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PRESENTATION

Falcon airplanes fitted with EASy feature primary means of information that have never been used so far in corporate aviation. Based on basic flight mechanics principles, all these primary means work toward providing the pilot with direct, immediate, intuitive assessment and control of the airplane trajectory.

Targeting pilots with a large variety of experiences, Dassault Aviation has created Technical Information Pages for educational purpose. Reviewing them allows for pilots to remember basics of flight mechanics before any initial type rating training and checking.

In order to emphasize the acquisition of key principles rather than in-depth theory, all schematics, drawings, symbols or equations have been voluntarily simplified. As a result, although they may depict an approximate theoretical situation, they provide pilots with an easy-to-review and an easy-to-remember tool.

The Technical Information Pages (TIP) section has been organized to support a progressive learning process. Consequently, Dassault Aviation recommends reviewing them in the following sequence:

REVIEW SEQUENCE	AIRPLANE TRAJECTORY
1	03-05-00 - Flight Path Symbol – General
2	03-05-05 - Flight Path Symbol – Detailed
3	03-05-10 - Acceleration Chevron
4	03-05-15 - Rotation Symbol

Most given examples correspond to normal situations where pilot inputs cause a progressive and smooth change in flight characteristics, except where otherwise mentioned. Consequently, any deviations to this assumption may result in different interpretation or visualization. Detailed information is provided in CODDE1 / Chapter 02.

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PREREQUISITES

Technical Information Page to be reviewed prior to this one:

- 03-00-05 – GENERAL.

GENERAL PRINCIPLES

In the vertical plan, 3 angles can have a direct or indirect influence on the flight path of an airplane. These angles characterize the Flight Path Vector, which is the instantaneous actual airplane trajectory:

- The pitch angle (θ), angle between the horizon reference and the fuselage reference
- The path angle (γ) (also called slope), angle between the horizon reference and the airplane flight path vector
- The angle of attack (α), angle between the airplane flight path vector and the fuselage reference

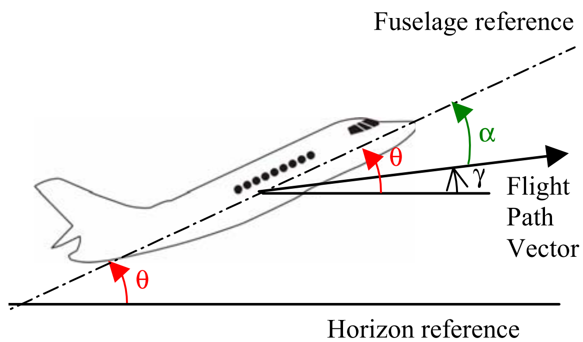


FIGURE 03-05-00-00

Piloting an airplane consists of controlling its trajectory, in particular in the vertical plane. Usually, the pilot will set a reference pitch attitude and then adjust it by acting on the yoke and / or the engine power, in order to:

- have the airplane level off (see FIGURE 03-05-00-01),
- have the airplane descend (see FIGURE 03-05-00-02),
- have the airplane climb (see FIGURE 03-05-00-03).

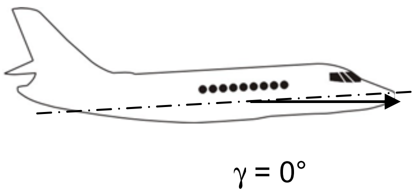


FIGURE 03-05-00-01
AIRPLANE LEVELLING OFF

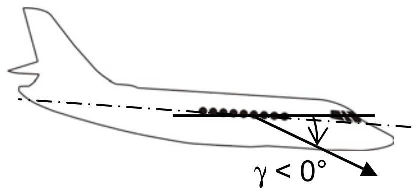


FIGURE 03-05-00-02
AIRPLANE DESCENDING

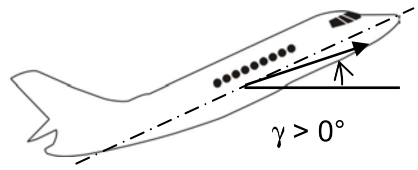


FIGURE 03-05-00-03
AIRPLANE CLIMBING

Flying the pitch angle does not offer the most intuitive mean to control the airplane trajectory, as pitch and flight path angles can be opposite in some flight conditions. For instance, the pitch angle can be positive or equal to zero while the airplane is descending, or worse, stalling.

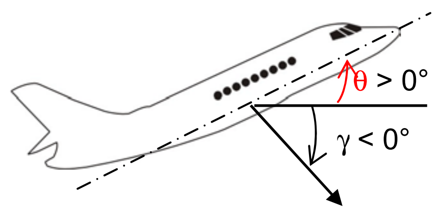


FIGURE 03-05-00-04

To understand the airplane actual flight path or to maintain a defined slope (ex: descent at a constant – 3° slope), the pilot has to interpret the pitch symbol position on the Attitude Display Indicator (ADI) in relation to other information (airspeed, vertical speed, altitude, ...).

In order to help pilots control accurately or be aware of the airplane trajectory actually flown, Dassault Aviation has decided to provide crews flying EASy Falcons with a direct and intuitive primary mean of control and awareness: the Flight Path Symbol (FPS), displayed on the ADI and the SFD (Secondary Flight Display).

OPERATIONAL BENEFITS

The position of the FPS  with respect to the horizon reference line gives an instant indication of the actual airplane vertical trajectory, as follows:

