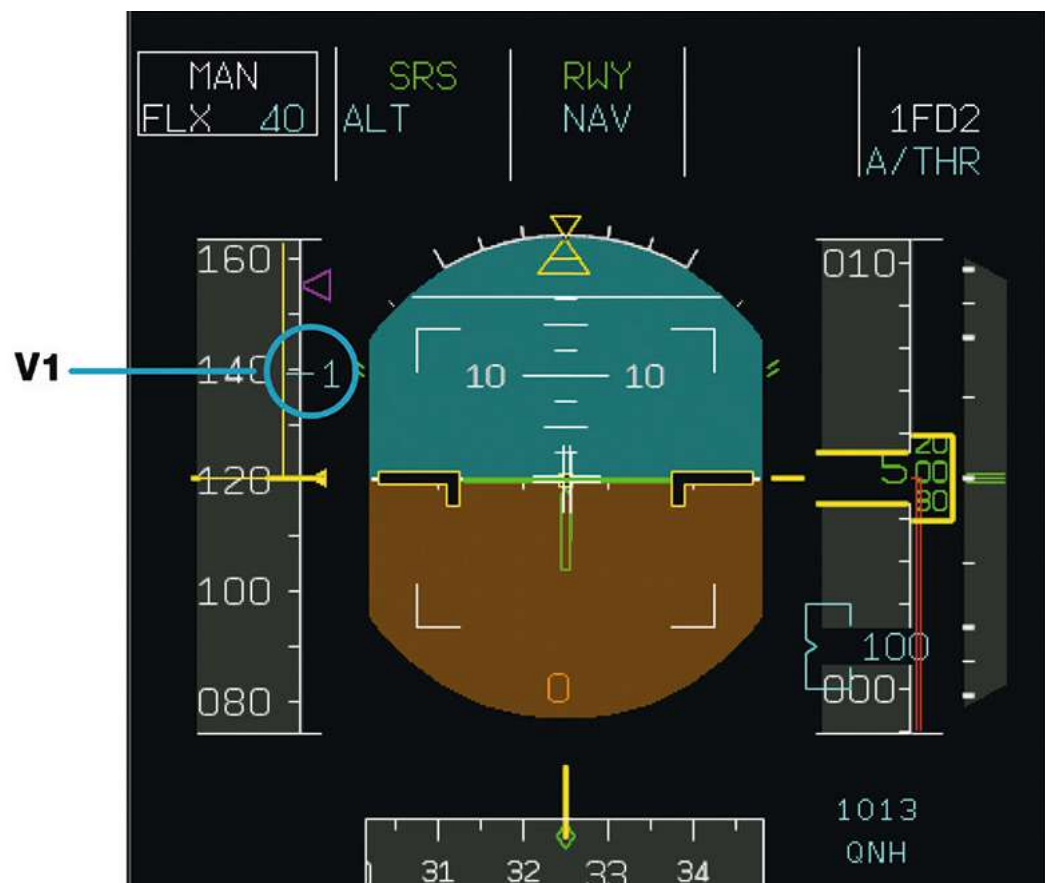
In addition, if an engine failure occurs after V1, then the aircraft must be able to achieve safely take-off with TOGA or derated power (enough lateral control).

These two conditions require identifying:

- The ground speed at which maximum energy is put into the brakes, when a RTO is performed at MTOW. This limit speed is defined during Airbus flight tests and is called **V<sub>MBE</sub> = Maximum Brake Energy speed**. V1 must be lower than V<sub>MBE</sub>.

**(fig.2)**

V1 on the PFD speed scale





- The minimum speed during take-off roll at which the aircraft can still be controlled after a sudden failure of one engine (be it a two or four-engine airplane).

In such a case, and if the take-off is continued, only the rudder will be able to counteract the yaw moment that is generated by asymmetric engine(s) thrust. Therefore if a failure occurs before reaching this minimum speed, the take-off must be interrupted to maintain control of the aircraft. This limit speed is determined during Airbus flight tests and is called  **$V_{MCG}$  = Minimum Control speed on the Ground**.  $V_{MCG}$  mainly depends on engine(s) thrust and pressure altitude.  $V_1$  must be greater than  $V_{MCG}$ .

- The maximum aircraft speed at which the most critical engine can fail without compromising the safe completion of take-off after failure recognition. This design speed is called  **$V_{EF}$  = Engine Failure speed**.

Considering that it is generally assumed humans have a reaction time to an unexpected event (such as a failure) of 1 second,  $V_1$  must be greater than  $V_{EF}$ .

In addition, if an engine failure happens at  $V_{EF}$ , then it must be possible to continue and achieve safely take-off with TOGA power. This means that  $V_{EF}$  must be greater than  $V_{MCG}$ .

$$V_{MCG} \leq V_{EF} \leq V_1 \leq V_{MBE}$$

## » What are the operational implications of not respecting $V_1$ ?

Supposedly, there are two different ways of “disrespecting” the  $V_1$  speed criteria:

1. **The crew decides to continue take-off while an engine failure occurred before  $V_1$ .** Standard procedures encourage the crew to reject take-off if an engine fails before  $V_1$ . If take-off is continued despite this recommendation, then the aircraft can potentially exit the runway laterally, or be unable to take-off before the end of the runway.



## BEST PRACTICE

In the event of an engine failure at low speed, any delay in reducing the thrust of the good engine(s) will lead to a loss of directional control and a very quick lateral deviation. Max rudder pedal and max manual differential braking may be required (refer to the new FCTM recommendation AO-020 “Low speed engine failure”).

## 2. An RTO is initiated above $V_1$ .

Virtually, any take-off can be “successfully” rejected, on the proviso that the reject is initiated early enough and is conducted properly. In this respect, the crew must always be prepared to make a GO/ NO GO decision prior to the aircraft reaching  $V_1$ .

Doing otherwise exposes the aircraft to an unsafe situation where there either may not be enough runway left to successfully stop the aircraft - therefore resulting in a longitudinal runway excursion-, or maximum brake energy is exceeded and brakes catch fire.

## PROCEDURES

Control your speed... at take-off



### BEST PRACTICE

As speed approaches V1, the successful completion of an RTO becomes increasingly more difficult. After V1, the crew must continue take-off and consider using TOGA thrust except if a derated take-off was performed (refer to FCOM PRO-ABN-10 operating techniques).

#### V1 IN A NUTSHELL

**Do not continue take-off  
in the event of an engine failure below V1.  
Do not initiate an RTO at speeds in excess of V1.**



## VR: Rotation speed

### » Definition

VR is the speed at which rotation can be initiated at the appropriate rate of about 3° per second. VR ensures that V2 is reached at 35 feet above the runway surface at the latest, including in the event of an engine failure at V<sub>EF</sub>. Therefore at 35 feet, the actual speed is usually greater than V2.

### » How is VR determined?

In principle, VR shall not be lower than V1.

In addition, whenever pilots initiate the rotation at VR, they must be assured that the aircraft will be controllable once airborne, including when the most adverse engine has failed after V<sub>EF</sub>.

On the upper end, if the rotation of the aircraft is started at VR at maximum practicable rate, lift-off must be possible at the end of the maneuver.

These concepts involve understanding the following limit speeds:

- The minimum speed in the second segment (take-off) at which the pilot is still able to maintain lateral and directional control when the most adverse engine fails.

This limit speed is demonstrated by Airbus flight tests and is called **V<sub>MCA</sub> = Minimum Control speed in the Air**. VR shall not be lower than 1.04 or 1.05 V<sub>MCA</sub>, the factors 1.04 and 1.05 being defined by Airworthiness Authorities to ensure a safety margin.

- The minimum speed at which the aircraft becomes able to lift off and escape ground effect.

This limit speed is based on evidence collected during certification tests and is called **V<sub>MU</sub> = Minimum Unstick speed**. V<sub>MU</sub> is achieved by pitching the aircraft up to the maximum (tail on the runway, for aircraft that are geometrically limited) during the take-off roll. The speed at which the aircraft first lifts off is V<sub>MU</sub>; therefore lift-off is not possible prior to V<sub>MU</sub>.

V<sub>MU</sub> is different from the design lift-off speed V<sub>LOF</sub>, which applies to general case scenarios and is necessarily greater than V<sub>MU</sub>, according to the following criteria:



### NOTE

The multiplicative factors that were applied were specified by Airworthiness Authorities, in consideration of safety margins.

$$\begin{aligned} 1.04 \text{ or } 1.05 V_{MU(N-1)} &\leq V_{LOF} \\ 1.08 V_{MU(N)} &\leq V_{LOF} \end{aligned}$$



## PROCEDURES

Control your speed... at take-off

In turn,  $V_{LOF}$  is limited by the design speed  $V_{TIRE}$ , which corresponds to the maximum tyre speed (tyre structural limit).

$$V_{LOF} \leq V_{TIRE}$$

Coming back to VR, if we consider that when a rotation is initiated at VR at the maximum practicable rate, it has to result in a satisfactory lift off speed, then VR must be limited by  $V_{LOF}$ .

$$\begin{aligned} V_1 &\leq VR \\ 1.05 V_{MCA} &\leq VR \\ VR &\leq V_{LOF} \end{aligned}$$

### » What are the operational implications of not respecting VR?

One direct consequence of initiating a rotation before VR is a tail strike. Second, if the rotation is done at VR but too slowly, or if the rotation is initiated after VR, then the aircraft intrinsic performance will very likely not allow it to reach 35 feet at the end of the runway, and/or not respect the clearway if the take-off speeds were limited by the runway length or obstacles.

### VR IN A NUTSHELL

**Do not start rotation below or above VR.**



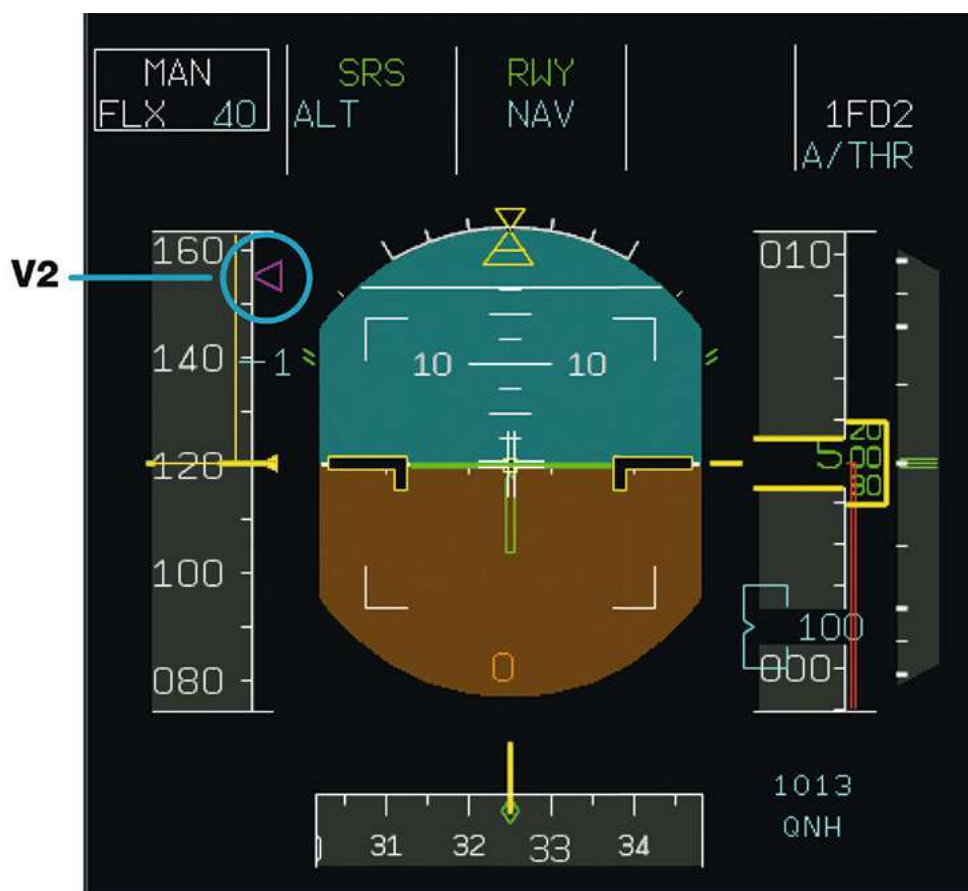


## V2: Take-off safety speed

### » Definition

V2 is the minimum take-off speed that the aircraft must attain by 35 feet above the runway surface with one engine failed at  $V_{EF}$ , and maintain during the second segment of the take-off.

This speed must be entered by the crew during flight preparation, and is represented by a magenta triangle on the PFD speed scale **(fig.3)**.



**(fig.3)**

V2 on the PFD speed scale

### » How is V2 determined?

V2 is always greater than  $V_{MCA}$  and facilitates control of the aircraft in flight.

On the upper end, Airworthiness Authorities have agreed that all operating speeds must be referenced to a stall speed that can be demonstrated by flight tests. This speed is designated  $V_{S1g}$ . V2 must obviously be greater than this stall speed.

$$1.13 V_{S1g} \leq V2$$

$$1.10 V_{MCA} \leq V2$$



### NOTE

The multiplicative factors that were applied were specified by Airworthiness Authorities, in consideration of safety margins.

## PROCEDURES

Control your speed... at take-off

### » What are the operational implications of not respecting V2?

Supposedly, there are two different ways of “disrespecting” the V2 speed criteria:

#### 1. Flying below V2 in case of an engine failure.

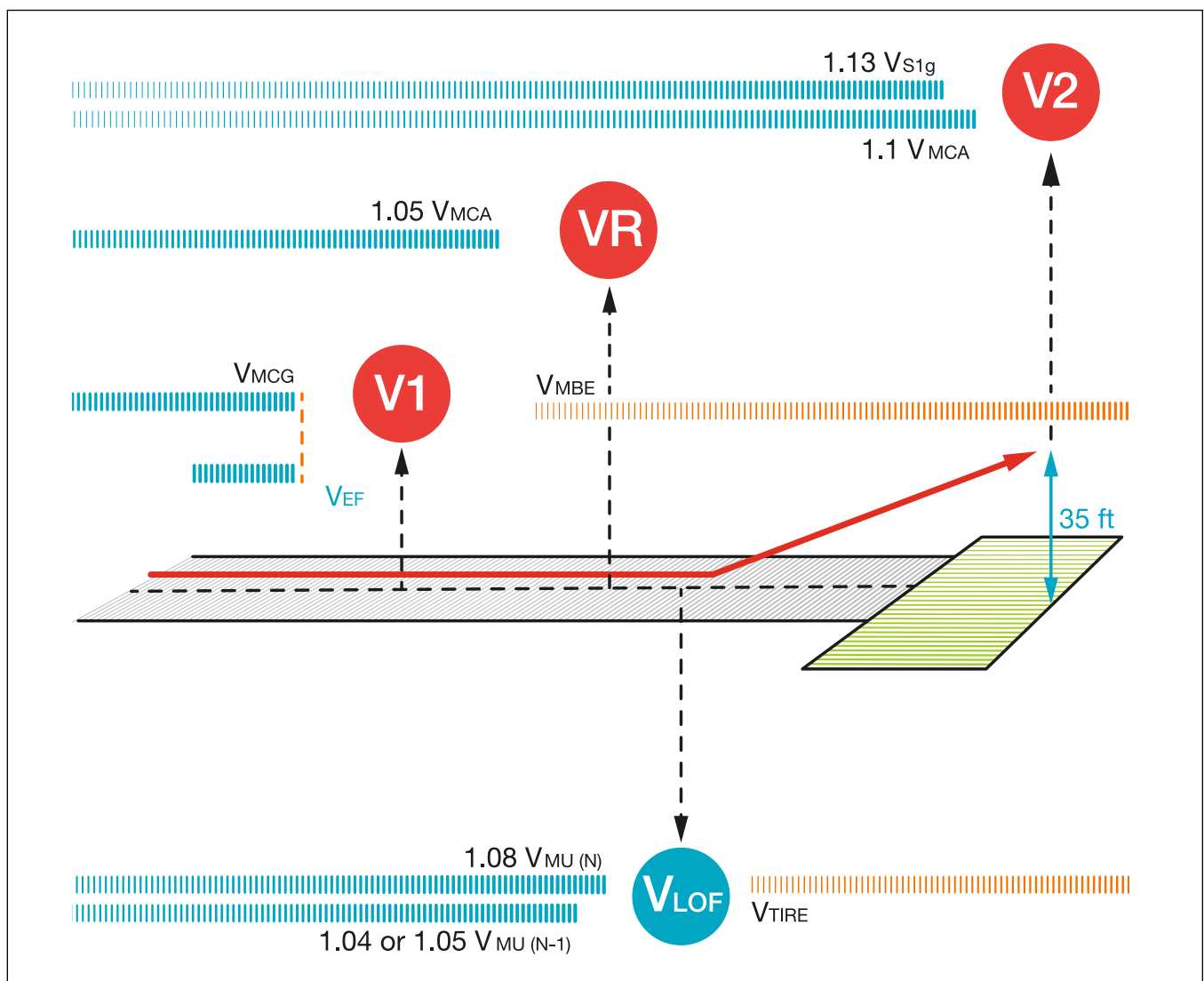
The drag increase below V2 may lead to a situation where the only way to recover speed is to descend.

If the speed further decreases and V2 is not recovered, then the high angle of attack protection may be reached, and the aircraft may ultimately enter into an unrecoverable descend trend. In particular, if the speed decreases below  $V_{MCA}$ , the aircraft might not be recoverable due to lack of lateral control.

#### 2. Flying above V2 in case of an engine failure.

In case of excessive speed, the required climb performance may not be reached, thus increasing the chance to trespass the obstacle clearance. ■

## Take-off speeds in a nutshell



# SECURING YOUR TAKE-OFF: THE ROLE OF THE PILOT MONITORING (PM)

**The take-off phase is a very dynamic and demanding one, during which the PM plays a central role for a timely monitoring from cockpit preparation, all the way through take-off speeds computation and utilization.**

Clearly flight crews are expected to be able to rapidly scan the essential and relevant parameters that support key decisions, such as continue or abort a take-off essentially. Doing so, the PM must be able to differentiate between situations that are detrimental to operational safety, and those that are not.

