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.

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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.

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.

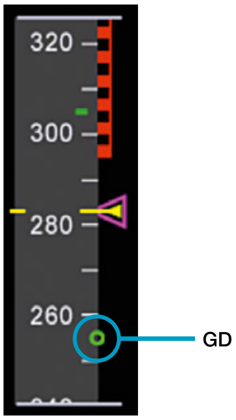
For this reason, a recap of GD definition is provided hereafter, as well as the consequences of flying slower than GD in cruise.

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)**.



(fig.1)
GD on the PFD speed scale

» 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:

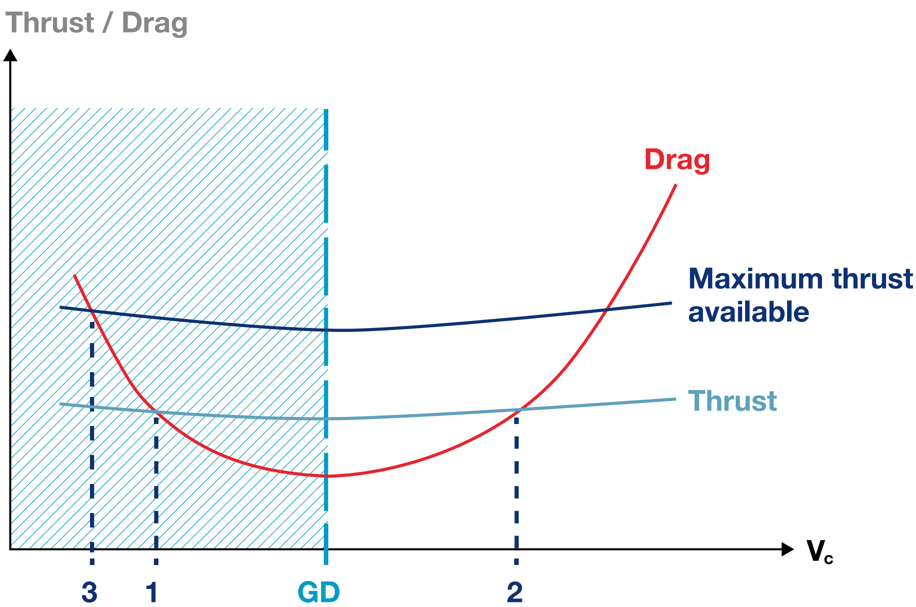
- Above GD, the drag and thrust required to maintain speed increase with the speed
- Below GD, the drag and thrust required to maintain speed increase with speed decrease (second regime) **(fig.2)**.

(fig.2)
Thrust curves and speed polar

Region of reversed command (second regime)

Given:

- altitude
- temperature
- weight
- thrust



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 scenarii 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.

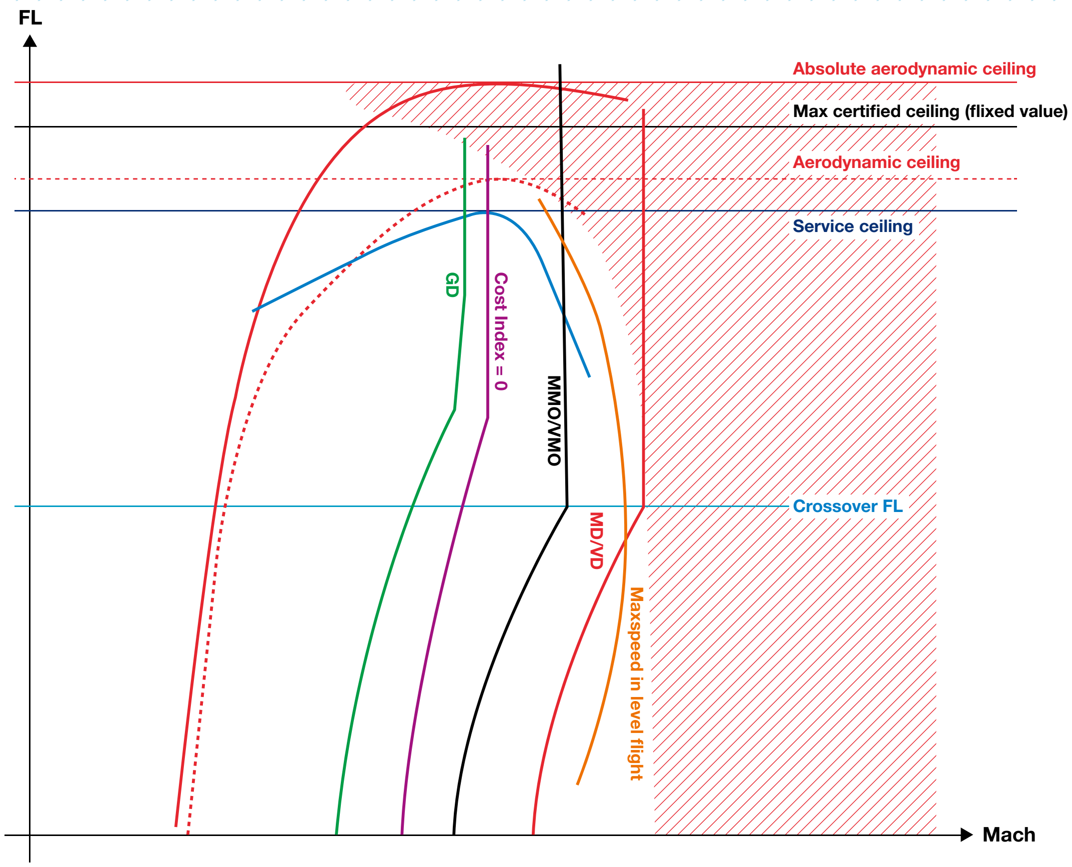
HOW IS THE REC MAX (RECOMMENDED MAXIMUM ALTITUDE) COMPUTED?