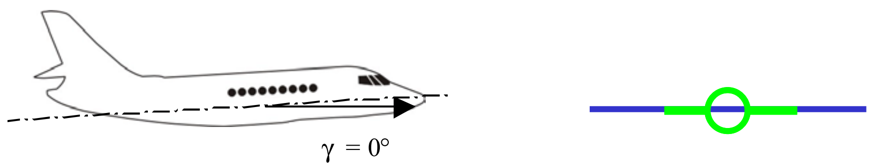


FIGURE 03-05-00-05
AIRPLANE LEVELLING OFF

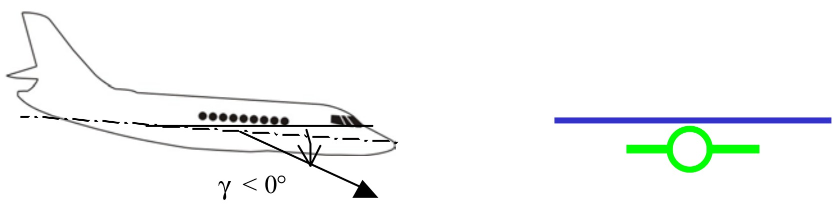


FIGURE 03-05-00-06
AIRPLANE DESCENDING

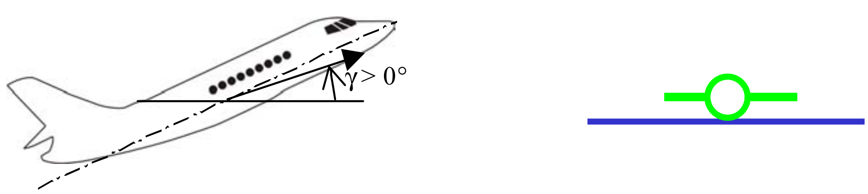
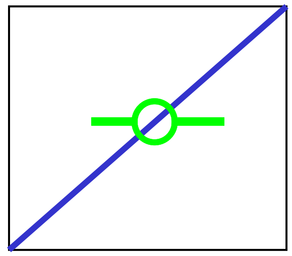


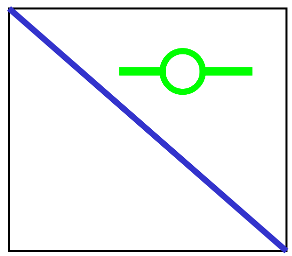
FIGURE 03-05-00-07
AIRPLANE CLIMBING

In addition to the FPS position, the position of the little “wings” on both sides of the FPS circle with respect to the horizon reference line gives also instant indication of the actual airplane horizontal trajectory and roll attitude, as follows:

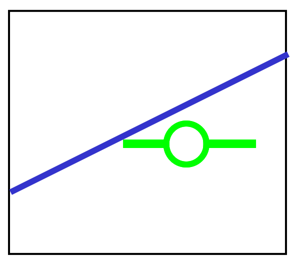
The airplane is performing a right turn at a 45° bank angle and is level.



The airplane is performing a left turn at 45° bank angle and is climbing.



The airplane is performing a right turn and is descending



CONCLUSION

Using the FPS results in reduced pilot workload and awareness of actual trajectory since the pilot has now the capability of:

- instantly visualizing and controlling the actual airplane trajectory,
- managing the airplane flight path in a better and easier way, regardless of aircraft configuration, airspeed variations, wind velocity and direction, turbulence, …

PREREQUISITES

Technical Information Pages to be reviewed prior to this one:

- 03-00-05 – GENERAL,
- 03-05-00 – FLIGHT PATH SYMBOL – GENERAL.

DESCRIPTION

GENERAL PRINCIPLES

The Flight Path Vector (FPV) can be described with respect to two different reference systems:

- the ground reference system,
- the air mass reference system associated to the air mass in which the airplane is flying.

As shown on the figure 03-05-05-00 thereafter, the difference between ground and air mass reference systems is wind dependent. For given flight conditions (speed, thrust setting) and when observed from the ground, both FPV direction and magnitude (FPV_G) will be affected by variations of wind force and direction. Whereas, in the same flight conditions and when observed from the air mass, FPV direction and magnitude (FPV_A) will not be affected by wind variations.

Currently, pilots use pitch attitude as the primary parameter to control flight path.

On EASy Falcons, the combination of modern technology equipment such as the IRS (Inertial Reference System) and computers offers both measurement capability and computing power to calculate FPV_G and $FPV_{A.}$ The two flight path vectors are presented to the pilot, in addition to the Pitch Symbol:

- the FPS displayed in the ADI (Attitude Director Indicator) shows the FPV direction observed from the ground (FPV_G) and provides the flight path angle relative to the ground (γ_G)
- whereas the FPS displayed in the SFD (Secondary Flight Display) shows the FPV direction observed from the air mass (FPV_A) and provides the flight path angle relative to the air mass (γ_A).

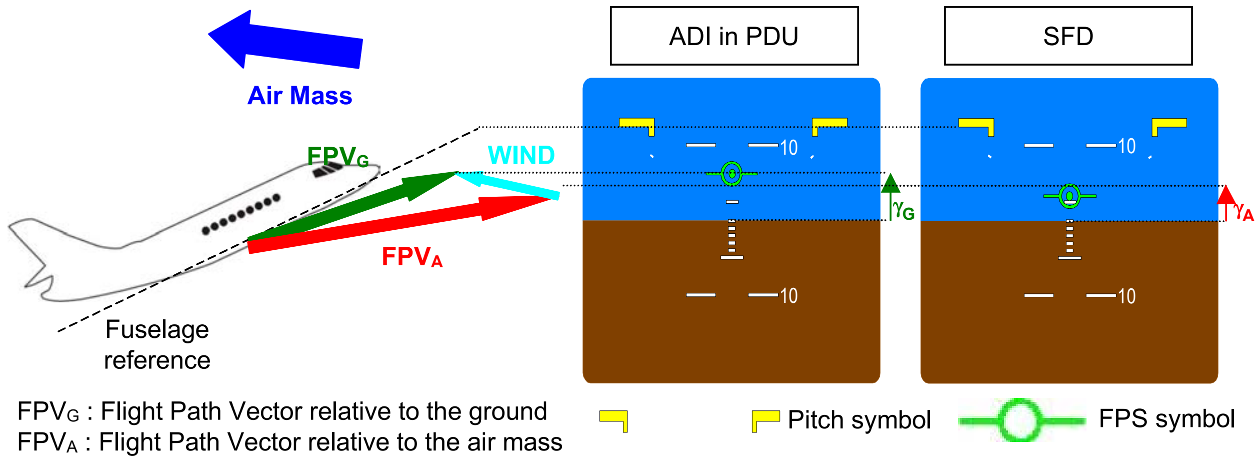


figure 03-05-05-00 flight path angle values

Consequently, one pitch angle setting may correspond to two different flight path angles displayed in the ADI and the SFD, depending on wind force and direction.

OPERATIONAL BENEFITS

Example No 1 hereafter (figure 03-05-05-01) gives 2 graphical representations of trajectories flown at a constant True Air Speed (TAS) in identical wind conditions, but obtained by setting and keeping constant 2 different primary attitude flight parameters.