In this respect, he/she must be prepared to adapt his/her monitoring to the level of the threat and reach out in a communication sense to the PF to encourage action if necessary, by making callouts as per SOP. Callouts coupled to responses are a very effective means indeed to cope with demanding situations, and allow the crew to act as a well coordinated team.

Second, he/she must be aware of the primary threats to the safe completion of take-off in order to actively help to prevent take-off speed errors. Take-off speed calculation errors are often due to a combination of two factors:

- Error in parameter entry
- Poor crosschecks by other crew member.

Prevention strategies should therefore be developed to ensure efficient crosschecks, particularly after last-minute changes (runway change, loadsheet modification, etc).

For this purpose, we want to highlight the main factors often observed when analysing take-offs in which speeds were not respected:

## » Errors in take-off speed computation

- Data issued from a computerized system is rarely challenged. However, incorrect inputs may occur, thus resulting in inadequate take-off speed values computation.
- In take-off speed calculations, Zero Fuel Weight (ZFW) is sometimes mistaken for Gross Weight (GW). This is particularly true when a last minute change occurs in cargo loading, or when time pressure and workload are high. Therefore calculated speeds will be much lower than expected, and will potentially lead to tailstrikes, "heavy aircraft" sensation, and high-speed rejected take-offs.
- Take-off speeds calculations are based on specific configurations. Any change in the parameters of these configurations will invalidate take-off speeds. Examples of such parameters include a runway change, a wet runway that becomes contaminated, or a take-off from an intersection.

## PROCEDURES

Control your speed... at take-off



### » Errors in take-off speed utilization

- When a last minute change occurs, take-off speeds are sometimes modified and crosschecked during pushback or taxi. During such phases of flight, the PF workload is high. As a result, the PF may not have sufficient time or resources to perform efficient crosschecks.
- If an incident occurs before V1, the PM's attention may be focused on trying to assess the situation and may forget the V1 announcement.
- In the event of an engine failure after take-off, and in an attempt to climb faster, there may be a tendency to set a pitch attitude too high if FD bars are not followed. The aircraft is then flown below V2, and climb performance cannot be maintained. ■

### OPERATIONAL RECOMMENDATIONS FOR THE PM

- Compute/crosscheck V1, VR and V2.
- Enter V1, VR and V2 in the FMS, and ensure these data are re-inserted during taxi as per SOP in case of last minute changes. Attention should be paid to keystroke errors.
- Crosscheck information set or used by the PF.
- Ensure a take-off briefing is conducted that highlights take-off speeds (particularly if they were changed during taxi), slats/flaps configurations and weight.
- For aircraft that are not equipped with a V1 auto-callout: pay a close attention to the V1 standard callout.







Understanding the implications of take-off speeds is paramount to enable pilots to sense instantly the available margin of maneuver they have left to preserve safety of flight, and make a wise GO/NO GO decision.

In practice, crew coordination and the PM's involvement in the take-off phase preparation and execution are essential parameters to satisfactorily manage the risks associated to this particular phase of flight, such as: a lateral or longitudinal runway excursion, maximum brake energy exceedance causing a brake fire, tail strike, lack of lateral control once the aircraft is airborne, or obstacle clearance trespassing.

Whatever the flying conditions, it is essential that flight crews number one objective remains to fly the aircraft according to the 4 Golden Rules for Pilots.

- 1 **Fly, navigate and communicate:**  
In this order and with appropriate tasksharing
- 2 **Use the appropriate level of automation at all times**
- 3 **Understand the FMA at all times**
- 4 **Take action if things do not go as expected**



## DID YOU KNOW

Read our brochure "Getting to grips with aircraft performance", available on AirbusWorld.



# Control your speed... during climb

Second of a series of articles on the theme of speed control during a flight, which started in issue #18 of this magazine, we have just taken off and are now entering the climb phase. The main objective is to retract the slats / flaps at an adequate speed, while sustaining enough lift to accelerate and climb.

After take-off, the aircraft continues in the climb phase and flies away from the busy airspace. The objective for the crew is to accelerate to the en-route climb speed and at the same time, manage various aircraft configuration changes, usually consisting of gears, slats and flaps retraction, and a change from take-off power to climb power.

This article aims at shedding some light on the way the different maneuvering and limit speeds that are of use during climb are defined and determined, and how they can be implemented in daily operations.

## MANAGING YOUR CLIMB: UNDERSTANDING SPEEDS

**A climb is generally flown at an airspeed that is often initially limited by Air Traffic Control (ATC) instructions. To safely manage the climb phase within these restrictions, some characteristic speeds are useful tools, and they require a close monitoring. What speeds exactly should be monitored? What do these speeds mean and what happens if they are exceeded?**

For every flight, characteristic speeds are computed automatically by the aircraft Auto Flight Systems (Flight Management System (FMS), Flight Guidance (FG) and Flight Envelope (FE)) and effectively displayed on the PFD airspeed scale. They are extremely useful as maneuvering speeds and limit speeds to safely guide the pilots configuration change decisions through the climb phase.

Our objective is to highlight the design and operational considerations underlying all recommendations Airbus has issued to flight crews regarding the monitoring of these speeds during climb.

Amongst other parameters, the maneuvering speeds Flaps (F), Slats (S) and Green Dot (GD) are a function of the Zero Fuel Weight (ZFW) inserted by the crew at FMS initialization. Therefore, any erroneous entry will impair these speeds.

### Maneuvering speeds

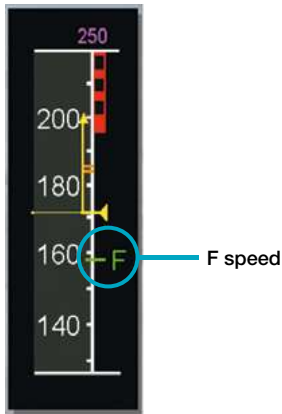
In nominal conditions (all engines operative), the climb phase poses some challenges to the crew: accelerate the aircraft, maintain a satisfactory climb gradient and manage several configuration changes at the same time. To help pilots fly their aircraft safely through the different steps of this phase of flight, some characteristic speeds were defined as maneuvering speeds.

F, S and Green Dot speeds frame the aircraft climb performance limits.

“ F, S and Green Dot speeds frame the aircraft climb performance limits. ”

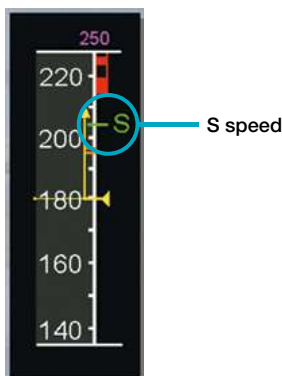
## PROCEDURES

Control your speed... during climb



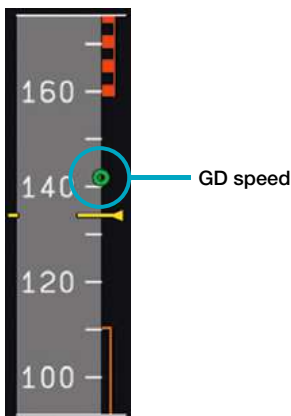
(fig.1)

F on the PFD speed scale



(fig.2)

S on the PFD speed scale



(fig.3)

GD on the PFD speed scale

### F and S: Flaps and Slats minimum retraction speeds

#### » Definitions

**F speed** is the minimum speed at which flaps should be retracted from CONF 3 or 2 to CONF 1+F.

It is represented by a green “F” on the PFD speed scale and displayed only when the slats / flaps control lever is on position 3 or 2 (CONF 3 or 2) during the take-off phase, the initial climb and go-around (**fig.1**). It is no longer displayed when in configuration 1 or 1+F.

**S speed** is the minimum slats retraction speed, i.e. the minimum speed at which a clean configuration should be selected.

It is represented by a green “S” on the PFD speed scale and displayed only when the slats / flaps control lever is on position 1 (CONF 1 and 1+F) (**fig.2**).

#### » How are F and S determined during the take-off phase?

**F speed** varies according to the aircraft weight and altitude. It is tabulated in the Flight Envelope as a function of  $V_{S1g CONF 1+F}$ , which is the reference stall speed demonstrated by flight tests and agreed by the Airworthiness Authorities.

In this respect, F speed allows a margin above the stall speed in the configuration 1+F.

$$F \text{ speed} = k \times V_{S1g CONF 1+F}, \text{ with } k \text{ equal to about } 1.18 \text{ to } 1.26$$

**S speed** varies according to the aircraft weight and altitude. It is tabulated in the Flight Envelope as a function of  $V_{S1g CLEAN CONF}$ .

In this respect, S speed allows a margin above the stall speed in the clean configuration.

$$S = k \times V_{S1g CLEAN CONF}, \text{ with } k \text{ equal to about } 1.21 \text{ to } 1.25$$

### Green Dot (GD): best lift-to-drag ratio

#### » Definition

**GD speed** is the engine-out operating speed in clean configuration. In other words, it corresponds to the speed that allows the highest climb gradient with one engine inoperative in clean configuration.

In all cases (all engines operative), the GD speed gives an estimate of the speed for best lift-to-drag ratio. It is also the final take-off speed and it represents the operational speed of the clean configuration and the recommended speed in holding in clean configuration.

It is represented by a green dot on the PFD speed scale and displayed only when the slats / flaps control lever is in the ‘0’ (CLEAN) position and landing gears are not compressed (**fig.3**).



## » How is GD determined?

**GD speed** is computed by the Auto-flight systems and is based on the aircraft weight and altitude. The GD formula has been set up so that the resulting airspeed provides the best lift-to-drag ratio for a given altitude, air temperature and aircraft weight, in clean configuration with one engine out.

In some phases of flight, GD is computed to minimize drag and thus, the fuel consumption (for example during the HOLD phase).

## Limit speed

We have seen that deviations from the maneuvering speeds  $F$ ,  $S$  and  $GD$  during climb can have an impact on the aircraft's aerodynamic performance. We will now focus on the limit speed  $V_{FE}$ .

### $V_{FE}$ : Maximum speed with Flaps Extended

With the A/THR engaged and active (CLB / OP CLB / SPEED green on FMA), the aircraft remains below  $V_{FE}$ .

When the A/THR is not active,  $V_{FE}$  exceedance may occur (for example during a go-around).

### » Definition

$V_{FE}$  is the maximum speed with flaps extended. It has a specific value for each flap setting.

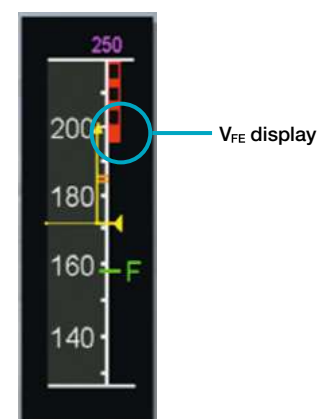
Generally speaking, the maximum speed defining the aircraft's flight envelope is called  $V_{MAX}$ .  $V_{MAX}$  is equal to  $V_{LE}$  (maximum speed with landing gears extended) or  $V_{FE}$  according to the aircraft configuration.  $V_{MAX}$  is equal to  $V_{MO}$  (or speed corresponding to  $MMO$ ) only in the clean configuration.

On the PFD speed scale, it corresponds to the lower end of the red and black strip (**fig.4**).

### » How is $V_{FE}$ determined?

$V_{FE}$  is the maximum speed for high lift configurations, i.e. with slats / flaps extended: it is related to the structural limitation of the slats / flaps. A  $V_{FE}$  is computed for each slats / flaps configuration, based on either the slats / flaps control lever position or the actual aircraft configuration (slats / flaps control surfaces position), depending on the aircraft type.

In order to keep a sufficient margin between the  $V_{FE\ CONF\ 3}$  and the speed at which the next configuration is selected, the following inequality is met:  $V_{FE\ CONF\ 3} \geq F + 10\ kts$ .



**(fig.4)**

$V_{FE}$  on the PFD speed scale



# MANAGING YOUR CLIMB: OPERATIONAL RECOMMENDATIONS

**Flying a safe and steady climb requires pilots' attention to carefully manage the different configuration changes, while accelerating to the en-route climb speed and eventually, cruise speed.**

Indeed, not respecting the maneuvering and limit speeds leads to adverse consequences that we will review. Avoiding an overspeed situation during the slats / flaps retraction - with its potential structural damage consequences - is important. It is therefore worth understanding the different  $V_{FE}$  display logics implemented in each aircraft family, and the resulting overspeed aural warning behaviour during the climb.

## What are the operational implications of not respecting the maneuvering or limit speeds?

### F and S: Flaps and Slats minimum retraction speeds

F speed (resp. S) is defined as the recommended minimum flaps (resp. slats) retraction speed. Retracting the flaps (resp. slats) at a speed significantly lower than F (resp. S) would reduce the margin against the high Angle-Of-Attack (AOA) protection. This could lead the aircraft to reach a speed below the lowest selectable speed  $V_{LS\ CONF\ 1+F}$  (or 0), and possibly low enough to break through the high AOA protection threshold.

Retracting the flaps (resp. slats) at a speed significantly higher than F speed (resp. S) would reduce the climb performance and thus, possibly compromise the aircraft ability to clear any obstacles (this is more likely if one engine is inoperative).

If flaps need to be maintained for a turn before acceleration altitude for instance, F speed (resp. S) can be used safely to perform a turn while climbing.

### GD: Green Dot

At a given weight and engine rating, the potential climb gradient is maximum when (Thrust – Drag) is at a maximum - i.e. when the lift-to-drag ratio is maximum.

Deviating below GD involves an increase in the drag on the aircraft and would eventually undermine the aircraft's ability to continue a climb. Indeed, if the aircraft speed goes significantly below GD, with the maximum available thrust already in use (assuming that thrust levers have just been set to CLIMB / MCT), then the only way for the crew to recover a satisfactory climb gradient is to decrease the rate of climb (even enter a descent if necessary) in order to accelerate to or above GD. This maneuver is obviously counteractive to the objectives of the climb phase.

Therefore in the clean configuration, the crew should not fly below GD in order to avoid degrading climb performance.

**GD IN A NUTSHELL**  
**Avoid flying below**  
**GD during climb.**

### **V<sub>FE</sub>: Maximum speed with flaps extended**

In case of take-off with A/THR not active, flying with slats / flaps extended, or extending slats / flaps well above V<sub>FE</sub> directly poses a risk of structural damage through the slats / flaps track mechanisms. This may result in distortion of the flaps and slats or the extension mechanism or even the aircraft structure upstream.

In case V<sub>FE</sub> is exceeded, an overspeed aural warning is triggered in the cockpit in order to alert the crew. The flight crew will have to reduce the speed or to retract the slats / flaps accordingly.

Exceeding V<sub>FE</sub> may subsequently trigger inspections of the slats/flaps mechanism and/or the aircraft structure.

Specific trouble shooting procedures exist to inspect and repair an aircraft after flight above V<sub>FE</sub>. These procedures are available in the Aircraft Maintenance Manual (AMM).

### **V<sub>FE</sub> IN A NUTSHELL**

**Do not fly with slats / flaps extended above V<sub>FE</sub>.**

### **How to avoid an overspeed during slats / flaps retraction?**

Avoiding an overspeed during slats / flaps retraction relies on a variety of complementary aspects. Procedures, pilots' attention and coordination, anticipation of configuration changes, understanding of the limit speed and of the different V<sub>FE</sub> display logics and overspeed aural warning behaviour implemented in each aircraft family.

#### **The common approach**

Slats and flaps retraction during climb can be managed safely by following SOP, and observing the visual F and S indications on the PFD. Incidentally, doing so allows the crew to respect the V<sub>FE</sub> indication displayed on the PFD and thus, avoid triggering an aural overspeed warning (with potential structural damage). The use of A/THR also enables the crew to avoid an overspeed condition during slats / flaps retraction.

While the PF is expected to manage these configuration changes, the PM plays a key role in facilitating his/her task by anticipating them. During the initial climb phase, the PM needs to be vigilant to speed trends and alert the PF in case the margin that is left against the applicable limit speed V<sub>FE</sub> becomes too tight. This is valid at all time, for all aircraft families.

Differences arise when we look more closely at the V<sub>FE</sub> display logics for each family. In particular, we want to emphasize the possibility of a temporary, yet inconsequential, overspeed aural warning on A300/A310, A320 and A330/A340 Families.

### **The case of untimely temporary overspeed aural warning during slats / flaps retraction**

#### **» A300/A310, A320 and A330/A340 Families**

On A300/A310, A320 and A330/A340 Families,

- The  $V_{FE}$  value displayed on the PFD is based on the slats / flaps control lever position and it moves by one step as soon as this lever is moved.
- The overspeed aural warning triggering threshold varies according to the actual aircraft configuration, i.e. the slats / flaps surfaces real time position.

Therefore, during slats / flaps transition, the dynamic acceleration of the airplane may lead to a temporary OVERSPEED WARNING even if the current speed is out of the red and black strip displayed on the PFD. In this situation, there are neither operational consequences nor safety issues.

This is due to the following logic:

- When the flap lever is moved from CONF 2 (or 3) to CONF 1+F, F speed could be very close to  $V_{FE}$  before flaps retraction. Once the flap retraction is initiated,  $V_{FE \text{ CONF } (2 \text{ or } 3)}$  moves in one step to  $V_{FE \text{ CONF } 1+F}$  before the flaps actually reach CONF 1+F. As a consequence, in acceleration towards S speed, the  $V_{FE}$  aural warning could activate although the actual surfaces speed is below the displayed  $V_{FE}$ .
- When the flap lever is moved from CONF 2 (or 3) to CONF 1+F, S speed could be greater than  $V_{FE \text{ CONF } 1+F}$  before the surfaces retract. When automatic flap retraction occurs, the barbers pole does not move before the flaps fully retract.

#### **» A350 and A380 Families**

On A350 and A380 Families, a different logic was developed. The  $V_{FE}$  display on the PFD is directly based on the actual aircraft configuration, as is the overspeed aural warning triggering threshold. This means that the two signals are perfectly synchronized, thus the risk of an untimely temporary overspeed warning is eliminated.