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]

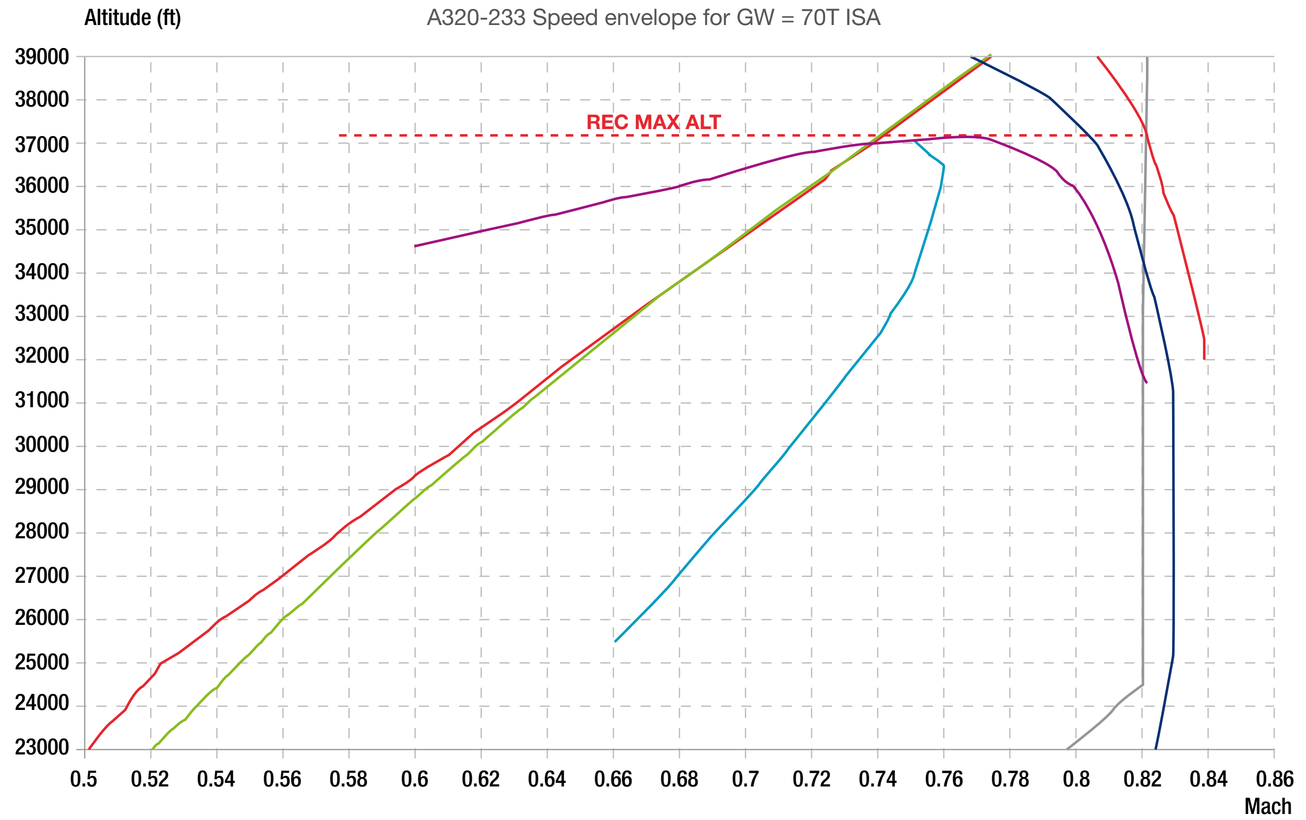
The schematic below applies to a heavy aircraft, which has a ceiling lower than the maximum certified one.