- On trajectory 1 , the pilot has set the Flight Path Symbol in the ADI for a constant descent at – 3°. The result is:
  - on the trajectory, a constant straight slope relative to the ground unaffected by significant wind variations; reaching the expected trajectory end on the ground is ensured whatever wind variation in force or direction during descent,
  - necessary pilot actions on the yoke dictated by wind effect in order to maintain the FPS set at -3°; in this example, it results in significant pitch attitude variations all along the flight path.
- On trajectory 2, the pilot has set the Pitch Symbol in the ADI at +1° and maintained it constant during the descent. The result is:
  - on the trajectory, variation of the slope relative to the ground as wind varies during descent; if no pitch correction is applied, reaching the expected trajectory end on the ground will depend on the magnitude of wind variation in force or direction along the flight path,
  - with no pilot action, a constant position and magnitude of the FPV relative to the air (FPV_A) during descent, and affection of the FPV position relative to the ground (FPV_G) directly caused by wind variations.

NOTE

Along both trajectories 1 and 2, the FPV_A magnitude has remained constant, meaning that the True Air Speed (TAS) has also remained constant. Wind changes along the flight path result in Ground Speed (GS) variations shown by FPV_G magnitude variations in the figure shown.

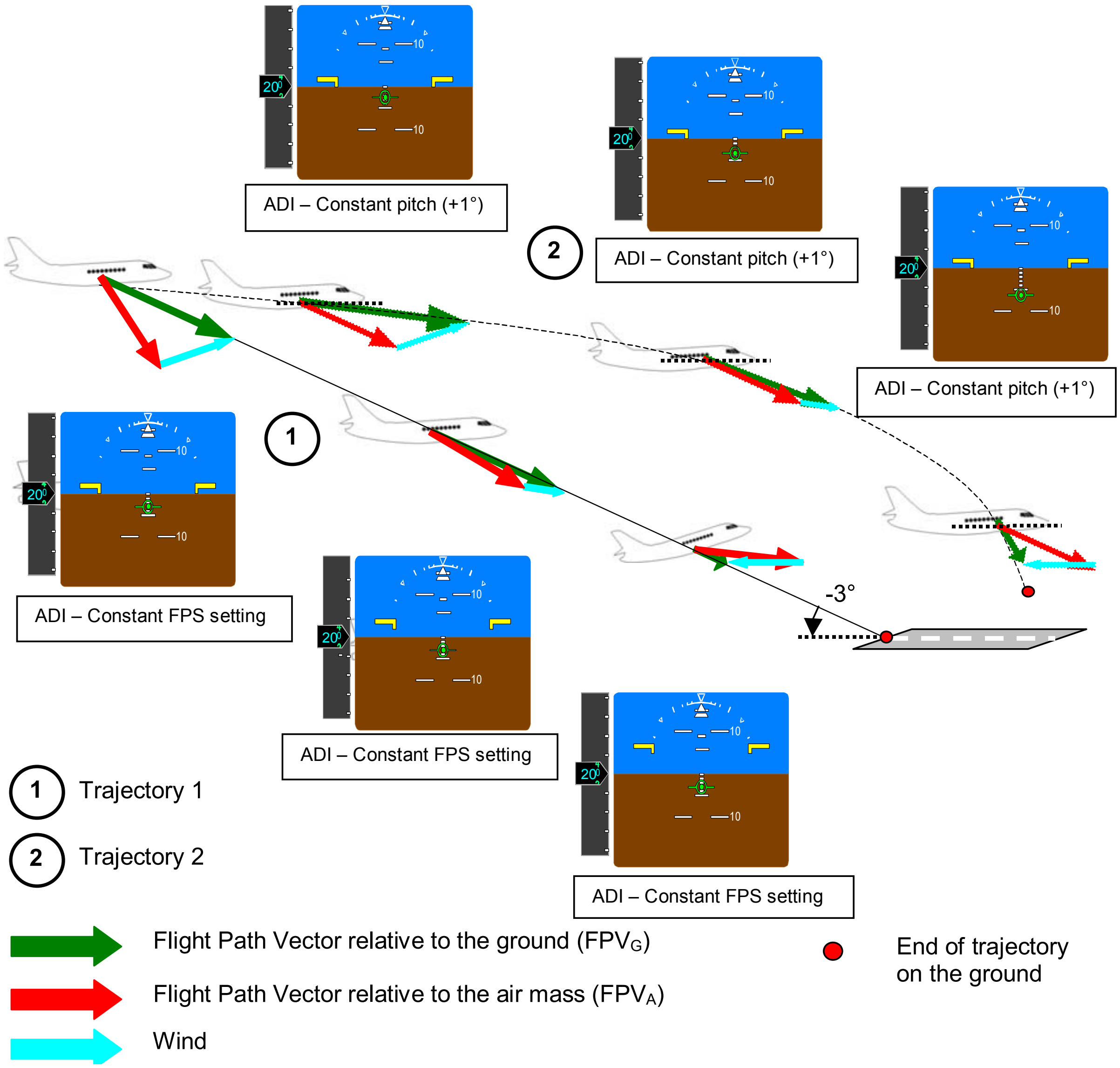


FIGURE 03-05-05-01 EXAMPLE No 1

Example No 2 (see figure 03-05-05-02) shows an another situation where flying a constant flight path angle relative to the ground contributes directly and obviously to safety enhancement.

(Constant FPS setting on the ADI along trajectory 1 instead of constant pitch angle setting along trajectory 2):