### **The case of temporary overspeed aural warning during slats / flaps retraction after a heavy-weight take-off**

In the particular case of a heavy-weight take-off, the risk of a temporary overspeed aural warning is increased. Indeed, in this configuration, S speed is quite close to  $V_{FE \text{ CONF } 1+F}$  because the aircraft weight is higher and the lift needed to climb is higher too. Therefore the slats need to remain extended for longer. As a result, the crew will order flaps retraction at a speed that might be higher than the Flaps Auto-retraction speed. In that case, should the acceleration of the airplane be rapid, a  $V_{FE}$  aural warning may momentarily trigger. This logic is as per design and structural limits are not encountered.

For example, an A320 at a Take-Off Weight (TOW) of 76T, S speed of 205 kts, the pilot will order flaps retraction most probably at or slightly above 210 kts, which is precisely the Flaps Auto-retraction speed. Once the slats / flaps control lever is in the retracted position, the  $V_{FE}$  red and black strip is no longer displayed on the PFD speed scale. If the airplane accelerates rapidly, then the airspeed may catch up the actual instantaneous  $V_{FE}$  momentarily, which will trigger the  $V_{FE}$  aural warning.

Again, this logic is as per design and structural limits are not encountered. ■



## **BEST PRACTICE**

After a heavy-weight take-off, do not delay slats / flaps 0 selection above S speed in order to prevent possible temporary  $V_{FE}$  overspeed aural warning.





During climb, in manual flight, the main risk is to experience an aural overspeed warning (with potential structural damage) as a result of a late slats / flaps retraction. Understanding the implications of climb speeds is paramount to enable pilots to sense instantly the available margin they have left to avoid exceeding the limit slats / flaps retraction speed.

In practice, once the aircraft is airborne, pilots must be fully cognisant of the airspeed as well as the speed trends at all time in flight.



## DID YOU KNOW \_\_\_\_\_

To know more about speeds, read our brochure “Getting to grips with aircraft performance”, available on AirbusWorld.

A presentation was also made at the 11th Perf and Flight Ops Conference in Dubai in 2011.



# Control your speed... in cruise

Third article in the “Control your speed” series started in issue #18 of this magazine, our aircraft is now flying in clean configuration, travelling in cruise. The main objective is to manage threats to the airspeed and avoid speed excursions.

Technically, cruising consists of heading changes and aircraft systems monitoring (fuel in particular), at a relatively constant airspeed and altitude. It ends as the aircraft approaches the destination where the descent commences in preparation for landing.

Speed monitoring and control are crucial during this phase of flight to guarantee that the aircraft flies within its certified flight envelope at all times, and any threats to the airspeed can be properly managed.

This article will not immerse readers into the challenge of optimizing the aircraft performances in cruise, but it will aim at shedding more light on the existing threats to the airspeed during cruise, as well as good practices to best manage them. While planning their cruise to make the right speed and flight level choices, the flight crew needs to remain vigilant to speed excursions, and be able to recover if needed.

## MANAGING YOUR CRUISE: UNDERSTANDING SPEEDS

**Speed in cruise is often driven by performances and fuel burn considerations; however, Air Traffic or weather considerations sometimes intervene and require modifications to the optimum cruise profile. Whatever the flight crew's decisions to best optimize their flight, one needs to be constantly aware of the applicable limits and maneuvering speeds. To safely manage the cruise phase within the aircraft certified flight envelope, some characteristic speeds are useful references for flight crews to monitor the aircraft's actual speed. What speeds exactly should be monitored? What do these speeds mean and what happens if they are ignored?**

Many speeds are used to certify and fly an aircraft operationally. For every flight, the applicable characteristic speeds are computed automatically by the aircraft Auto Flight Systems (Flight Management System (FMS), Flight Guidance (FG) and Flight Envelope (FE)) and displayed on the PFD airspeed scale. They are extremely useful as target maneuvering and limit reference speeds to safely guide the pilots navigation decisions through the cruise phase.

Our objective is to highlight the design and operational considerations underlying all recommendations Airbus has issued to flight crews regarding the monitoring of these speeds in cruise.

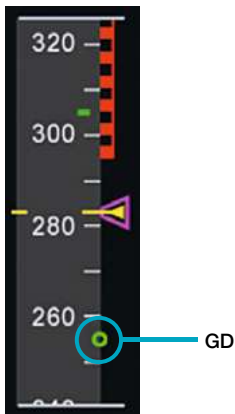


### NOTE

System descriptions and information included in this article are mainly referring to fly-by-wire aircraft. However, the recommendations for speed management remain applicable to all aircraft.

# PROCEDURES

Control your speed... in cruise



**(fig.1)**  
GD on the PFD speed scale

**(fig.2)**  
Thrust curves and speed polar



Region of reversed  
command  
(second regime)

## Given:

- altitude
- temperature
- weight
- thrust

## Maneuvering speed

Green Dot was presented already in the previous article dedicated to the climb phase. Nevertheless, it is important to have this speed in mind during the cruise phase as well, because it is a clearly visible reference speed on the PFD airspeed scale. We will see hereafter why pilots should not routinely fly slower than GD in cruise.

For this reason, a recap of GD definition is provided hereafter, as well as the consequences of flying slower than GD in cruise.

### Green Dot (GD): best lift-to-drag ratio speed

#### » Definition

GD speed is the engine-out operating speed in clean configuration. It corresponds to the speed that allows the highest climb gradient with one engine inoperative in clean configuration. In all cases (all engines operative), the GD speed gives an estimate of the speed for best lift-to-drag ratio.

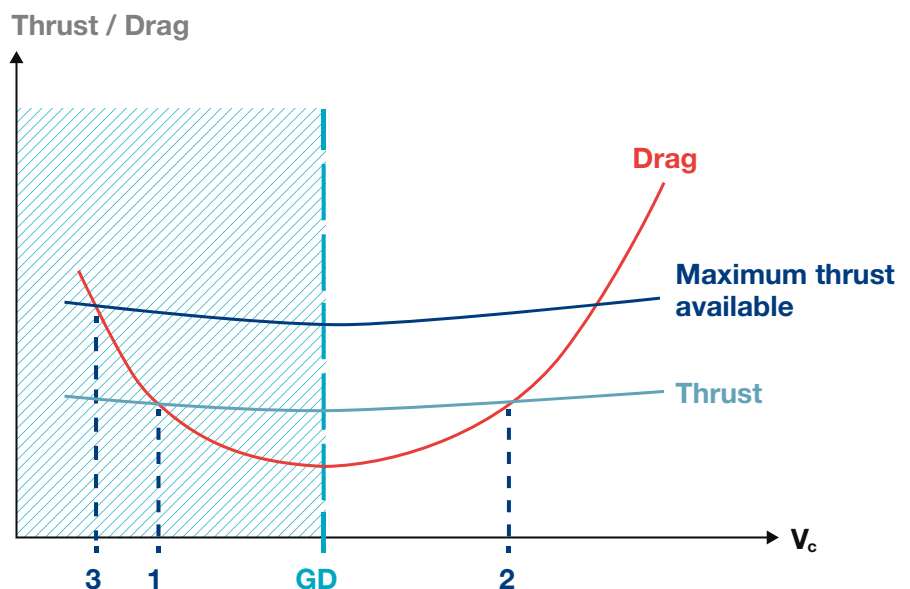
It is represented by a green dot on the PFD speed scale and displayed only when the slats / flaps control lever is in the '0' (CLEAN) position and landing gears are not compressed **(fig. 1)**.

#### » How is GD determined?

GD speed is computed by the Auto Flight Systems (AFS) and is based on the aircraft weight (thanks to the Zero Fuel Weight (ZFW) inserted in the FMS during flight preparation). The GD formula has been set up so that the resulting airspeed provides the best lift-to-drag ratio for a given altitude, Mach number and aircraft weight, in clean configuration with one engine out.

In cruise:

- Above GD, the drag and thrust required to maintain speed increase with the speed
- Below GD, the drag and thrust required to maintain speed increase with speed decrease (second regime) **(fig. 2)**.





## FIRST OR SECOND REGIME?

At a given altitude, temperature, weight and thrust, figure 2 shows 2 points of equilibrium where the thrust precisely compensates for the drag (thrust = drag) and stabilized level flight is possible: point 1 (where  $V_C$  is lower than GD) and point 2 (where  $V_C$  is higher than GD). Let's have a closer look at the aircraft behaviour if the speed is moving away from these speeds:

- Point 2 is a stable equilibrium: in cruise, when the aircraft flies at this point 2, the airspeed is stabilized. Small variations of airspeed will naturally be compensated for and the aircraft will return to point 2. At point 2, the aircraft flies in the **first regime**.
  - If a disturbance increases the aircraft's speed above point 2, then the drag increases. Consequently, the aircraft will decelerate back to the equilibrium point 2.
  - If a disturbance reduces the aircraft's speed below point 2, then the drag decreases. This generates acceleration and the aircraft's speed will naturally increase back to the equilibrium point 2.
- Point 1 is an unstable equilibrium: at this point, the aircraft flies in the **second regime**.
  - If a disturbance increases the aircraft's speed above point 1, the drag reduces; therefore the aircraft will continue to accelerate until point 2.
  - If a disturbance reduces the aircraft's speed below point 1, then the drag becomes increasingly higher. If no action is taken, the aircraft will be naturally induced into a continuous deceleration.

To stop the deceleration and be able to accelerate again, two scenarios are possible:

  - » When speed reduces below point 1 and remains higher than point 3: if maximum thrust available is applied, then the aircraft can accelerate.
  - » When speed reduces below point 3: there is no thrust margin available to accelerate while maintaining a stabilized level flight. Then the only way to stop the deceleration is to lose altitude in order to accelerate beyond point 3.

To sum up:

- Faster than GD, the aircraft flies in the first regime: it is stable with regards to speed.
- Slower than GD, the aircraft flies in the second regime: it is unstable with regards to speed.

### » What are the operational implications of flying below GD?

Point 3 is not displayed on the PFD airspeed scale. Only GD is shown.

The higher the aircraft, the lower the maximum thrust available. This means that at high altitude, close to REC MAX (RECommended MAXimum altitude), point 3 and GD are close to each other because the thrust margin is small. Therefore flying below GD in level flight could easily drive the aircraft slower than point 3 and eventually in a continuous deceleration.

Consequently, in clean configuration in cruise, the crew should not fly below GD.

Exceptionally, if flight slightly below GD is required for some reason, then vigilant monitoring is necessary to ensure that further uncommanded speed reductions are immediately checked and recovered from.

**GD IN A NUTSHELL**  
Do not fly below GD  
in cruise.

## PROCEDURES

Control your speed... in cruise

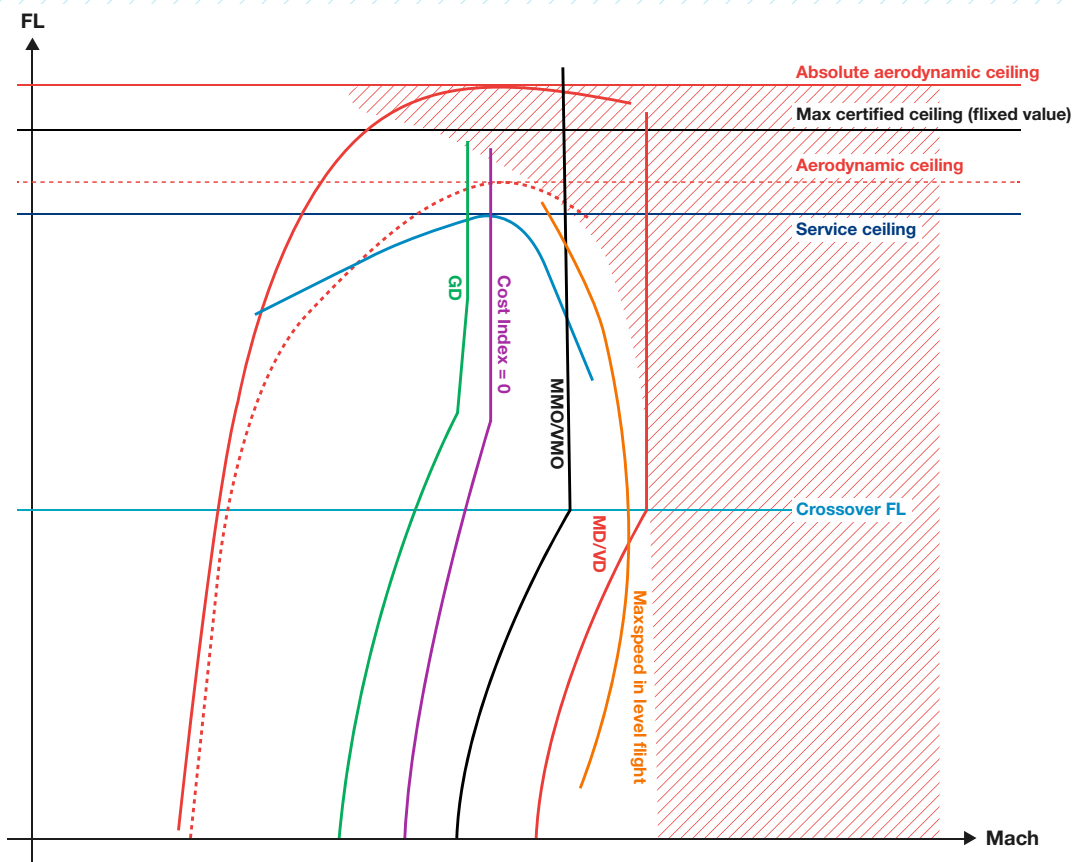
### HOW IS THE REC MAX (RECOMMENDED MAXIMUM ALTITUDE) COMPUTED?

Looking more closely at the exact conditions limiting the altitude where a subsonic aircraft can safely fly at, these can range from aerodynamic limitations to propulsion and certification limitations.

**REC MAX is the upper cruise limit:**

**REC MAX = Min [Service ceiling; Aerodynamic ceiling; Max certified ceiling]**

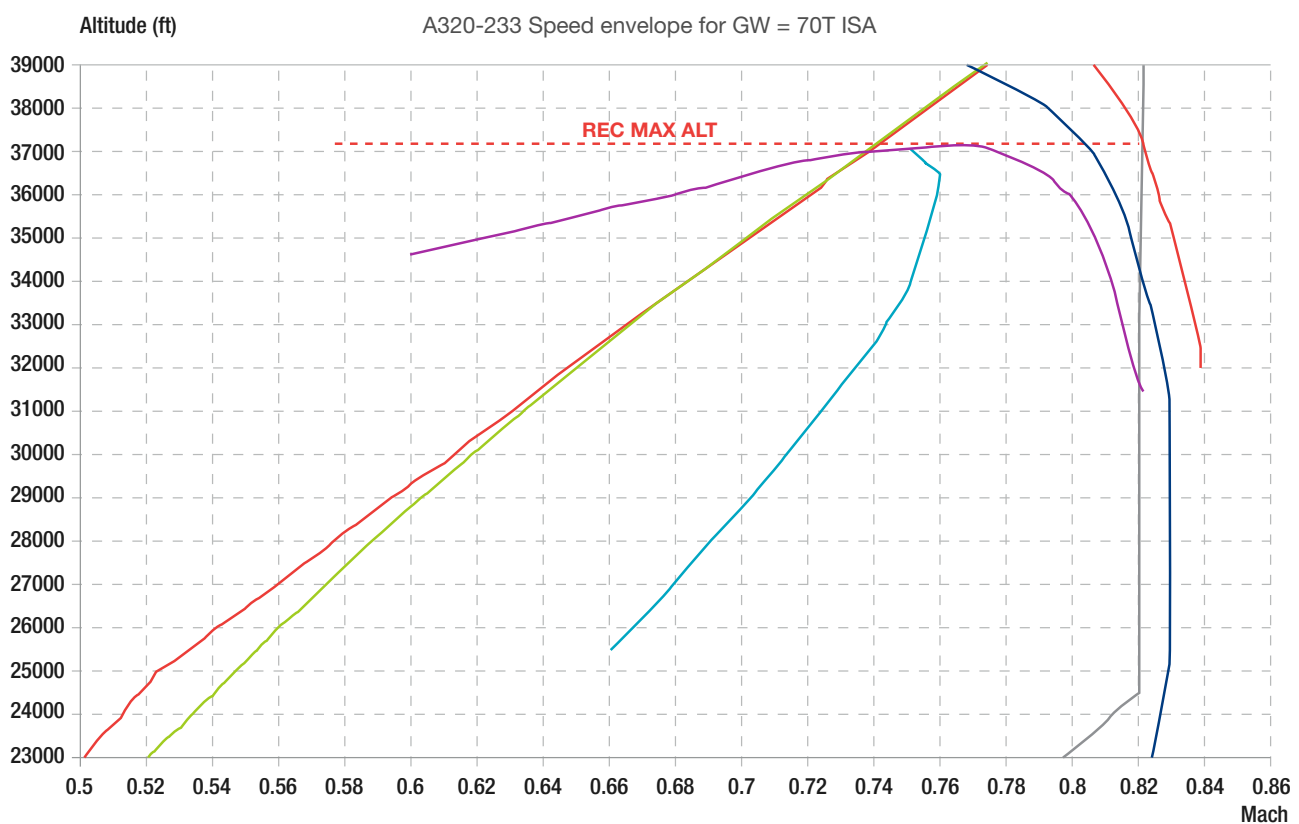
The schematic below applies to a heavy aircraft, which has a ceiling lower than the maximum certified one.



- Stall limit ( $V_{S1g}$ ): this speed curve lowers with a weight increase.
- .... This curve provides a safety maneuver margin against the Stall limit curve.  
At low Mach, it starts at  $1.23 \times V_{S1g}$ .  
At higher Mach, it corresponds to buffet onset of  $1.3g$  (corresponding to  $40^\circ$  of bank angle in level flight).  
This curve lowers with weight increase.
- .... Aerodynamic ceiling (increases with weight decrease).
- Service curve, corresponding to the propulsion capacity of the aircraft's engines to maintain  $+300\text{ft}/\text{minute}$  at a constant Mach.  
This curve increases with weight decrease and with static temperature decrease.
- Service ceiling (increases with weight decrease or temperature decrease).
- Maximum speed in level flight (in stable weather conditions with maximum thrust available in use)
- /// Inaccessible domain (drag exceeds thrust), except if the aircraft is being subject to extreme weather conditions or enters a steep dive with maximum thrust.