- 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 x V_{S1g}.
  At higher Mach, it corresponds to buffet onset of 1.3g (corresponding to 40° 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 + 300ft/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.

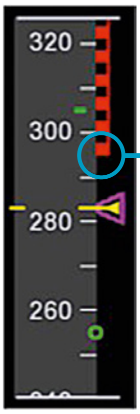


- Green Dot
- Buffet (1,3g)
- Vz 300 ft/min
- V_{MO}/M_{MO}
- V_{MAX} level at Max CLB
- Econ speed CI = 0

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

(fig.3)
V_{LS} on the PFD speed scale

> GD and V_{LS} both depend on the aircraft weight, therefore these speeds will be wrong if the ZFW entered in the FMS is wrong.



(fig.4)
V_{MO} on the PFD speed scale

Limit speeds

For a given weight, each aircraft has a minimum selectable speed (V_{LS}) and maximum speed (V_{MAX}) 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_{LS}: Lowest Selectable speed

» Definition

V_{LS} is the lowest selectable speed with A/THR engaged. Even if the target speed is below V_{LS}, the A/THR will continue to target V_{LS}.

V_{LS} is indicated by the top of the amber line on the PFD speed scale **(fig.3)**.

» How is V_{LS} determined?

V_{LS} 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).

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

Where:

V_{S1g} 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_{LS} is higher when the speed brakes are extended, since speed brakes extension increases V_{S1g}.

» What are the operational implications of not respecting V_{LS}?

Deliberately flying below V_{LS} 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_{LS} IN A NUTSHELL.

V_{LS} is the slowest speed the AFS lets you fly in normal law.

V_{MO}/M_{MO}: Maximum Operating speed/Mach number

» Definition

In cruise, in clean configuration, V_{MO}/M_{MO} 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

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 20th 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.

> "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."

» 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 hasardous 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 overshot 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.

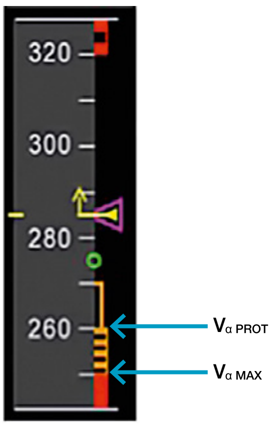
Flight envelope protection speeds: $V_{\alpha\ PROT}$ and $V_{\alpha\ MAX}$

» Definition

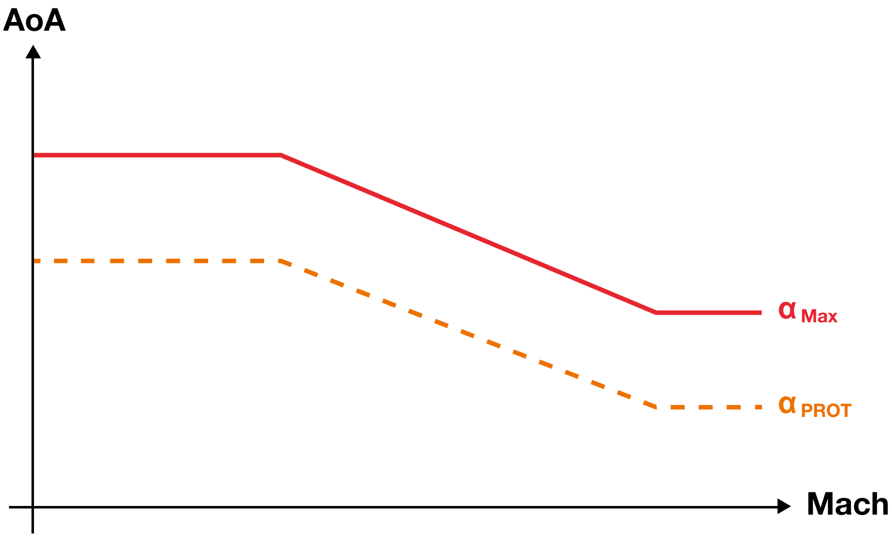
$V_{\alpha\ PROT}$ is the speed corresponding to the maximum Angle-Of-Attack (AOA) at which Alpha Protection becomes active. **It is only displayed in normal law** and corresponds to the top of the black and amber strip along the PFD speed scale **(fig.5).**
In practice, the AOA value of the Alpha Protection decreases as the Mach number increases. When the AOA value of the Alpha Protection decreases, the Alpha Protection strip on the PFD moves upward.