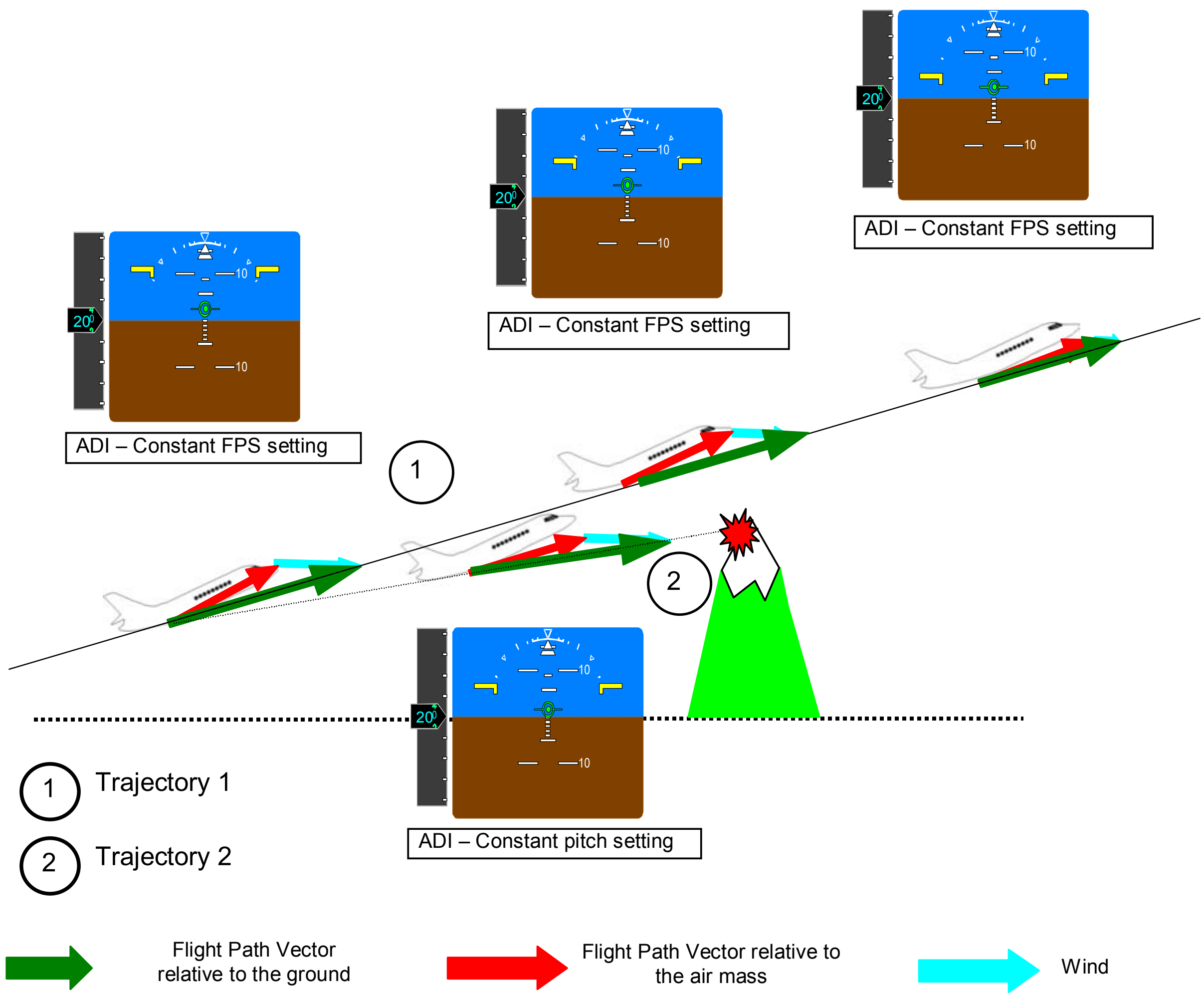


FIGURE 03-05-05-02 EXAMPLE No 2

CONCLUSION

The benefit for pilots of knowing the aircraft flight path angle through the FPS position in the ADI and using it as the primary mean of flight path control is really outstanding. The FPS is the unique tool to control the airplane trajectory with respect to the ground, which is a safety requirement particularly during descent, approach and obstacle clearance.

PREREQUISITES

Technical Information Pages to be reviewed prior to this one:

- 03-00-05 – GENERAL,
- 03-05-00 – FLIGHT PATH SYMBOL – GENERAL.

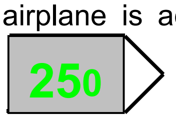
DESCRIPTION

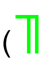
WHAT IS THE ACCELERATION CHEVRON (AC) ?

The Acceleration Chevron (AC) is the green V-marker symbol  displayed in the ADI (Attitude Director Indicator). When used in relation with the Flight Path Symbol (FPS), it gives an immediate and intuitive indication about the airplane ability to stabilize and maintain speed, accelerate or decelerate.

When used in relation with the FPS scale in the ADI, and for smooth maneuvers, it gives an immediate and intuitive indication about the maximum flight path angle that can be instantaneously flown at steady speed, which is a valuable information for a pilot in an engine failure situation for instance.

WHAT IS THE TREND VECTOR (TV) ?

The Trend Vector (TV) is a green double-line bar which is displayed above (when the airplane is accelerating) or below (when the airplane is decelerating) the speed pointer 

in the ADI. On Falcon fitted with EASy, this green double-line bar can be topped by a horizontal line when the acceleration is above the scale limit ().

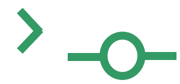
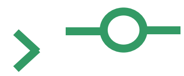
WHAT IS THE THRUST DIRECTOR (TD) ?

The Thrust Director (TD) is the magenta open box  displayed in the ADI. It represents the box inside which the AC must be to fly the pre-selected target speed displayed in magenta on the speed scale and on the Flight Guidance Panel (FGP).

GENERAL PRINCIPLES

Acceleration Chevron and Trend Vector

The relative position of the AC with respect to the FPS provides the pilot with an immediate, direct and intuitive mean to assess and precisely control the acceleration along any given flight path, whatever the instantaneous airplane trajectory (straight level flight, descent, climb):

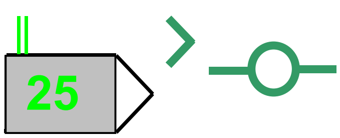
- when the AC is above the FPS, the airplane is accelerating 
- when the AC is below the FPS, the airplane is decelerating 
- when the AC is aligned with the FPS, the airplane is maintaining speed. 

The pilot will control the AC position and consequently the speed, they are controlled by the pilot through the power levers that command thrust. The AC position can also vary upon landing gear, airbrakes or slats / flaps activation, due to the consequent variation in drag.

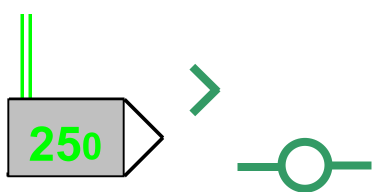
The airplane acceleration or deceleration along the flight path can be cross-checked through the TV position with respect to the speed pointer.