On Airbus aircraft, the REC MAX is always limited by the service ceiling or the certified ceiling; with the exception of A319 CJ aircraft and some versions of A340-500/600 aircraft at heavy weights.

The following graph gives an illustrative example of the above theoretical curves for an A320. This graph is used by the FMS to determine REC MAX.

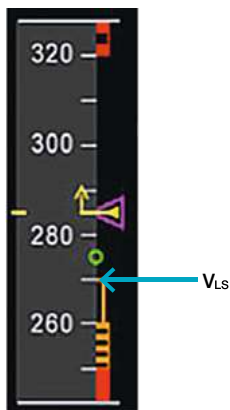


- Green Dot
- Buffet (1,3g)
- Vz 300 ft/min
- V<sub>MO</sub>/M<sub>MO</sub>
- V<sub>MAX</sub> level at Max CLB
- Econ speed CI = 0

CI = 0 (Cost Index 0) is the point that gives the maximum rate of climb at a steady Mach.

## PROCEDURES

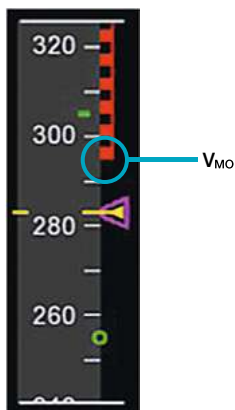
Control your speed... in cruise



(fig.3)

V<sub>LS</sub> on the PFD speed scale

“ GD and V<sub>LS</sub> both depend on the aircraft weight, therefore these speeds will be wrong if the ZFW entered in the FMS is wrong. ”



(fig.4)

V<sub>MO</sub> on the PFD speed scale

### Limit speeds

For a given weight, each aircraft has a minimum selectable speed (V<sub>LS</sub>) and maximum speed (V<sub>MAX</sub>) at a particular altitude. At the cruise altitude, there needs to be a safe margin in relation to these lowest and highest speeds, before the flight envelope protections activate.

#### V<sub>LS</sub>: Lowest Selectable speed

##### » Definition

V<sub>LS</sub> is the lowest selectable speed with A/THR engaged. Even if the target speed is below V<sub>LS</sub>, the A/THR will continue to target V<sub>LS</sub>.

V<sub>LS</sub> is indicated by the top of the amber line on the PFD speed scale (fig.3).

##### » How is V<sub>LS</sub> determined?

V<sub>LS</sub> is a characteristic speed computed by the AFS as a function of the aircraft weight (dependent on the Zero Fuel Weight (ZFW) inserted in the FMS during flight preparation).

$$V_{LS} = 1.23 V_{S1g} \text{ when in clean configuration}$$

Where:

V<sub>S1g</sub> is the stall speed demonstrated by flight tests.

Note: the 1.23 factor is applicable to fly-by-wire aircraft (1.3 for the others).

This formula means that V<sub>LS</sub> is higher when the speed brakes are extended, since speed brakes extension increases V<sub>S1g</sub>.

##### » What are the operational implications of not respecting V<sub>LS</sub>?

Deliberately flying below V<sub>LS</sub> could either lead to an activation of the Angle-Of-Attack protection on a protected aircraft, or expose the aircraft to a stall if it is not protected, i.e. flying in a degraded law.

### V<sub>LS</sub> IN A NUTSHELL.

V<sub>LS</sub> is the slowest speed the AFS lets you fly in normal law.

#### V<sub>MO</sub>/M<sub>MO</sub>: Maximum Operating speed/Mach number

##### » Definition

In cruise, in clean configuration, V<sub>MO</sub>/M<sub>MO</sub> is the higher limit of the aircraft speed envelope.

It is indicated by the lower end of the red and black strip along the PFD speed scale (fig.4).



## THE CROSSOVER ALTITUDE

Aircraft normally fly at an optimal IAS until they reach their optimal climb/cruise Mach. This transition between airspeed and Mach occurs at a point called the “crossover altitude” (usually between FL250 and FL300 depending on the aircraft type).

When the aircraft climbs to the crossover altitude at a constant IAS, Mach increases. The opposite happens when in descent to the crossover altitude, at a constant Mach. Then the IAS increases.

At altitudes above the crossover altitude, pilots will fly a Mach number instead of an IAS because it then becomes the most meaningful parameter.

Different phenomena exist according to the speed or Mach the aircraft flies at. The aerodynamic world can therefore be split into two areas: low and high Mach numbers.

- At high Mach number, when accelerating beyond  $M_{MO}$ , slight vibrations may appear. These are vibrations due to unsteady early onset shock waves developing on the wings upper surface. These shock waves significantly worsen the drag and can alter the aircraft's controllability. But this phenomenon has nothing to do with buffet announcing lack of lift to come or an approaching stall. Airbus airplanes operated up to VD/MD are not exposed to the so-called high speed buffet.
- At high Indicated AirSpeed (IAS), the main threat to the aircraft structural integrity lies in the dynamic pressure exerted by air on the structure. Aircraft controllability remains optimum as long as the Mach number is not too high.

In practice, the aircraft is designed to be safe up to Mach/speeds well above  $V_{MO}/M_{MO}$ . Indeed, according to certification requirements the aircraft must be safe to fly up to the design limit speed/Mach number VD/MD. In other words, up to VD/MD, the aircraft remains controllable and free of any flutter.

### » How is $V_{MO}/M_{MO}$ determined?

$V_{MO}/M_{MO}$  is established with regards to the aircraft's structural limits and it provides a margin to the design limit speed/Mach number VD/MD. VD/MD must be sufficiently above  $V_{MO}/M_{MO}$  to make it highly improbable that VD/MD will be inadvertently exceeded in commercial operations. Several certification criteria exist. As a result, on Airbus aircraft, MD is usually equal to  $M_{MO} + 0.07$  and VD approximately equal to  $V_{MO} + 35$  kt.

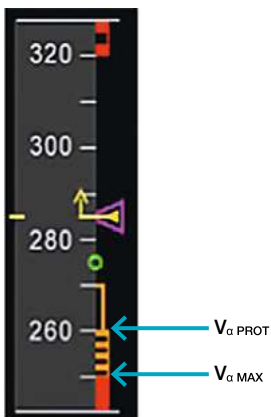
The applicable  $V_{MO}/M_{MO}$  are indicated in each Aircraft Flight Manual. For example,  $V_{MO}/M_{MO}$  and VD/MD are given in the following table.

Aircraft type	$V_{MO}$ (kt)	$M_{MO}$	VD (kt)	MD
A350	340	0.89	375	0.96
A380	340	0.89	375	0.96
A330/A340	330	0.86	365	0.93
A320 Family	350	0.82	381	0.89
A300-600	335	0.82	395	0.89
A310	360	0.84	420	0.90

## PROCEDURES

Control your speed... in cruise

“ At low altitudes, the threat of exceeding  $V_{MO}$  by a significant amount is real and it can dramatically affect the integrity of the aircraft's structure. ”



(fig.5)

$V_{\alpha \text{ PROT}}$  and  $V_{\alpha \text{ MAX}}$  on the PFD speed scale

These concepts involve understanding the maximum structural speed and Mach of the aircraft **VD/MD**.

VD is a Calibrated Air Speed (CAS). During test flights, VD/MD are reached by test pilots with the objective to demonstrate that the aircraft structural integrity is not put at stake at these speeds, and that the aircraft remains safely recoverable at all times. The article “High-altitude manual flying” that was published in the 20<sup>th</sup> issue of this magazine provides a good explanation of the maneuver performed by test pilots to determine these speed and Mach.

Key points to remember are:

- Reaching VD is much easier than reaching MD,
- At high altitude, reaching the aircraft's structural limit is almost impossible,
- At lower altitudes (i.e. below the crossover altitude), reaching VD is possible because the available thrust is higher, and drag due to Mach is lower.

### » What are the operational implications of not respecting $V_{MO}/M_{MO}$ ?

The JAR / FAR 25 rule dictates that  $V_{MO}$  or  $M_{MO}$  may not be deliberately exceeded in any regime of flight. The parameter  $V_{MO}/M_{MO}$  basically sets upper boundaries to the aircraft speed envelope.

Crews should keep in mind that

- At high altitude, whilst it is important to always respect MMO, a slight and temporary Mach increase above that value will not lead the aircraft into an immediate hazardous situation.
- At lower altitudes, exceeding  $V_{MO}$  by a significant amount is a real threat and can dramatically affect the integrity of the aircraft's structure.

Although intentional  $V_{MO}/M_{MO}$  exceedance cases are rare, this limit speed can typically be overshoot when the aircraft is subject to unusual wind and/or temperature gradient. Prevention is therefore essential.

### $V_{MO}/M_{MO}$ IN A NUTSHELL

$V_{MO}/M_{MO}$  is the “never to exceed” speed.

## Flight envelope protection speeds: $V_{\alpha \text{ PROT}}$ and $V_{\alpha \text{ MAX}}$

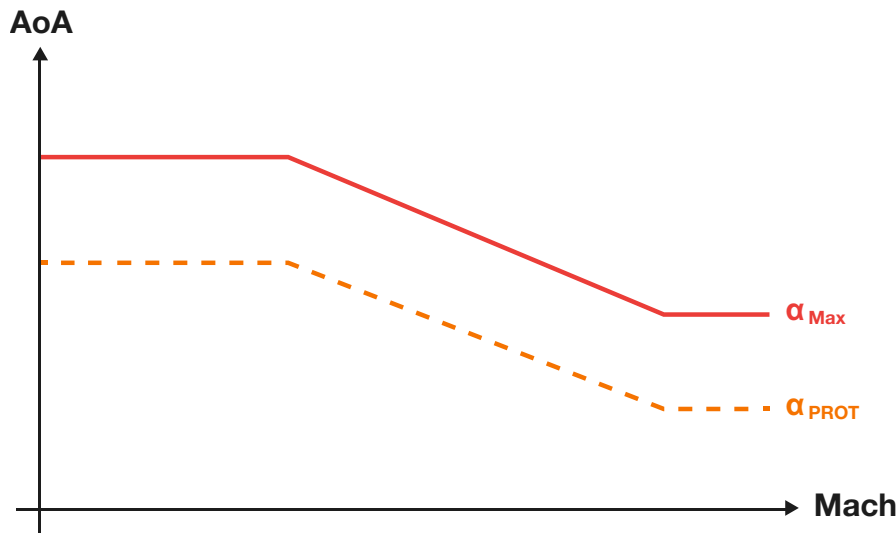
### » Definition

$V_{\alpha \text{ PROT}}$  is the speed corresponding to the maximum Angle-Of-Attack (AOA) at which Alpha Protection becomes active. **It is only displayed in normal law** and corresponds to the top of the black and amber strip along the PFD speed scale (fig.5).

In practice, the AOA value of the Alpha Protection decreases as the Mach number increases. When the AOA value of the Alpha Protection decreases, the Alpha Protection strip on the PFD moves upward.

$V_{\alpha \text{ MAX}}$  is the maximum Angle-Of-Attack speed. It is the speed corresponding to the maximum Angle-Of-Attack the aircraft can fly at in **normal law**. It corresponds to the top of the solid red strip along the PFD speed scale (fig.5).

$\alpha_{\text{MAX}}$  is a function of the Mach number: it decreases when the Mach increases (fig.6).



(fig.6)

Evolution with the Mach number of the AOA value triggering the  $\alpha$  Protection and  $\alpha$  Maximum, in clean configuration

#### » How are $V_{\alpha \text{ PROT}}$ and $V_{\alpha \text{ MAX}}$ determined?

Contrary to GD and VLS,  $V_{\alpha \text{ PROT}}$  and  $V_{\alpha \text{ MAX}}$  are not based on the aircraft weight, as inserted in the FMS during flight preparation through the ZFW.

$V_{\alpha \text{ PROT}}$  (resp.  $V_{\alpha \text{ MAX}}$ ) as displayed on the PFD is a prediction of what the aircraft speed would be if it flew at an Angle-Of-Attack (AOA) equal to  $\alpha_{\text{PROT}}$  (resp.  $\alpha_{\text{MAX}}$ ). In fact, both speeds are calculated on the basis of the aircraft longitudinal equilibrium equation, along with the actual aircraft speed and AOA.

$$V_{\alpha \text{ MAX}} = V_C \times \sqrt{(\alpha - \alpha_0) / (\alpha_{\text{MAX}} - \alpha_0)}$$

$$V_{\alpha \text{ PROT}} = V_C \times \sqrt{(\alpha - \alpha_0) / (\alpha_{\text{PROT}} - \alpha_0)}$$

Where:

$\alpha_0$  is the AOA for a Lift Coefficient ( $C_L$ ) equal to 0.

$V_C$  is the calibrated airspeed (CAS)

$\alpha$  is current AOA

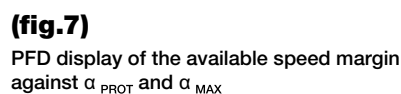
On the A320 Family,  $V_{\alpha \text{ PROT}}$  and  $V_{\alpha \text{ MAX}}$  can have different numerical values on both PFDs because  $V_C$  comes from different sources for left and right PFDs.

On A330/A340, A350 and A380 Families,  $V_{\alpha \text{ PROT}}$  and  $V_{\alpha \text{ MAX}}$  have the same numerical values on both PFDs.

“  $V_{\alpha \text{ PROT}}$  and  $V_{\alpha \text{ MAX}}$  are not based on the aircraft weight. ”

Data source	A320 Family	A330/A340, A350 and A380 Families
$V_C$	<b>Left PFD:</b> FAC 1, or FAC 2 if not available in FAC 1. <b>Right PFD:</b> FAC 2, or FAC 1 if not available in FAC 2.	Same value as the one used by the flight controls.
AOA	Same value used for PFD display as the one used by the flight controls.	

## Control your speed... in cruise



### » What are the operational implications of flying below $V_{\alpha \text{ PROT}}$ ?

At any time during cruise, the actual AOA is compared to  $\alpha_{\text{PROT}}$  (or  $\alpha_{\text{MAX}}$ ) in real time. The difference of AOA is then converted to speed and applied on each PFD: the delta between current speed and  $V_{\alpha \text{ PROT}}$  (or  $V_{\alpha \text{ MAX}}$ ) represents the actual margin against  $\alpha_{\text{PROT}}$  (or  $\alpha_{\text{MAX}}$ ) **(fig. 7)**.

**In normal law**, on a protected aircraft, exceeding the AOA value of the  $\alpha_{\text{PROT}}$  threshold would immediately trigger the high AOA protection, thus resulting in a nose down pitch rate ordered by the flight control laws. Further increasing the AOA by maintaining full back stick would eventually result in reaching the  $\alpha_{\text{MAX}}$  threshold.

When flying in a degraded law, increasing the AOA would directly expose the aircraft to stall. ■

“ When flying in a degraded law, increasing the AOA would directly expose the aircraft to stall, like on any conventional aircraft. ”

VD/MD

High speeds

$V_{MO}/M_{MO}$

Operational speeds

$V_{LS}$

$V_{\alpha Max}$

Low speeds

$V_{stall}$

Unknown domain

Unknown domain

Flight Tests

# MANAGING YOUR CRUISE: SPEED EXCURSIONS OPERATIONAL RECOMMENDATIONS

---

**Understanding how the aircraft's speed envelope is defined is essential to speed excursion avoidance. Knowing the threats to airspeed and the tools at the crew's disposal to tackle them is another part of that goal. This includes knowing exactly which information should be looked at and how, with the aim to acquire the best possible situational awareness and be able to avoid an overspeed (i.e.  $V_{MO}/M_{MO}$  exceedance) or a speed decay (i.e. reaching below  $V_{LS}$ ), and react wisely in case of an actual encounter.**

Reading the first section of this article and understanding how  $V_{MO}/M_{MO}$  and  $VD/MD$  are determined highlighted that:

- **At high altitude**, reaching the aircraft's structural limit Mach number is almost impossible (except in a steep dive with maximum thrust); therefore at high altitude, flying at high Mach number should not be viewed as the biggest threat to the safety of flight. Conversely, flying too slow (below Green Dot) at high altitude can lead to progressive reductions in speed until the protections are triggered. Should this speed reduction take place in a degraded law, it could lead to a loss of control due to stall. At and near the performance altitude limit of the aircraft, the range of available speeds between Green Dot and  $MMO$  will be small. Speed decay at high altitude must be avoided as a result.
- **At lower altitudes** (i.e. below the crossover altitude), too large a speed decay can similarly lead a non protected aircraft (i.e. flying in a degraded law) to enter a stall. Nevertheless, at low altitude, the available envelope is greater and the thrust margin is much higher, thus providing flight crews a greater ability to safely control the airspeed and recover from a speed decay. On the other hand, at low altitude, reaching  $V_{MO}$  and  $VD$  is possible; therefore high speed should be viewed indeed as a significant threat to the safety of flight.

This chapter offers pilots background knowledge of available prevention means in order to properly manage the main threats to the airspeed, and eventually prevent an overspeed or a speed decay thanks to anticipation and use of dedicated procedures.

## How to anticipate a speed excursion

Clearly flight crews are expected to be able to rapidly scan the essential and relevant parameters, in every situation, in every flight phase, including dynamic ones. In most cases, speed excursion situations are due to rapid wind and temperature variations/evolutions.

“ The biggest threat to the safety of flight both at high and low altitude relates to speed decay. ”



“ The nearer the aircraft is to the REC MAX FL, the smaller the thrust margin. ”

### Gaining a good awareness of weather

Weather is an important factor that influences aircraft performances. Be it a local flight or a long haul flight, decisions based on weather can dramatically affect the safety of the flight. As it turns out, the first external threat to airspeed comes from weather disturbances, such as turbulent areas that can lead to significant speed changes.