$V_{\alpha\ MAX}$ 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).**

α_{MAX} is a function of the Mach number: it decreases when the Mach increases **(fig.6).**



(fig.5)
$V_{\alpha\ PROT}$ and $V_{\alpha\ MAX}$ on the PFD speed scale



(fig.6)

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

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

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

$V_{\alpha\ PROT}$ (resp. $V_{\alpha\ MAX}$) 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 α_{PROT} (resp. α_{MAX}). In fact, both speeds are calculated on the basis of the aircraft longitudinal equilibrium equation, along with the actual aircraft speed and AOA.

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

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

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

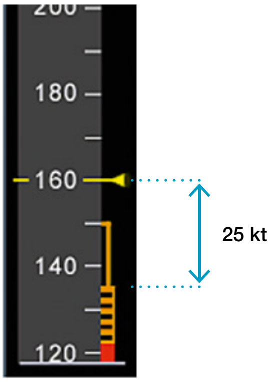
Where:

α_0 is the AOA for a Lift Coefficient (C_L) equal to 0.
V_C is the calibrated airspeed (CAS)
α is current AOA

On the A320 Family, $V_{\alpha\ PROT}$ and $V_{\alpha\ MAX}$ 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, $V_{\alpha\ PROT}$ and $V_{\alpha\ MAX}$ have the same numerical values on both PFDs.

Data source	A320 Family	A330/A340, A350 and A380 Families
V_C	**Left PFD:** FAC 1, or FAC 2 if not available in FAC 1. **Right PFD:** 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.	



(fig.7)
PFD display of the available speed margin against α PROT and α MAX

In order to avoid a fluctuating $V_{\alpha\ PROT}$ and $V_{\alpha\ MAX}$ display, AOA and V_C values are filtered so that fast AOA variations (for example during turbulence) do not pollute the PFD speed scale. As a result of this filtering, a little delay can be observed; therefore during a dynamic maneuver, the aircraft may enter into a protection law with the IAS not yet below the displayed $V_{\alpha\ PROT}$.

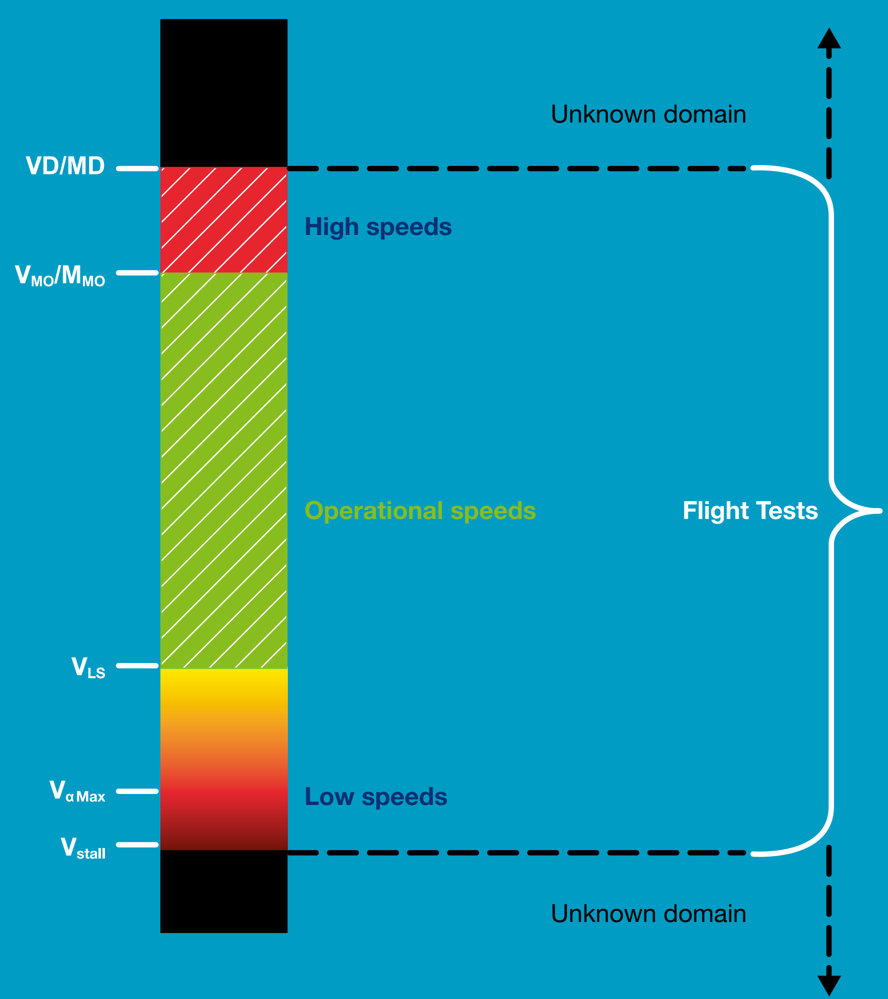
» What are the operational implications of flying below $V_{\alpha\ PROT}$?