Additionally, the length of the TV, as well as the distance between the AC and the FPS, are proportional to the acceleration (when AC is above FPS) or deceleration (when AC is below FPS):

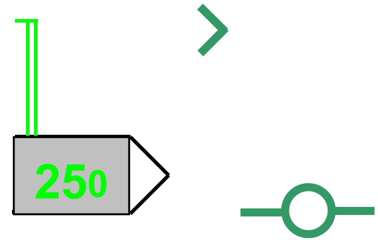
Low acceleration



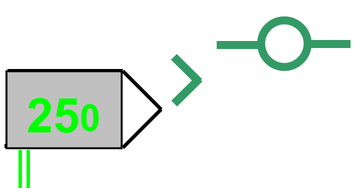
Medium acceleration without exceeding scale limit



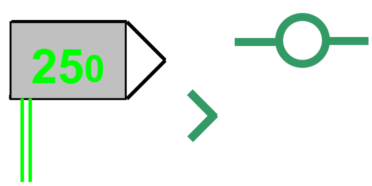
High acceleration exceeding scale limit



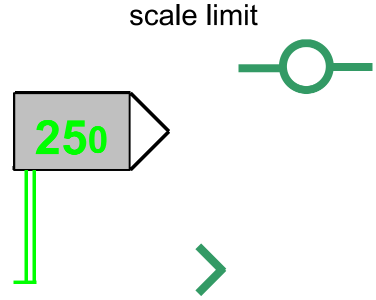
Low deceleration



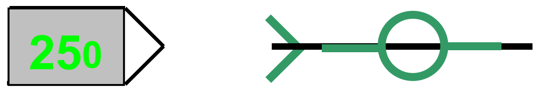
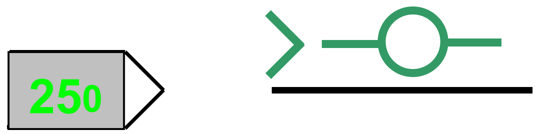
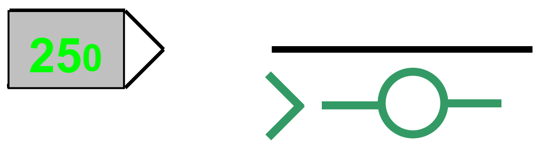
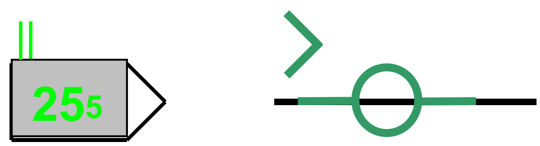
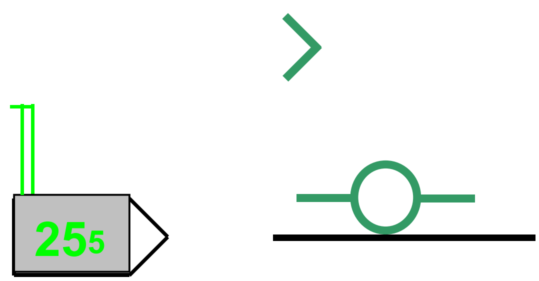
Medium deceleration without exceeding scale limit

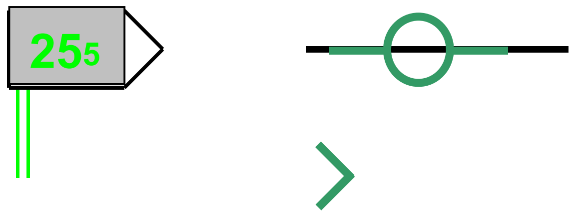
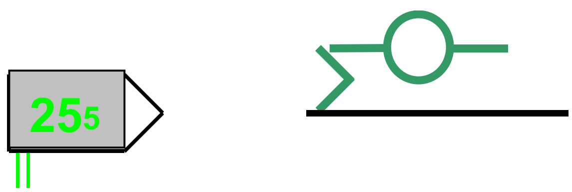
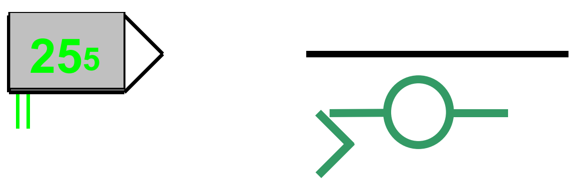


High deceleration exceeding scale limit



As a result, three main situations may occur:

SITUATIONS	VISUALIZATION	COMMENTS
Maintaining the current speed	Airplane straight level flying and maintaining speed  Airplane climbing and maintaining speed  Airplane descending and maintaining speed 	The AC is aligned with the FPS: speed is steady and no TV is displayed
Acceleration	Airplane straight level flying and accelerating  Airplane climbing and accelerating  Airplane descending and accelerating 	The AC is above the FPS: speed is increasing and TV is displayed above the speed pointer In addition, the more distant the AC and the FPS are, the longer the TV is, the higher the acceleration is, the faster the speed is increasing

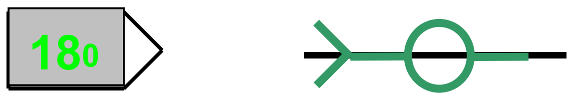
SITUATIONS	VISUALIZATION	COMMENTS
Deceleration	Airplane straight level flying and decelerating  Airplane climbing and decelerating  Airplane descending and decelerating 	The AC is below the FPS: speed is decreasing and TV is displayed below the speed pointer In addition, the more distant the AC and the FPS are, the longer the TV is, the higher the deceleration is, the quicker the speed is decreasing

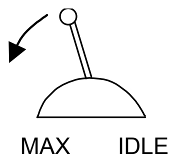
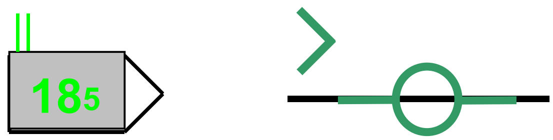
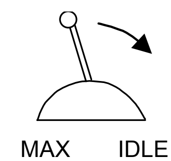
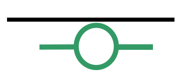
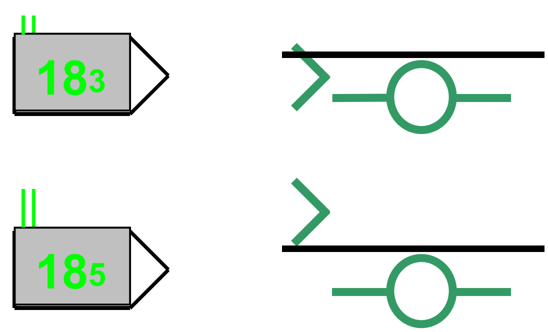
HOW TO USE THE ACCELERATION CHEVRON (AC)

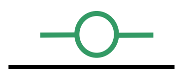
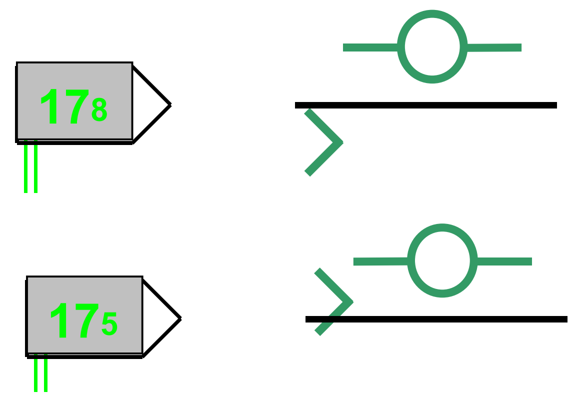
Acceleration Chevron uses without Thrust Director

The following gives examples of how to use the AC, the FPS and the TV without using the TD.