Common sense generally makes pilots avoid those areas; however, they sometimes end up in a situation where some solid turbulence is encountered, when dodging thunderstorms for example. At this point, the airspeed begins to fluctuate, thus making speed exceedance or speed decay more likely. Such situations need to be planned ahead and as far as possible, avoided through regular scanning of weather conditions and flight path adaptation.

The first key to preventing speed excursion events is gaining awareness of the available weather predictions along the forecasted route.

Before take-off, the weather briefing has to be as complete as possible. Pilots should check weather reports at alternate and destination airports and, depending on the weather context, this information needs to be updated in flight as often as necessary. Weather information can be communicated either by the Air Traffic Controllers or by the other crews flying in the area.

Once airborne, the weather radar is one powerful tool to help the crew make sound weather related decisions to avoid adverse weather and turbulence areas.

### Altitude and wind gradients: the main contributing factors

On aircraft with no failure, and the A/THR engaged or the MAX CLB thrust applied in manual mode, a continuous speed decay during cruise phase may be due to:

- A large and continuous increase in tailwind or decrease in headwind, in addition to an increase in the Outside Air Temperature (OAT), that results in a decrease of the REC MAX FL, or
- A large or prolonged downdraft, when the flight crew flies (parallel and) downwind in a mountainous area, due to orographic waves. The downdraft may have a negative vertical speed of more than 500 ft/min. Therefore, if the aircraft is in a downdraft, the aircraft must climb in order to maintain altitude, and the pitch angle and the thrust values increase. Without sufficient thrust margin, the flight crew may notice that aircraft speed decays, but the REC MAX FL is not modified.

The flight crew must be aware that at high altitude, the thrust margin (difference between the thrust in use and the maximum available thrust) is limited. The maximum available thrust decreases when there is an increase in altitude and/or outside temperature. The REC MAX FL indicated in the FMS decreases when the OAT increases. The nearer the aircraft is to the REC MAX FL, the smaller the thrust margin.

### Preventing a speed decay: detecting the phenomenon

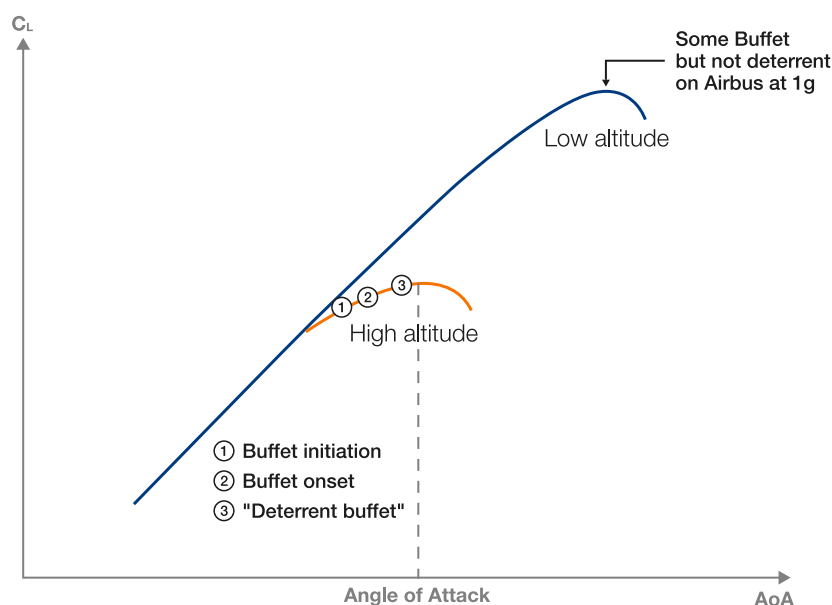
At any altitude, decreasing the speed too much will certainly lower the aircraft's level of energy and decrease margins for maneuvering, thus potentially leading to a loss of control due to stall with an aircraft flying in a degraded law. It is important to understand and detect signs of a significant speed decay in order to be able to recover.

When speed decreases, pilots should be attentive to their speed trend vector as displayed on the PFD and take action if an unfavourable speed trend develops in order to remain above GD.

If the speed decreases further, then the Angle-Of-Attack (AOA) must be increased in order to increase the lift coefficient  $C_L$ , which keeps the forces balanced. However, it is not possible to indefinitely increase the AOA.

As per basic aerodynamic rules, the lift coefficient  $C_L$  increases linearly with the AOA up to a point where the airflow separates from the upper wing surface. If the AOA continues to increase, the point of airflow separation is unstable and rapidly fluctuates back and forth. Consequently, the pressure distribution along the wing profile changes constantly and also changes the lift's position and magnitude. This effect is called **buffeting** and is evidenced by vibrations. Buffet is a clear sign of an approaching stall or even of the stall itself depending on its severity: it is created by airflow separation and is a function of AOA (**fig.8**).

- At buffet initiation, the pilot starts to feel airflow separation on wings upper surface.
- The buffet onset corresponds by definition to 1.3g (corresponding to 40° of bank angle in level flight).
- The “deterrent buffet” is so strong that any pilot will feel he/she needs to leave these buffet conditions. It corresponds to one of the definitions of stall.



**(fig.8)**  
AOA effect on lift

When the AOA reaches a maximum value, the separation point moves further forward on the wing upper surface and almost total flow separation of the upper surface of the wing is achieved: this phenomenon leads to a significant loss of lift, referred to as a stall. Incidentally, stall is not a pitch issue and can happen at any pitch value.

These conditions should be avoided thanks to anticipation and regular scanning of both the weather conditions along the flown route, and of the speed trend on the PFD. Nevertheless, these conditions might be approached unintentionally. As soon as any stall indication is recognized – be it the aural warning “STALL + CRICKET” or buffet – the aircraft’s trajectory becomes difficult to control and the “Stall recovery” procedure must be applied immediately.

“ Stall is not a pitch issue and can happen at any pitch. Stalling is only an AOA issue. ”

## PROCEDURES

Control your speed... in cruise



### NOTE

A video illustrating buffet is presented in the tablet application of Safety first for this issue.

#### Approach to stall

- **Indications**
  - Artificial stall warnings
  - Some natural stall warning indications may be present
- **Progressive airflow separation**
- **Trajectory controllable with decreasing margin for maneuvering**

#### Stall

- **Indications**
  - Artificial stall warnings
  - Natural stall warnings
  - Buffeting
  - Lack of pitch authority
  - Lack of roll control
  - Inability to arrest descent
- **Airflow separated from wing**
- **Trajectory no longer controllable**



### Preventing and recovering from a $V_{MO}/M_{MO}$ exceedance: dedicated procedures

#### Using dedicated procedures

As soon as an unfavourable speed trend develops, pilots must take action and prevent a speed exceedance, following the operating techniques and recommendations detailed in the OVERSPEED PREVENTION procedure.



### DID YOU KNOW

On the A320 Family, speed brakes extension and retraction rates at high Mach/Vc are roughly twice as slower Auto Pilot (AP) engaged compared with AP disengaged. As a consequence, if used to avoid a  $V_{MO}/M_{MO}$  exceedance, crew should keep this in mind to retract them timely in order to avoid reducing their speed below GD. This is particularly true when flying close to REC MAX.

In most cases, the use of this OVERSPEED PREVENTION procedure will effectively prevent exceeding  $V_{MO}/M_{MO}$ . Nevertheless, due to system design and limited authority, this may not be sufficient. For this reason, a OVERSPEED RECOVERY procedure was developed as well and implemented in the FCOM /QRH.

The OVERSPEED warning is triggered when the speed exceeds  $V_{MO} + 4$  kt or  $M_{MO} + 0.006$ , and lasts until the speed is below  $V_{MO}/M_{MO}$ . In this case, the flight crew must apply the OVERSPEED RECOVERY procedure.

### Maintaining the aircraft after a $V_{MO}/M_{MO}$ exceedance

The flight crew must report any type of overspeed event (i.e. if the OVERSPEED warning is triggered). Indeed, in case of an overspeed, an inspection of the aircraft structure may be required.

Indeed, when an overspeed event occurs, the aircraft may experience a high load factor. Only an analysis of flight data allows to tell whether or not an inspection is required.

This supports the crucial need for flight crews experiencing an overspeed to report it! Then maintenance and engineering teams will judge whether or not further inspection is needed. ■

“ Any type of overspeed must be reported by the flight crew. Only an analysis of flight data allows to tell whether or not an inspection is required. ”



In cruise, the aircraft airspeed might not be the desired one at all times. The aircraft may encounter adverse weather and turbulences, or even winds, which all have a direct impact on the airspeed. For this reason, flight crews must remain vigilant at all times and anticipate the main threats to the airspeed by planning ahead and communicating.

In practice, once the aircraft is airborne, pilots must be fully cognisant of the airspeed as well as the speed trends at all times in flight. In case of need, the FCOM/QRH and FCTM provide procedures and adequate guidelines to prevent and to recover from a speed excursion, and react wisely to any variation of airspeed. They are worth being thoroughly read and understood in advance.



### DID YOU KNOW

To know more about speeds, read our brochure “Getting to grips with aircraft performance”, available on AirbusWorld.





# Control your Speed... During Descent, Approach and Landing

This article is the conclusion of our theme of speed management during a flight, which began in Safety first Issue #18. We are entering into the descent phase. Our objective is to cover descent from cruise altitude down toward the destination airport and prepare the aircraft for its approach and landing.

This article aims to highlight how the reference, limit and operating speeds are useful during descent, approach and landing. It also provides a description of the tools that are available and operational recommendations on how to manage the aircraft energy during the last phases of flight.



Energy management, and as a consequence speed management, is critical during descent, approach and landing phases. An aircraft flying at cruise altitude, and at its cruise speed, has a lot of energy to dissipate before reaching its destination airport and to land with an appropriate speed. Incorrect management of the speed in descent can result in excess-energy in final approach phase. This is shown to be a major cause of runway overrun events.

## MANAGING YOUR DESCENT, APPROACH AND LANDING: UNDERSTAND SPEEDS

### Maneuvering speeds

As for the previous flight phases, Green Dot, S and F speeds guide the flight crew during descent and approach phases.

#### Green Dot (GD) speed

##### » Definition

GD speed (**fig.1**) is the engine-out operating speed in clean configuration. It provides an estimate of the speed for best lift-to-drag ratio.

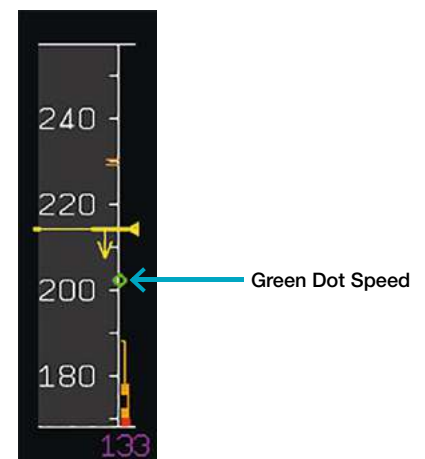
GD speed is the managed speed target in CONF CLEAN when the FMS approach phase is activated. It is also the recommended speed to extend flaps to CONF 1 and for a holding in clean configuration.

##### » How is GD speed determined?

The Auto Flight System (AFS) computes GD speed using the aircraft weight, based on the Zero Fuel Weight (ZFW) entered in the FMS during flight preparation, and the pressure altitude. The GD formula has been set up so that the resulting airspeed provides the best lift-to-drag ratio for a given altitude and aircraft weight, in clean configuration with one engine out.

In some phases of flight, GD is computed to minimize drag and thus, the fuel consumption (for example during the HOLD phase).

“ Green dot is the managed speed target in CONF CLEAN when the FMS approach phase is activated. ”



**(fig.1)**

Green Dot speed on the PFD speed scale



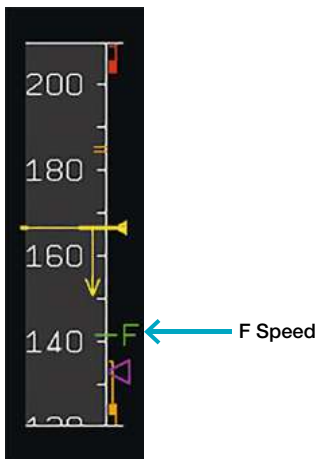
# PROCEDURES

Control your Speed... During Descent, Approach and Landing



(fig.2)

S speed on the PFD speed scale



(fig.3)

F speed on the PFD speed scale



(fig.4)

V<sub>MAX</sub> speed on the PFD speed scale

## S and F speeds

### » Definition

#### S speed:

In approach phase, S speed is the managed speed target, when in CONF 1 or 1+F. It is the recommended speed to select CONF 2.

It is displayed as a green "S" on the PFD airspeed scale (fig. 2) and shown only when the Slats/Flaps control lever is on position 1 (CONF 1 or 1+F).

#### F speed:

In approach phase, F speed is the managed speed target, when in CONF 2 or 3. It is the recommended speed to select CONF 3 when in CONF 2, and to select CONF FULL when in CONF 3.

It is displayed as a green "F" on the PFD airspeed scale (fig. 3) and shown only when the Slats/Flaps control lever is in CONF 2 or 3 during the approach phase and go-around.

### » How are S and F speeds determined?

S and F speeds are obtained using the Stall speed of the corresponding configuration ( $V_{S1G}$ ) demonstrated during flight tests multiplied by a specific factor depending on the aircraft type. Margins are kept with the Minimum Control speed at Landing ( $V_{MCL}$ ) determined during flight tests, and with the maximum speed with Flaps Extended of the next configuration ( $V_{FE\ NEXT}$ ):

$$S \text{ or } F = V_{S1G} \times \text{factor}$$

$$S = k \times V_{S1G\ CLEAN} \text{ with } 1.21 \leq k \leq 1.23$$

$$F_{CONF2} = k \times V_{S1G\ CONF\ 2} \text{ with } 1.38 \leq k \leq 1.47$$

$$F_{CONF3} = k \times V_{S1G\ CONF\ 3} \text{ with } 1.32 \leq k \leq 1.36$$

## Limit Speeds

During descent, approach and landing, the operation of the aircraft is also framed within limit speeds. Their indication on the PFD or on a placard enables the flight crew to easily identify the aircraft speed envelope.

### V<sub>MAX</sub>: Maximum speed

#### » Definition

V<sub>MAX</sub> is the maximum speed defining the aircraft's flight envelope. V<sub>MAX</sub> is equal to:

- V<sub>MO</sub>/M<sub>MO</sub> in clean configuration with landing gears up.
- V<sub>FE</sub> in high lift configurations with landing gears up.
- V<sub>LE</sub>/M<sub>LE</sub> in clean configuration with landing gears down.
- The minimum of V<sub>FE</sub> and V<sub>LE</sub>/M<sub>LE</sub> in high lift configurations with landing gears down.

On the PFD airspeed scale, it corresponds to the lower end of the red and black strip (fig.4).

**V<sub>MO</sub>/M<sub>MO</sub>: Maximum Operating speed/Mach number**

» **Definition**

In CONF CLEAN, V<sub>MO</sub>/M<sub>MO</sub> is the higher limit of the aircraft speed envelope.

» **How is V<sub>MO</sub>/M<sub>MO</sub> determined?**

V<sub>MO</sub>/M<sub>MO</sub> is derived from the design limit Mach/speed V<sub>D</sub>/M<sub>D</sub> by applying a margin related to aircraft dive characteristics. For more details on V<sub>MO</sub>/M<sub>MO</sub> determination, refer to the Safety first issue 21 dated January 2016.

**V<sub>FE</sub>: maximum speed with the Slats/Flaps extended**

» **Definition**

V<sub>FE</sub> is the maximum speed with the slats or flaps extended.

There is one V<sub>FE</sub> per configuration.

The V<sub>FE</sub> is displayed on the airspeed scale of the PFD as the V<sub>MAX</sub> **(fig. 5)** when the Slats/Flaps are extended, based either on the Slats/Flaps lever position or the actual Slats/Flaps position.

Aircraft	A320 A330/A340*	A340-500/600	A350/A380
<b>V<sub>FE</sub> PFD display based on:</b>	Slats/Flaps lever position	Actual Slats/Flaps position	<b>For retraction:</b> Actual Slats/Flaps position  <b>For extension:</b> Slats/Flaps lever position

The V<sub>FE</sub> of each Slats/Flaps configuration is also available on the speeds placard in the cockpit.

» **How is V<sub>FE</sub> determined?**

The V<sub>FE</sub> is based on the structural limit speed of the Slats/Flaps configuration plus a margin. It is a fixed value associated to the aircraft model.

**V<sub>FE NEXT</sub>**

» **Definition**

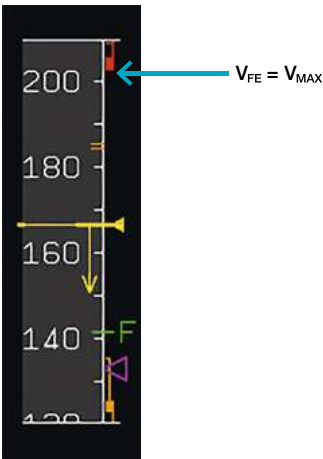
The aim of the V<sub>FE NEXT</sub> is to remind the flight crew the maximum speed at which they can extend the next Slats/Flaps configuration during approach.

V<sub>FE NEXT</sub> is displayed on the airspeed scale of the PFD **(fig. 7)**.

V<sub>FE NEXT</sub> is displayed in flight, below FL200 (FL220 on A350).

» **How is V<sub>FE</sub> determined?**

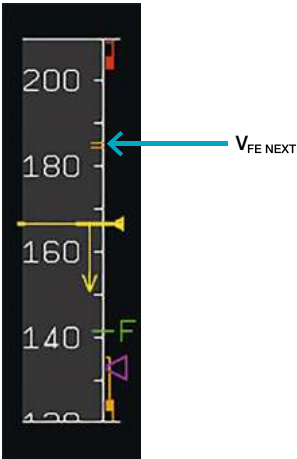
V<sub>FE NEXT</sub> is the V<sub>FE</sub> of the next Slats/Flaps configuration.