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

In normal law, on a protected aircraft, exceeding the AOA value of the α_{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 α_{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.”

Cruise speeds in a nutshell



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 M_{MO} 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.

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

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.

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.

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

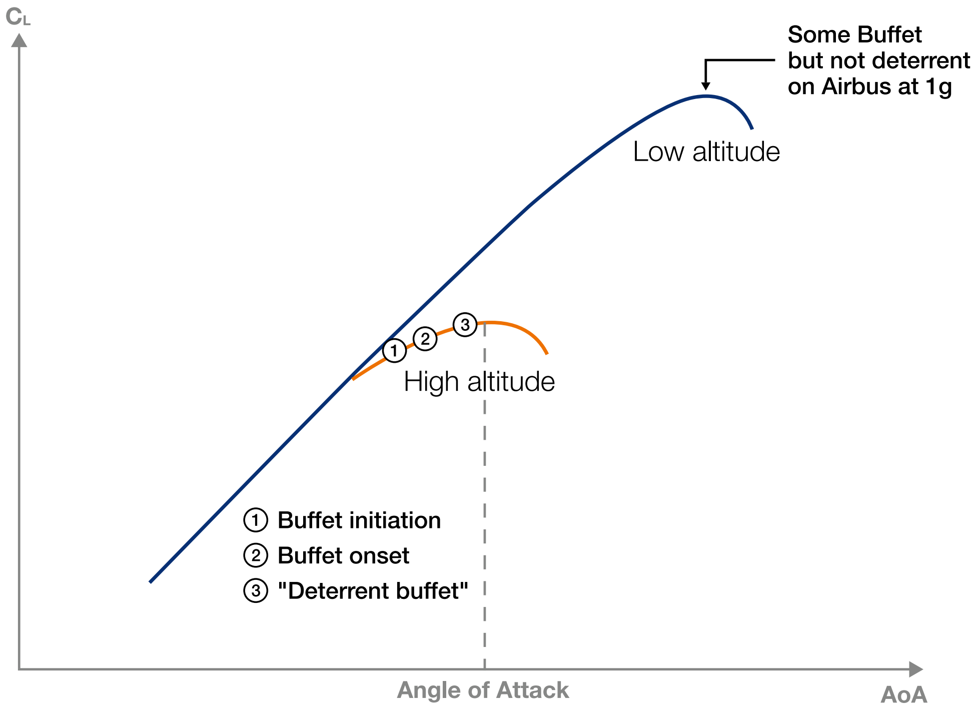
Preventing a speed decay: detecting the phenomenon

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. "

NOTE

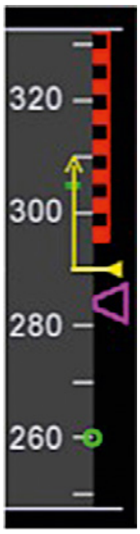
A video illustrating buffet is presented in the tablet application of Safety first for this issue.

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.

Safety first

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