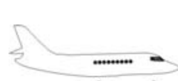
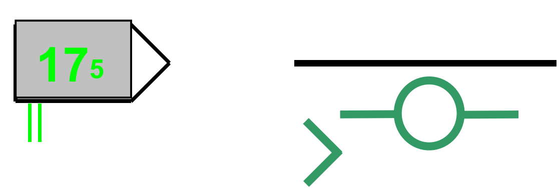
- **Initial Situation: airplane in level flight steady at 180 kt:**



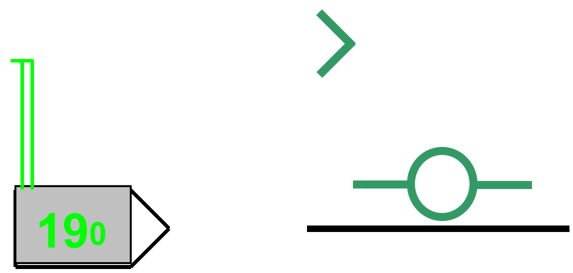
EVENT	NEW SITUATION
Power is slightly increased and flight path kept level 	 Speed is slowly increasing, as confirmed by the TV position and AC position above the FPS
Power is slightly decreased and flight path is kept level 	 Speed is slowly decreasing, as confirmed by the TV position and AC position below the FPS
Flight path is set to descent and power kept unchanged 	**Two examples of resulting situations:**  Speed is slowly increasing, as confirmed by the TV position and AC position above the FPS. Depending on how low or high the flight path value set by the pilot is, the AC can be more or less close to the FPS, indicating the airplane is more or less accelerating

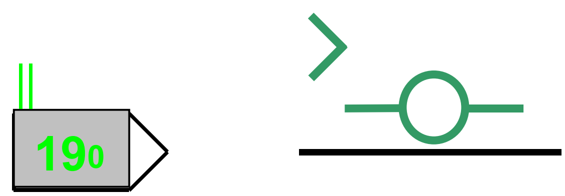
EVENT	NEW SITUATION
Flight path is set to climb and power kept unchanged 	**Two examples of resulting situations:**  Speed is slowly decreasing, as confirmed by the TV position and AC position below the FPS. Depending on how low or high the flight path value set by the pilot is, the AC can be more or less close to the FPS, indicating the airplane is more or less decelerating

- **Initial Situation: airplane in descent on a – 3° flight path steady at 180 kt**

EVENT	NEW SITUATION
Change in configuration: (example: landing gear and slats / flaps are extended) 	 Speed is slowly decreasing, as confirmed by the TV position and AC position below the FPS. Therefore, increase power to maintain airspeed on the same flight path.

- **Initial Situation: airplane in climb at 190 kt, accelerating, with a high acceleration rate**

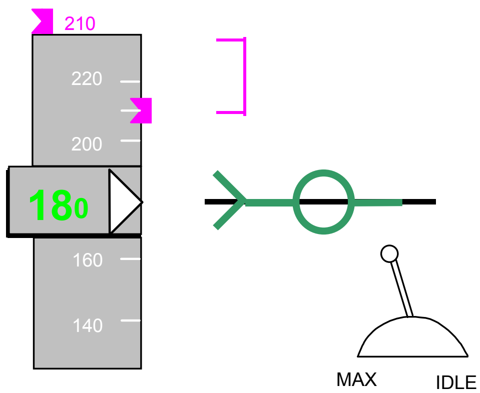


EVENT	NEW SITUATION
One engine fails and positions of the remaining engines power levers are unchanged	 The engine failure results in a lower AC position. In this particular case, the airplane is still accelerating but at a lower rate. The new AC position indicates the maximum instantaneous flight path angle that can be flown at a constant speed for smooth maneuvers

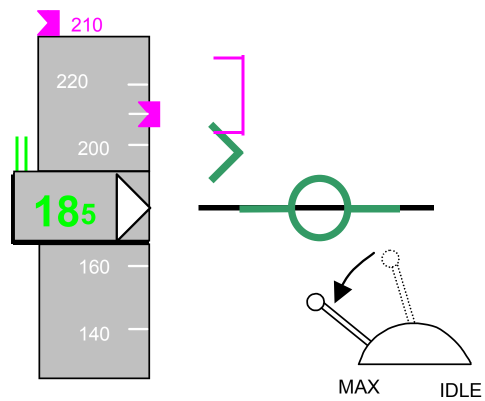
Acceleration Chevron uses with Thrust Director

TD tells the pilot where the AC must be positioned in the ADI to capture and hold a pre-selected target speed. Consequently, two main situations may occur:

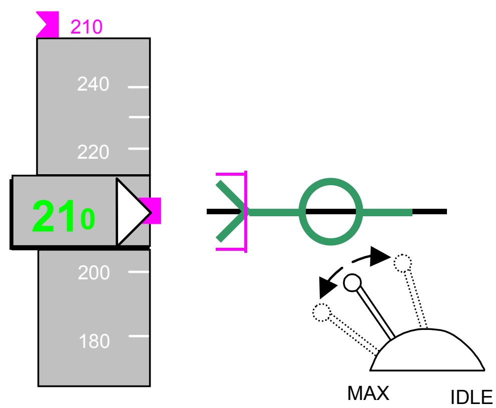
- Example No 1: a 210 kt target speed is commanded which triggers and positions the TD, while, initially, the airplane is in straight level flight and the thrust is adjusted to maintain a 180 kt steady speed.