**(fig.5)**  
V<sub>FE</sub> speed on the PFD speed scale

**(fig.6)**  
Table showing source of information for V<sub>FE</sub> display on PFD

\* A340-200/300.



**(fig.7)**  
V<sub>FE NEXT</sub> speed on the PFD speed scale

## PROCEDURES

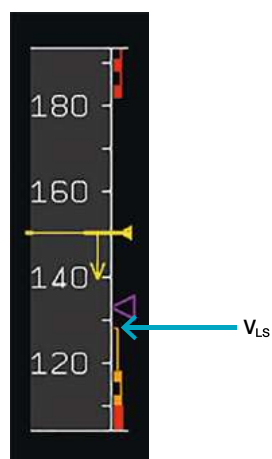
Control your Speed... During Descent, Approach and Landing

LIMIT SPD (IAS)	
VLO = VLE	
NORM :	250KT
	M 0.55
GRVTY:	220KT
VFE 1	263KT
1+F	222KT
2	220KT
3	196KT
FULL°	182KT

(fig.8)

Example of speed placard on the A380

“ Since Speedbrakes extension increases  $V_{s1g}$ ,  $V_{LS}$  increases when the speedbrakes are extended. ”



(fig.9)

$V_{LS}$  speed on the PFD speed scale

### $V_{LE}/M_{LE}$ : Landing gear Extended speed/Mach

#### » Definition

$V_{LE}/M_{LE}$  is the maximum speed/Mach at which the aircraft can fly with the landing gear extended.

$V_{LE}/M_{LE}$  is displayed on the airspeed scale of the PFD as the  $V_{MAX}$  when the landing gear is extended as long as  $V_{LE}/M_{LE}$  is lower than  $V_{FE}$ . It is also available on the speeds placard in the cockpit (fig. 8).

#### » How is $V_{LE}$ determined?

$V_{LE}$  is determined to provide sufficient flight domain with landing gear extended, taking into account the structural limitation of the landing gear and landing gear doors.

### $V_{LO}/M_{LO}$ : Landing gear Operating speed/Mach

#### » Definition

$V_{LO}/M_{LO}$  is the maximum speed/Mach to operate (both extend and retract) the landing gear.

$V_{LO}/M_{LO}$  is not displayed on the PFD; it is available on the speeds placard in the cockpit (fig. 8).

#### » How is $V_{LO}/M_{LO}$ determined?

$V_{LO}/M_{LO}$  is determined to provide sufficient flight domain for landing gear extension/retraction, taking into account the structural limitation of the landing gear and landing gear doors.

### $V_{LS}$ : Lowest Selectable Speed

#### » Definition

$V_{LS}$  is the lowest selectable speed for the autopilot and the autothrust. Even if the selected target speed is below  $V_{LS}$ , the A/THR will maintain  $V_{LS}$  as a minimum.  $V_{LS}$  is indicated by the top of the amber strip on the PFD airspeed scale (fig. 9).

$V_{LS}$  (of selected landing configuration: CONF 3 or FULL), is also displayed on the FMS APPR page.

#### » How is $V_{LS}$ determined in descent and approach?

For descent and approach flight phases,  $V_{LS}$  of Fly-By-Wire aircraft is obtained using the Stall speed demonstrated during flight tests ( $V_{S1G}$ ) of the corresponding configuration, multiplied by a factor of 1.23. On A320 family aircraft, the factor may be increased for some Slats/Flaps configurations for manoeuvrability improvement and/or to increase margins with protection speeds.  $V_{LS}$  is always greater or equal to the Minimum Control Speed at Landing ( $V_{MCL}$ ).

**FBW aircraft (except A320 family):  $V_{LS} = 1.23 \times V_{S1G}$**

**A320 family:  $V_{LS} = k \times V_{S1G}$  with  $1.23 \leq k \leq 1.28$**

$$V_{LS} \geq V_{MCL}$$

Since Speedbrakes extension increases  $V_{S1G}$ ,  $V_{LS}$  increases when the speedbrakes are extended.

## Operating Speeds

### ECON DES speed/Mach

#### » Definition

ECON DES speed/Mach is the optimum descent speed/Mach to lower the direct operating costs of the descent.

#### » How is ECON DES speed/Mach determined?

ECON DES speed/Mach is computed by the FMS based on the Cost Index (CI), cruise FL and on the aircraft weight.

### V<sub>APP</sub>: Approach speed

#### » Definition

V<sub>APP</sub> is the final approach speed when the Slats/Flaps are in landing configuration and the landing gears are extended.

V<sub>APP</sub> is displayed in the FMS PERF APPROACH page.

#### » How is V<sub>APP</sub> determined?

The V<sub>APP</sub> can be computed by the AFS or inserted manually by the pilot through the FMS PERF Page.

V<sub>APP</sub> is based on the V<sub>LS</sub> of the landing configuration. For Airbus aircraft, in normal operations, the V<sub>APP</sub> is defined by:

$$V_{APP} = V_{LS \text{ Landing CONF}} + APPR \text{ COR}$$

### AFS Computation of V<sub>APP</sub>

When computed by the AFS, the APPRoach CORrection (APPR COR) used by the AFS is

$$APPR \text{ COR} = 1/3 \text{ Headwind with } 5\text{kt} \leq APPR \text{ COR} \leq 15 \text{ kt}$$

Excepted on some older A320 aircraft where the APPR COR used by the AFS is 1/3 Headwind + 5kt, limited at 15kt.

### VAPP Computation by the Flight Crew

The flight crew can chose to insert any V<sub>APP</sub> by computing its own APPR CORR as follows:

- APPR COR = highest of:**
- 5kt if A/THR is ON
  - 5kt if ice accretion (10kt instead of 5kt on A320 family when in CONF 3)
  - 1/3 Headwind excluding gust
  - Flight crew speed increment (\*)

**with APPR COR ≤ 15 kt**

During autoland or when A/THR is ON or in case of ice accretion or gusty crosswind greater than 20kt, V<sub>APP</sub> must not be lower than V<sub>LS</sub> + 5kt.

“ ECON DES speed/Mach is the optimum descent speed/Mach to lower the direct operating costs of the descent. ”

(\*) In some situations (e.g. gusty conditions or strong crosswind), the flight crew may choose a higher V<sub>APP</sub> than the AFS computation as good airmanship.



## PROCEDURES

Control your Speed... During Descent, Approach and Landing

### **V<sub>APP</sub> in the case of a system failure**

In the case of a system failure during flight, the flight crew computes a new V<sub>APP</sub> value:

$$\mathbf{V_{APP} \text{ System Failure} = V_{REF} + \Delta V_{REF} + APPR \text{ COR}}$$

$$\text{With } \mathbf{V_{REF} = V_{LS \text{ CONF FULL}}}$$

$\Delta V_{REF}$  is the speed increment related to the failure to counter associated handling qualities issues and/or increased stall speed.

APPR COR depends on the  $\Delta V_{REF}$ , the ice accretion, the headwind value and the use of autothrust.

For more information on the determination of V<sub>APP</sub> with failure by the flight crew, refer to the Flight Crew Techniques Manual (FCTM). ■



“ The FMS can compute an accurate and optimized descent profile, provided the descent winds have been entered in the FMS during the descent preparation, and provided the PERF and IDLE factors are tuned according to the actual aircraft performance. ”

## MANAGING SPEED DURING DESCENT

The descent profile computed by the Flight Management System (FMS) is a very efficient and useful tool to help the flight crew in managing the aircraft energy during the descent and approach phases.

### **Descent Profile Computation**

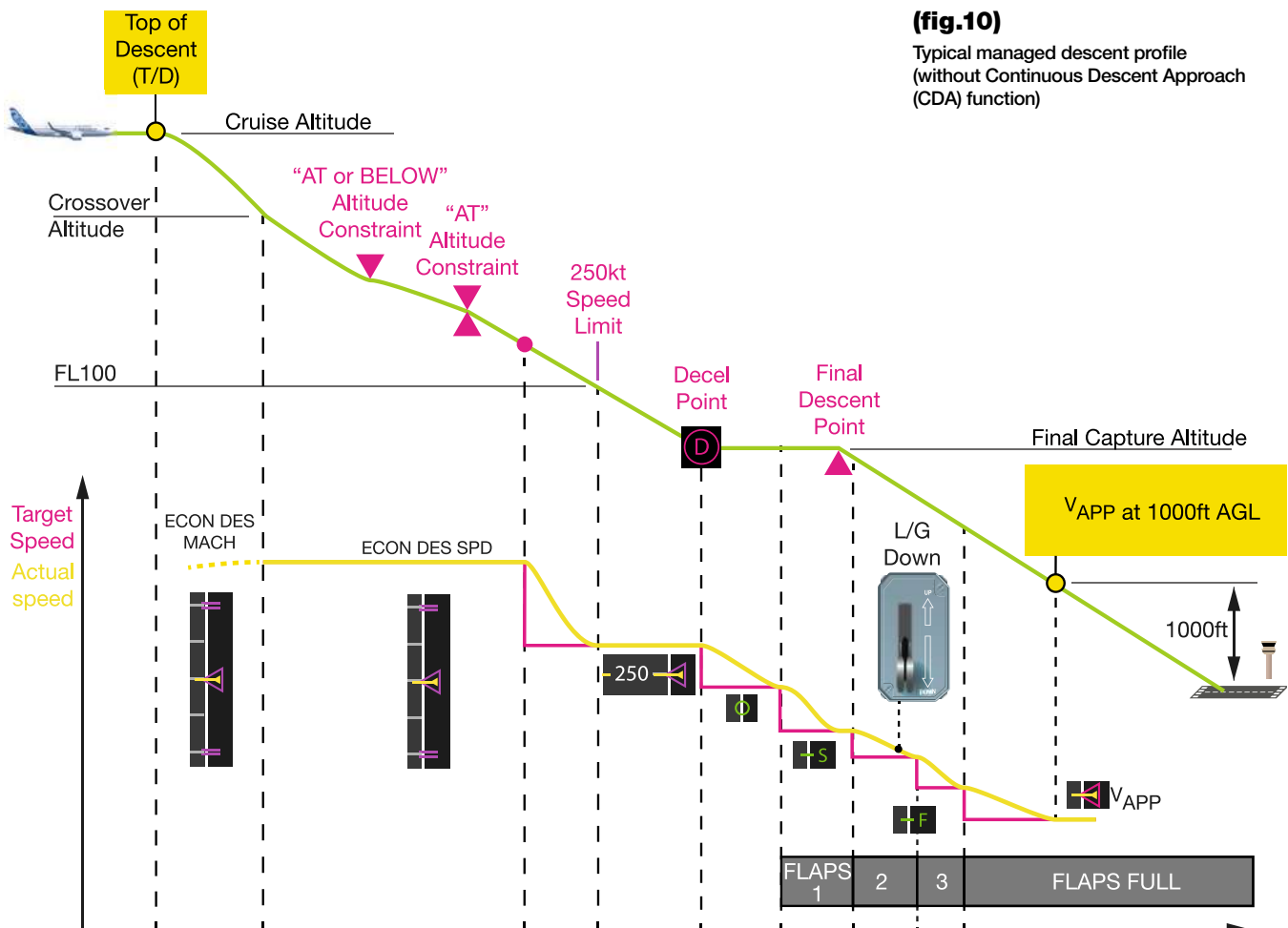
The FMS can compute an accurate and optimized descent profile, provided the descent winds have been entered in the FMS during the descent preparation, and provided the PERF and IDLE factors are tuned according to the actual aircraft performance.

To locate the Top of Descent (T/D), the FMS computes the descent profile backwards from the Missed Approach Point (MAP), assuming the aircraft is stabilized at its V<sub>APP</sub> 1000ft above the runway elevation, up to the T/D.

The FMS assumes the use of managed speed and accounts for all the speeds and altitude constraints coded on the FMS flight plan. Refer to **(fig.10)**.

During the descent, approach and landing the managed speed is equal to either:

- ECON DES speed or the descent speed manually entered in the PERF DES page of the FMS, or
- The speed constraint, or
- The manoeuvring speed of the current aircraft configuration, or
- $V_{APP}$ .



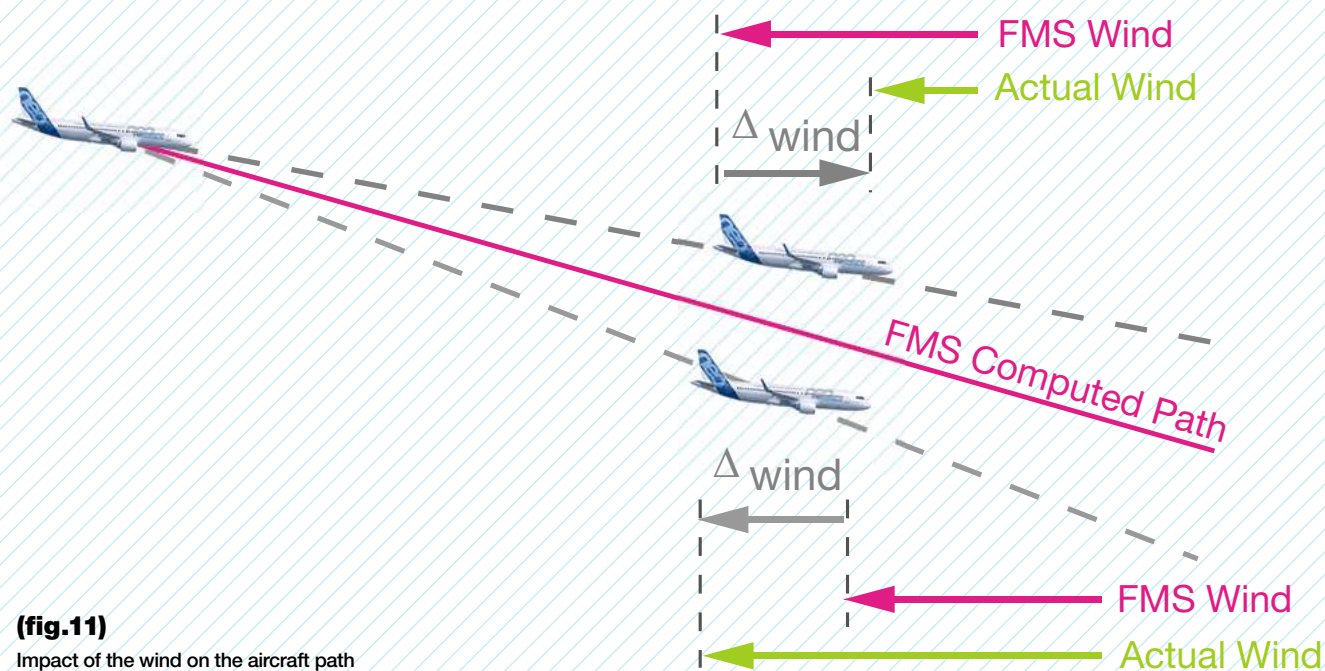
## PROCEDURES

Control your Speed... During Descent, Approach and Landing

### IMPACT OF THE WIND ON THE DESCENT PATH

The descent path computed by the FMS uses the forecasted wind entered in the DESCENT WIND page. However, in flight, actual conditions may vary from the predicted ones. As a consequence, the difference

between the predicted descent wind and the actual wind ( $\Delta_{\text{wind}}$ ) affects the aircraft's behavior. If the speed target is maintained (as in OP DES mode), the aircraft tends to leave the FMS computed idle path **(fig.11)**.



**(fig.11)**

Impact of the wind on the aircraft path



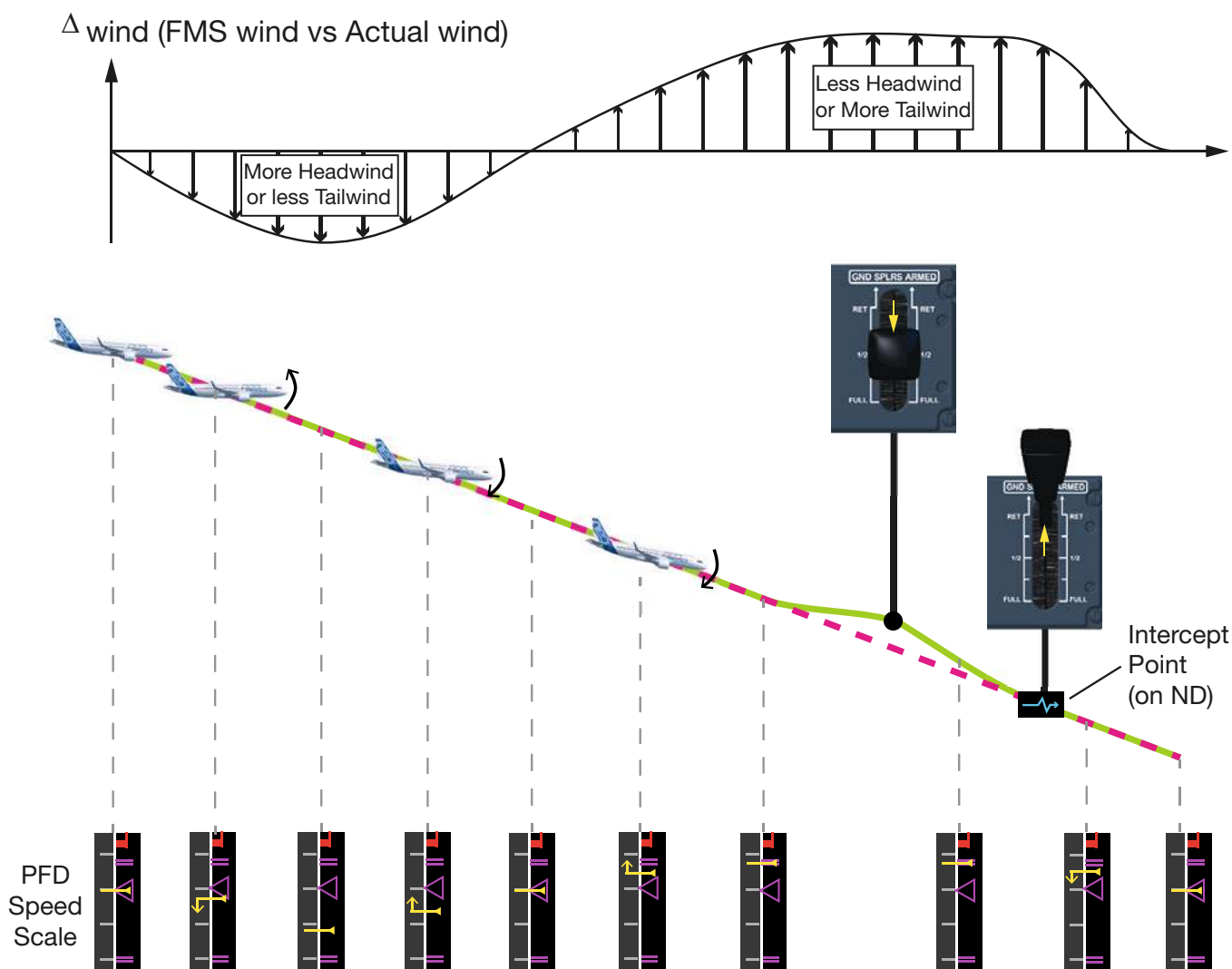
## Managed Descent (DES)

The managed descent mode guides the aircraft along the FMS computed vertical flight path. The **DES** mode is preferred when conditions permit since it ensures the management of altitude constraints and reduces the operating cost when flying at ECON DES speed.

The **DES** mode is only available when the aircraft flies on the FMS lateral flight plan, i.e. when the aircraft uses the **NAV** horizontal guidance mode.

(fig.12)

Speed range principle during the idle segment of a managed descent.



### » On idle segment

In **DES** mode with managed speed the elevators adjust the pitch to enable the aircraft to stay on the computed path and the A/THR commands idle thrust.

The AFS allows the aircraft speed to vary in a range of +/- 20 knots around the managed speed target (+5 kt or -20 kt in the case of a speed constraint), limited to  $V_{MAX} - 5\text{kt}$  to stay on path:

- If the speed decreases down to its lower limit, the A/THR will increase the thrust
- If the speed reaches its upper limit, the aircraft will leave the path to maintain the upper limit speed.

## PROCEDURES

Control your Speed... During Descent, Approach and Landing

### » On geometric segment

On the geometric segment, the A/THR adapts thrust to maintain the managed speed target.

### » Use of speedbrakes in **DES** mode

The use of speedbrakes in **DES** mode must be limited to the situation where there is either a strong tailwind or much less tailwind than expected, and the aircraft diverges from the profile. The flight crew should increase drag by extending the speed brakes **(fig. 12)**.

As a visual clue the ND displays the intercept point at which the aircraft will reach the profile with half speed brakes extended. If the flight crew does not extend the speed brakes the interception point will continuously move forward along the flight plan. If the interception point gets closer to an altitude constraint, a "MORE DRAG" or EXTEND SPD BRK" message is displayed on the FMA and on the MCDU scratchpad/MFD.

**Note:** The speed range does not apply below FL 100 for A350 and A330 equipped with HONEYWELL P5 FMS 2 release 2. In this case, the aircraft stays on the path and the flight crew must monitor the speed and use speedbrakes when appropriate.

“ In OP DES mode, the A/THR commands idle thrust and the elevators adjust the pitch to maintain the target speed. ”



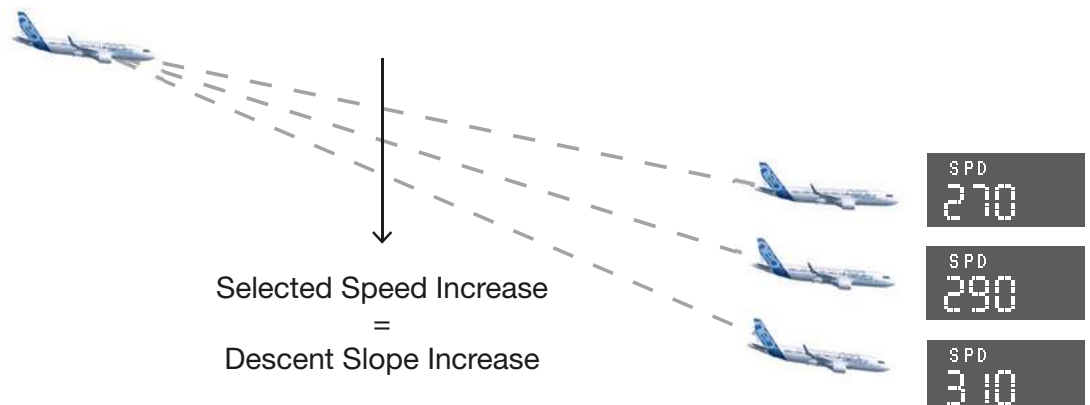
### Selected Descent (**OP DES** and **V/S**)

In **OP DES** mode, the AFS commands idle thrust and the elevators adjust the pitch to maintain the target speed (managed or selected).

The **OP DES** mode can be used to increase or reduce the descent slope. In **OP DES**, the flight crew adjusts the target speed to modify the descent path **(fig. 13)**.

**(fig. 13)**

Adjustment of the selected speed to modify the descent path.





The flight crew can use the **V/S** mode during descent to get accurate guidance to recover the intended flight path by adjusting the V/S using the V/S selector.

In **V/S** mode, the AFS adjusts pitch and thrust to maintain the selected vertical speed and the target speed.

## Tools for Energy Management during Descent

### V/DEV Indication

When in **NAV** lateral mode, the flight crew uses the “yoyo” indication to estimate its position relative to the FMS computed path. The Vertical deviation (V/DEV) value is provided on the FMS PROG page (A320/A330/A340) (**fig.14**) or PERF DES page (A380/A350).



**(fig.14)**

example of V/DEV indication on the PFD and on the FMS PROG page (A320)

### Energy Circle

When in **HDG** or **TRK** lateral mode, the ND displays the energy circle, and when the aircraft is within 180 NM of its destination. It provides a visual cue of the minimum required distance to land, i.e. the distance required to descend in a straight line from the current aircraft position at its current speed down to the altitude of the destination airport at approach speed. The descent profile used to compute the distance takes into account speed limits, the wind, a deceleration level off segment and a 3° final approach segment (**fig.15**). In other words, if the destination airport is inside the energy circle, the flight crew needs to lose some energy by extending the speed brakes and/or modifying the aircraft's trajectory, and/or increasing speed during descent.

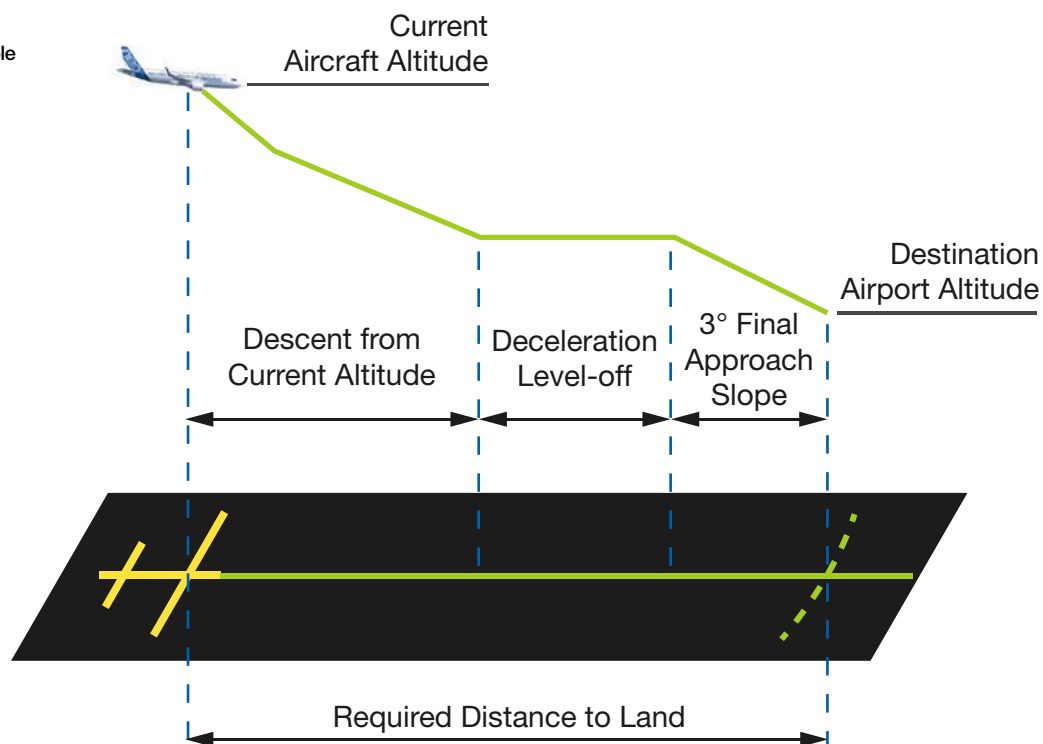
“ In HDG or TRK lateral mode, the Energy Circle provides a visual cue of the minimum required distance to land. ”

## PROCEDURES

Control your Speed... During Descent, Approach and Landing

**(fig.15)**

Energy Circle Computation Principle

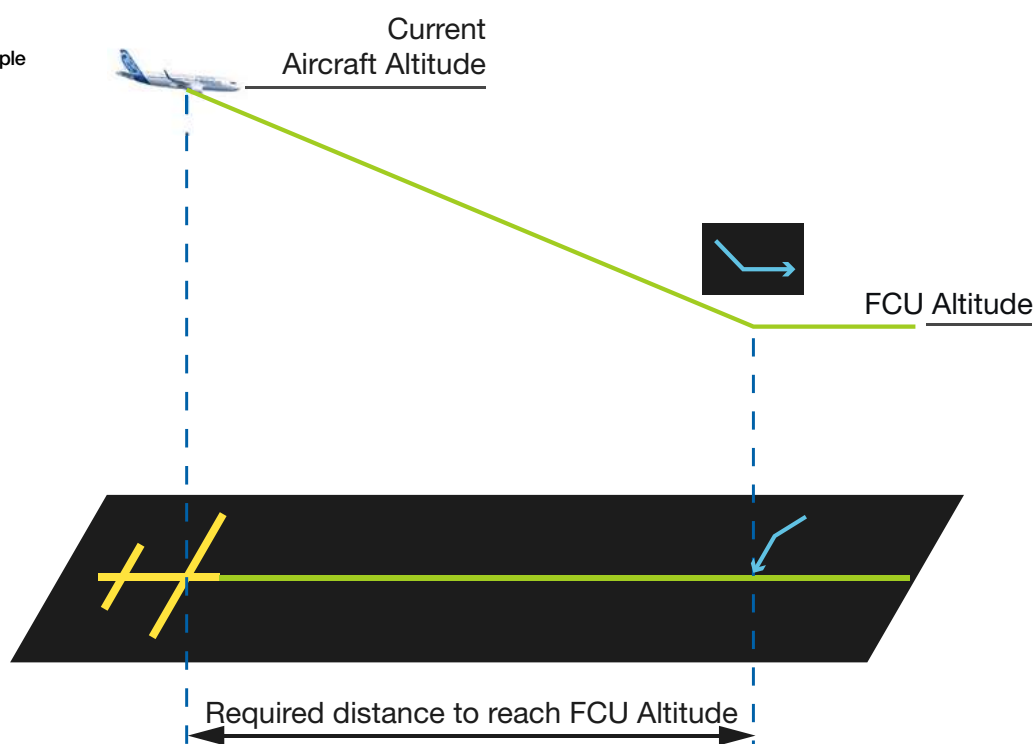


### Level-off Arrow

Another useful tool to use during descent is the level-off arrow provided by the FMS. It provides an indication to the flight crew of where the aircraft will reach the altitude selected on the FCU (**fig.16**). A blending of actual wind conditions and the values for winds entered in the FMS are used to improve the accuracy of the computation. If in selected descent, the flight crew can adjust the speed of the aircraft to adapt the descent path or V/S to the situation.

**(fig.16)**

Level-off Arrow Computation Principle





## Overspeed Avoidance during Descent

### Manual Flight at Crossover Altitude

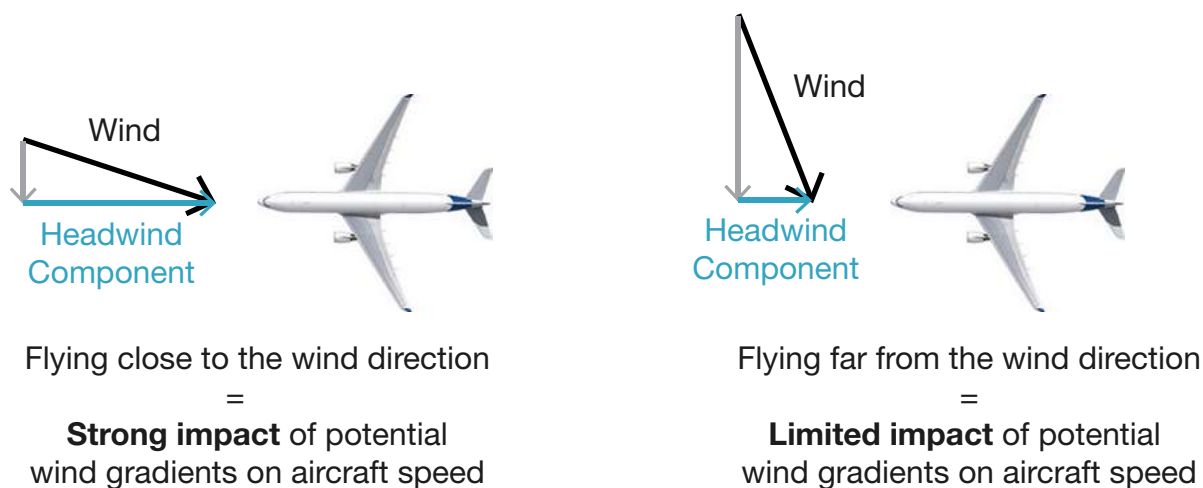
When in descent close to  $M_{MO}$ , if in manual flight (AP off), the risk of exceedance of the  $V_{MO}$  at the crossover altitude is high. In this situation, the flight crew should know its crossover altitude and anticipate the switch to speed by reducing the aircraft pitch on approaching the crossover altitude.

### Impact of Wind Direction

Flight crews should pay particular attention monitoring their speed in descent close to  $V_{MO}/M_{MO}$  and when flying close to the wind direction (**fig. 17**). The impact of a wind gradient can be significant and bring the aircraft beyond  $V_{MO}/M_{MO}$ . ■

(fig.17)

Impact of wind direction



## MANAGING SPEED DURING APPROACH AND LANDING

### Initial Approach

When reaching the Initial Approach Fix (IAF) the flight crew should have a defined approach strategy based on the selected type of approach: a choice of the guidance mode that will be used and the associated approach technique (decelerated approach or early stabilized approach). The flight crew is then ready to start the key phase of the approach in terms of speed management: the Intermediate Approach phase.

(fig.18)

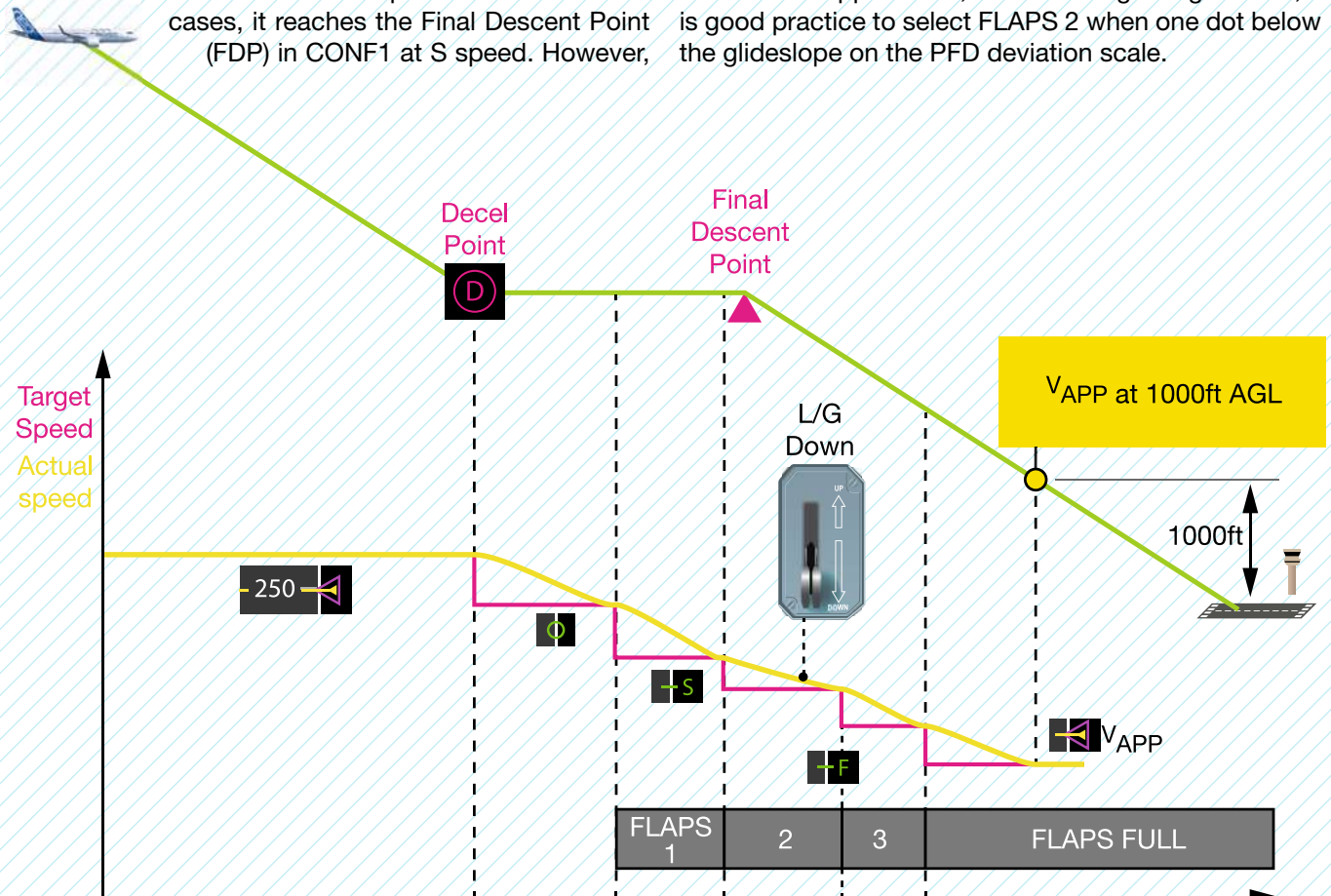
Example of decelerated approach

### DECELERATED APPROACH (WITHOUT CDA FUNCTION)

The decelerated approach is the default strategy used by the FMS to compute the descent and approach path. It is the recommended strategy for approaches using managed vertical guidance: ILS, GLS, SLS, MLS, FLS and FINAL APP.