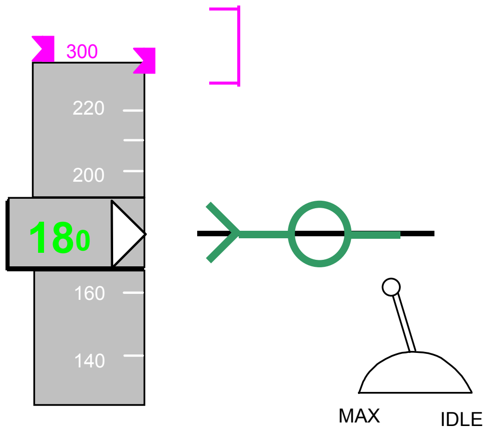
TRANSITION
The pilot increases the thrust to accelerate and bring the AC into the TD, without changing the flight path. While thrust is increased, the airplane accelerates, and speed increases. AC and TD close up toward each other



NEW SITUATION AND COMMENTS
In this example, there was enough available thrust to achieve the required increase in speed. The pilot has reached the target speed (AC inside TD) by using thrust only, and he can now adjust throttles to hold a 210 kt steady speed (no TV) without changing the flight path

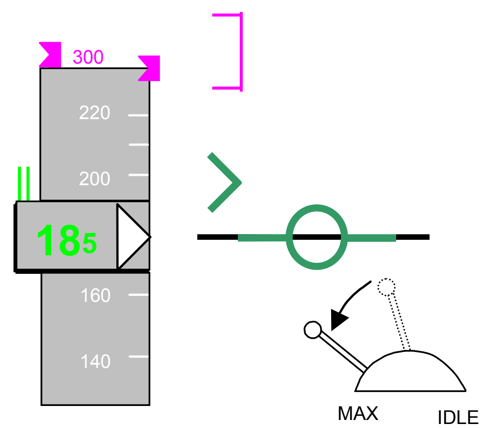


- A 300 kt target speed is commanded which triggers the TD at the appropriate location while, initially, the airplane is in straight level flight and the thrust is adjusted to maintain a 180 kt steady speed.



TRANSITION STEP 1

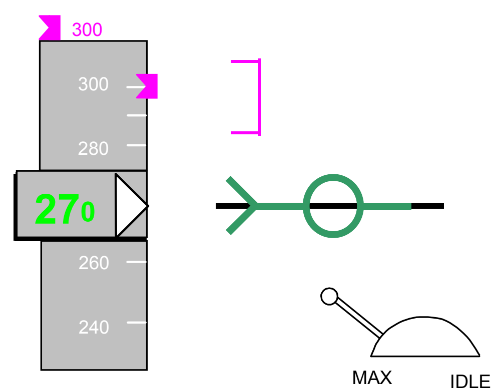
The pilot has commanded full authorized thrust to accelerate and bring the AC into the TD, without changing the flight path. While thrust is increased, the airplane accelerates, and speed increases.



TRANSITION STEP 2

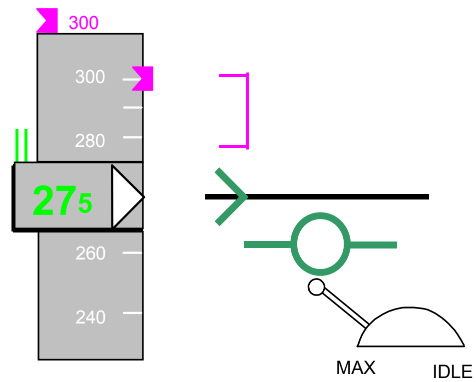
In this example, full available thrust is not enough to increase speed up to the pre-selected value.

Consequently, speed stabilizes below 300 kt although full available thrust has been set, in level flight.



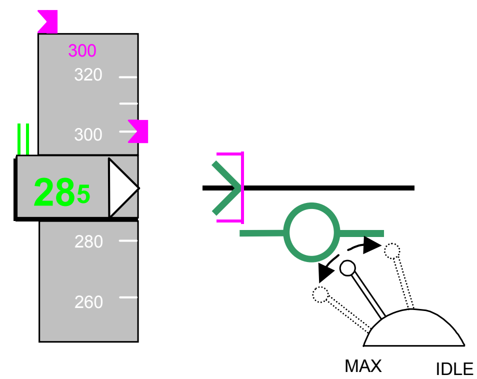
TRANSITION STEP 3

Therefore, to reach 300 kt, the pilot has to set a descent flight path that makes the airplane accelerate



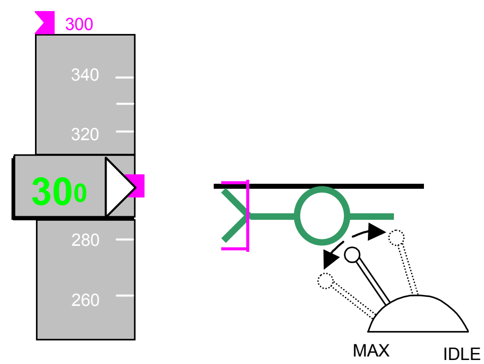
TRANSITION STEP 4

The AC meets the TD and the pilot can now adjust the throttles to keep the AC inside the TD



NEW SITUATION AND COMMENTS

Once speed has reached 300 kt, the AC, TD and FPS are aligned. To maintain 300 kt, the pilot will have to regulate the thrust setting while maintaining the flight path angle constant



CONCLUSION

The Acceleration Chevron (AC) is the complementary primary mean to assess the airplane energy along with the Flight Path Symbol (FPS) for flying EASy Falcon. When the AC and the FPS are used together with the Thrust Director (TD), they provide the pilot with a direct, intuitive and immediate mean to capture, track or control simultaneously the airspeed or the airspeed variation along the airplane flight path.

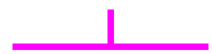
PREREQUISITES

Technical Information Pages to be reviewed prior to this one:

- 03-00-05 – GENERAL,
- 03-05-00 – FLIGHT PATH SYMBOL – GENERAL,
- 03-05-05 – FLIGHT PATH SYMBOL – DETAILED.

DESCRIPTION

WHAT IS THE ROTATION SYMBOL (ROS) ?

The ROtation Symbol (ROS) is the magenta inverted-T symbol  displayed in the ADI (Attitude Director Indicator) during take-off, from brake release to 3 seconds after lift-off. It is located at the bottom of the ADI at brake release, and on the horizon reference line at the end of the rotation. It provides the pilot with an easy-to-follow vertical mean to control the rotation phase of the airplane.