In a decelerated approach, the aircraft is decelerating during its final approach segment to be stabilized at  $V_{APP}$  at 1000ft above the airport elevation. In most cases, it reaches the Final Descent Point (FDP) in CONF1 at S speed. However,

in some cases, when the deceleration capabilities are low (e.g. heavy aircraft, a high elevation airport or tailwind), or for particular approaches with a deceleration segment located at low height, the flight crew should select CONF 2 before the FDP. The FCOM recommends to select CONF 2 before the FDP when the interception of the final approach segment is below 2000ft AGL (A320) or 2500ft AGL (A330/A340, A350 and A380). In this case, for ILS, MLS or GLS approaches, or when using FLS guidance, it is good practice to select FLAPS 2 when one dot below the glideslope on the PFD deviation scale.



## Intermediate Approach

The Intermediate Approach phase starts at the deceleration point or earlier, if the flight crew activates manually the approach phase of the FMS.

The aircraft reduces speed from its last descent speed, generally 250kt, corresponding to the speed limit below FL100. The aircraft slows down to green dot speed and then slows further to the manoeuvring speed for the various Slats/Flaps configurations. It finally ends up at  $V_{APP}$  at or before the stabilization point (decelerated approach) or at or before the Final Descent Point (early stabilized approach) depending on the approach strategy.

Airbus recommends using A/THR in managed speed to reduce crew workload. If the flight crew needs to use selected speed, they should revert to managed speed when out of the ATC speed constraint because it will ease the deceleration handling.

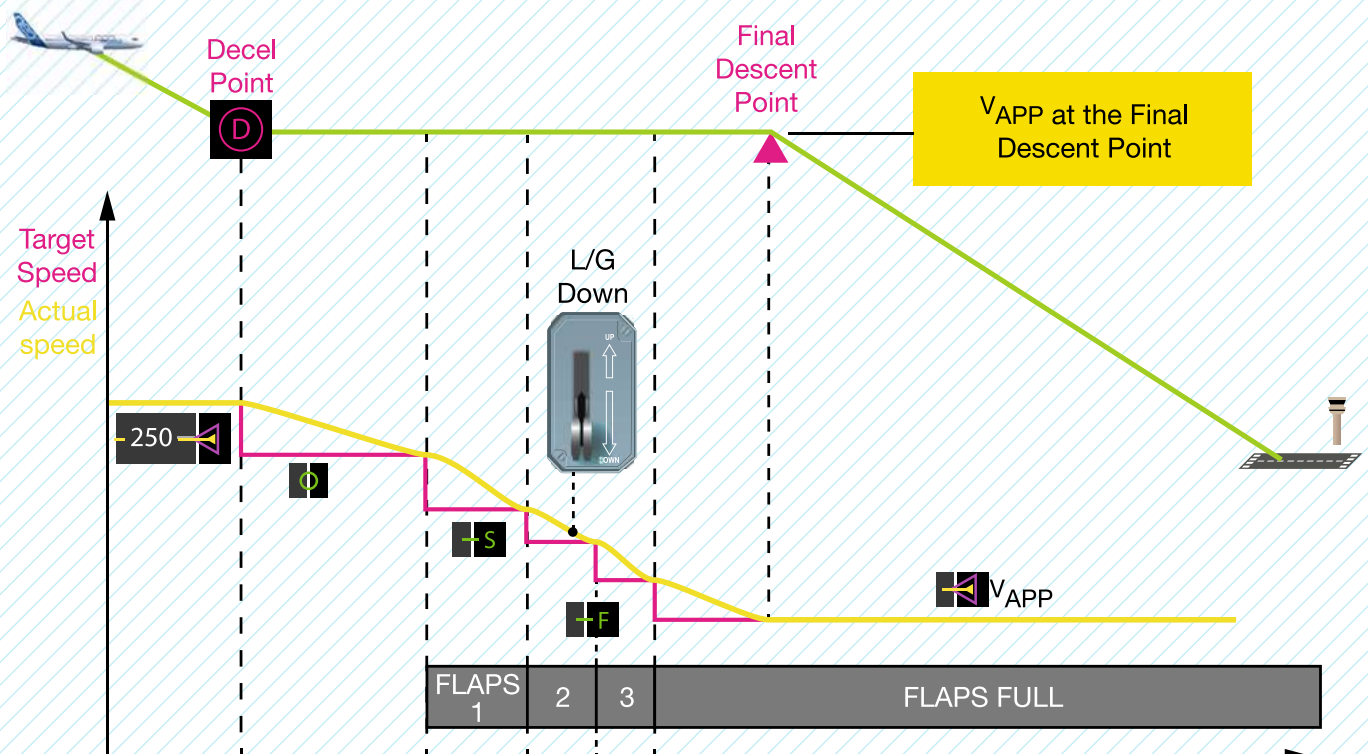
**(fig.19)**

Typical early stabilized approach

### EARLY STABILIZED APPROACH (WITHOUT CDA FUNCTION)

The early stabilized approach is the recommended technique for approach using selected FPA vertical guidance. When the interception height of the final descent segment is low (below 2000ft for A320 or 2500ft for A330, A340, A350 and A380), it may also be used as an alternative to the decelerated approach to reduce flight crew workload. Early stabilized approach

can also be used when the weather conditions make it too difficult to use the decelerated approach. During an early stabilized approach, the aircraft reaches the FDP at  $V_{APP}$  and in its landing configuration. To do so, the flight crew enters a speed constraint at the FDP in the FMS flight plan to enable the FMS to compute an associated deceleration point.





## PROCEDURES

Control your Speed... During Descent, Approach and Landing

The deceleration rate of the aircraft varies with its weight. A heavy aircraft will not decelerate as quickly as a lighter aircraft.

Whatever the Approach technique chosen by the flight crew (decelerated or early-stabilized approach), respecting stabilization criteria is key for a successful landing. Refer to the Flight Crew Operating Manual FCOM/PRO-NOR-SOP-18-A Stabilization Criteria.

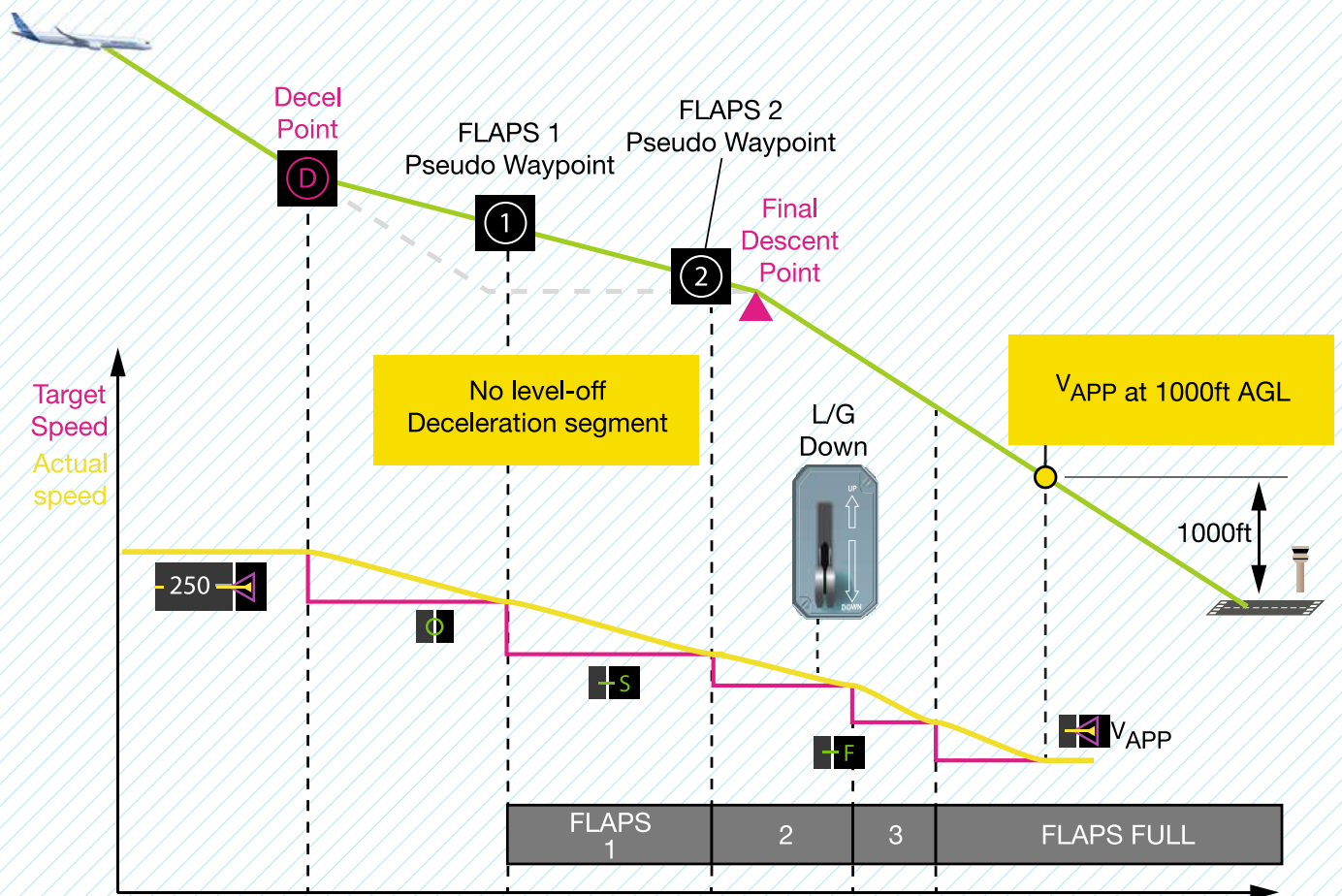
(fig.20)

Typical CDA approach

### CONTINUOUS DESCENT APPROACH (CDA) FUNCTION

The CDA function removes the deceleration level-off segment for fuel economy and noise reduction purposes. The function displays pseudo waypoints on the ND to indicate where to extend the flaps at the latest to reach the stabilization point ( $V_{APP}$  at 1000ft AGL for decelerated

approaches and  $V_{APP}$  at the FDP for early stabilized approach). CDA is basic on A350 aircraft and will be available as an option on A320 and A330 aircraft families on aircraft equipped with Release2 FMS standards from Honeywell.



### BEST PRACTICE

If needed and below  $V_{LO}/V_{LE}$ , early extension of the landing gear can help the aircraft to decelerate. The additional drag of the landing gear has a strong effect on the aircraft deceleration rate.

## Final approach and landing

### Speed Monitoring during approach and landing

When close to the ground, the wind can change, especially when in gusty conditions, and have a direct impact on the aircraft speed. As a consequence, monitoring of airspeed is crucial during final approach and landing to avoid:

- Runway undershoot, hard landing or tail strike if the aircraft speed becomes too low, or
- Runway overrun if the speed becomes too high.

If gusty conditions are expected at the destination airport, the flight crew can add an appropriate margin to the  $V_{APP}$  and manually enter the new  $V_{APP}$  in the FMS PERF APPR page.

Airbus recommends the use of autothrust during final approach to reduce crew workload and benefit from the Ground Speed Mini function (GS mini).

“ Monitoring of airspeed is crucial during final approach and landing. ”



## PROCEDURES

Control your Speed... During Descent, Approach and Landing

### WHAT IS THE GROUND SPEED MINI FUNCTION?

Significant headwind changes can be caused by the boundary layer effect when the aircraft is getting closer to the ground. Ground speed mini function ensures that the aircraft speed remains at least at  $V_{APP}$  if a stronger than expected headwind were to suddenly drop to the tower wind value or below. The GS mini function is only available when the flight crew uses the managed SPEED mode.

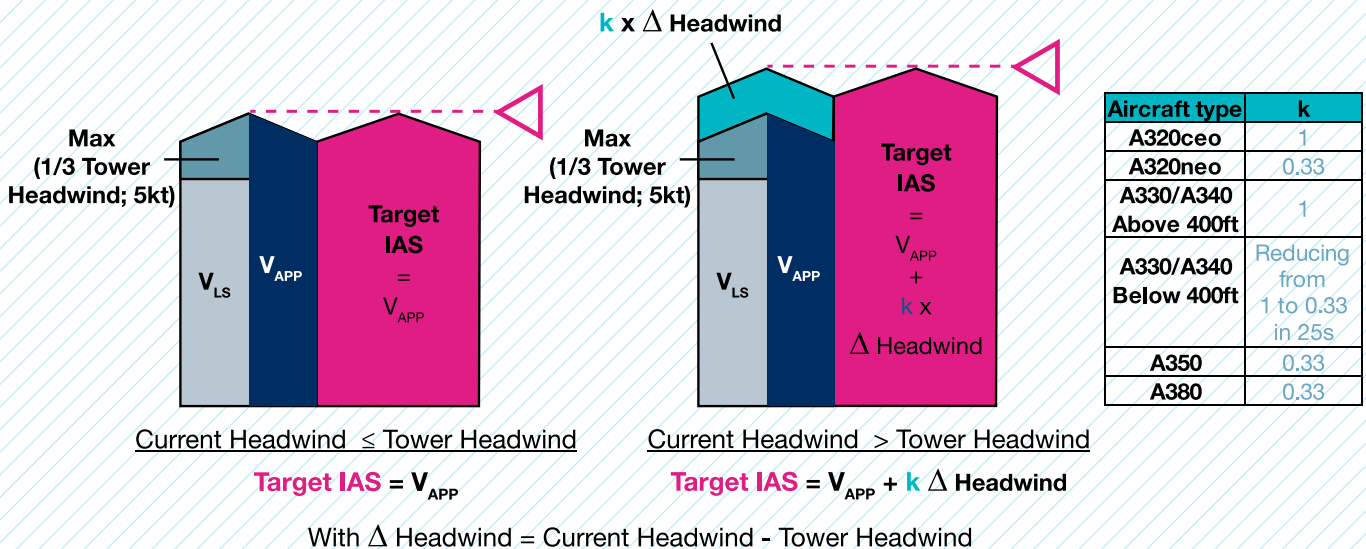
The AFS constantly computes and displays a target Indicated Airspeed (IAS) using:

- The approach speed ( $V_{APP}$  computed by the AFS or manually entered in the FMS),
- The tower headwind component from the tower wind value entered by the flight crew in the PERF APPR page of the FMS, and
- The current wind measured by the ADIRS.

As a consequence, the flight crew must ensure that the tower headwind value has been correctly entered in the FMS, even if it does not increase the  $V_{APP}$  (i.e. headwind < 15kts).

(fig.21)

Ground speed mini function



### Why is there a different 'k' factor for ground speed mini depending on the aircraft model?

The factor of 1 used on A320ceo aircraft could not be used for the other aircraft models due to differences of their deceleration capability. The A320ceo has a stronger deceleration capability when compared to A320neo, A330/A340 family aircraft, A350 and A380 aircraft.

In the case of a strong ground effect, a lower deceleration capability may lead to an excessive speed at flare. For example, a 20kt headwind at 200ft that reduces to 5kt on ground (corresponding to the 5kt tower headwind

inserted in FMS PERF APPR page), a factor of 1 requires a deceleration of 15kt to reach  $V_{APP}$ . With a k value of 0.33, the aircraft only needs to decelerate by 5kt to compensate its lower deceleration capability. It reduces the risk of excessive speed at flare. The drawback is that there is a slight increase in thrust variations in gusty conditions, since the speed increment will not be sufficient to counteract the IAS increase due to a gust. The best overall compromise was demonstrated to be a 0.33 factor.

## Manual Landing

In Normal or alternate law, the flight controls maintain the aircraft load factor demand (flight mode), if there is a wind change, the aircraft will maintain its path causing the speed to increase or decrease. This cannot be perceived by a pilot while looking outside, as the trajectory will not change (the aiming point will not move). Therefore, with autothrust disengaged, the flight crew must carefully monitor the speed as to detect any speed change. The role of the Pilot monitoring (PM) is key in this situation, especially when close to the ground.

### Stabilisation criteria

Flight crews must respect the stabilisation criteria provided in the FCOM Standard Operating Procedures (SOPs). These criteria ensure a safe approach and landing. The aircraft must be at approach speed with stabilized thrust at the stabilisation height (1000 ft AGL in IMC, 500 ft in VMC or according to airline's policy) If it is not the case, the PM should make a callout and a go around must be initiated if the flight crew assesses that the stabilisation can't be obtained prior landing. ■

“ Flight crews must respect the stabilisation criteria provided in the FCOM Standard Operating Procedures. ”



The aircraft can be in either an over energy or low-energy situation at landing if the crew does not manage the aircraft's speed correctly from top of decent, through approach and down to the flare. The consequences upon landing are increased risk of runway excursion, tail strike, hard landing or runway undershoot.

Whatever the level of automation chosen during descent, approach and landing, the flight crew should be aware of its capabilities, take full advantage of the tools available on airbus aircraft and apply the procedures and techniques provided in the FCOM/QRH and FCTM.

## NOTES

[illegible]



[illegible]

# 24<sup>th</sup> Flight Safety Conference

19-22 March 2018

Vienna, Republic of Austria