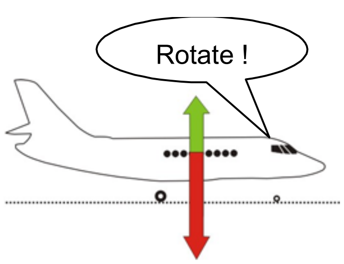
GENERAL PRINCIPLES

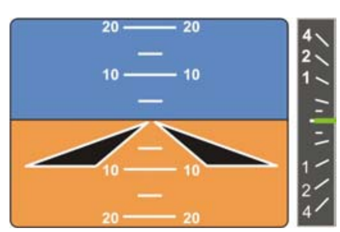
The rotation is a particular phase of the take-off where the combined increase of speed and angle of attack increase provides the necessary lift to get the airplane airborne and eventually climb.

The rotation phase can be divided into two consecutive parts:

- The first part starts with the rotation initiation created by the pilot pulling on the yoke. During this part, the lift increases but does not compensate for the weight of the airplane
- The second part starts as soon as the lift, created by the pilot still pulling on the yoke, exceeds the airplane weight. As a result, the airplane lifts off and starts climbing.

AIRPLANE NOT-EQUIPPED WITH EASY



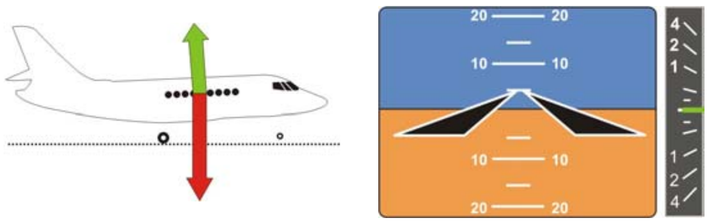


- The airplane is rolling on the ground, with no pitch
- Lift (created by airplane speed only) does not compensate for the airplane weight yet
- <Rotate> is called out

NOTE

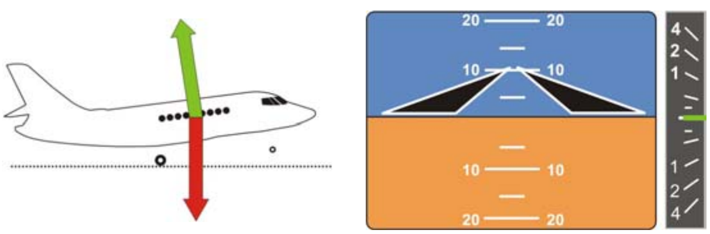
On an airplane with a FPS, the visualization would be:

ROTATION PHASE PART 1



- The pilot is pulling on the yoke to set the pitch to the take-off value
- The airplane initiates a rotation while still rolling on the ground. However, the combination of speed and angle of attack does not yet create lift enough to lift up the airplane

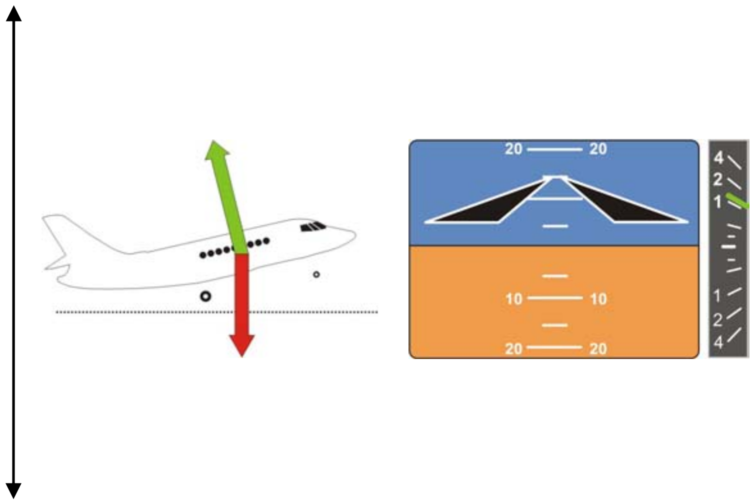
NOTE
On an airplane with a FPS, the visualization would be:



- The pilot keeps pulling on the yoke to set the pitch to the take-off value
- The airplane continues its rotation, and the combination of speed and angle of attack does almost create lift enough to lift the airplane up

NOTE
On an airplane with a FPS, the visualization would be:

R O T A T I O N P H A S E P A R T 2



- The pilot has set the pitch to the take-off value
- The combination of speed and angle of attack now creates enough lift to lift up the airplane

NOTE
On an airplane with a FPS, the visualization would be:

Legend:

Pitch symbol on EASy | Flight Path Symbol (FPS) | Vertical speed indicator | Airplane weight | Lift

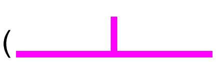
AIRPLANE EQUIPPED WITH EASY

On Falcons fitted with EASy, pilots are provided with both flight path and pitch information, by the way of the FPS  and the Pitch Symbol  .

However, it has been decided not to use the FPS during the rotation phase because:

- during the first part of the rotation phase, the FPS remains aligned with the horizon reference line whereas it is necessary to have a cue to set the appropriate take-off attitude,
- during the second part of the rotation phase, the FPS position permanently changes with the speed.

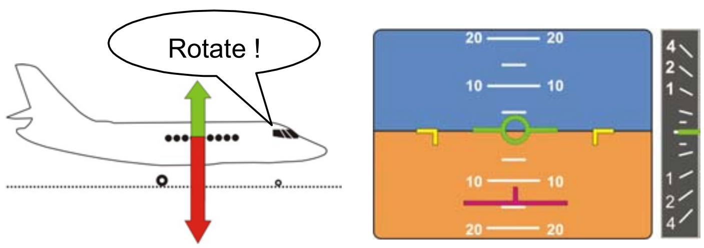
In addition, flying both FPS and Pitch Symbol simultaneously was perceived as possible but not comfortable for the pilot. This would imply non-intuitive and repeated eye pattern in the ADI between the horizon reference line (where the FPS is located) and the top of the ADI (where the Pitch Symbol is ultimately located) and this during a heavy work-loaded flight phase.

That is the reason why the ROS () was created to provide the pilot with a valid, easy-to-use pitch reference to control the two parts of the rotation phase. When the pilot brings the ROS from the bottom of the ADI up to the horizon reference line, he / she actually sets the appropriate pitch value for take-off. Moreover, being initially located at the bottom of the ADI, the ROS will move upward as the FPS will do when "pushed by the ROS" once the airplane is airborne. This results in a smooth, linear eye pattern from the bottom to the top of the ADI, significantly decreasing the pilot workload.

HOW TO USE THE ROTATION SYMBOL (ROS)

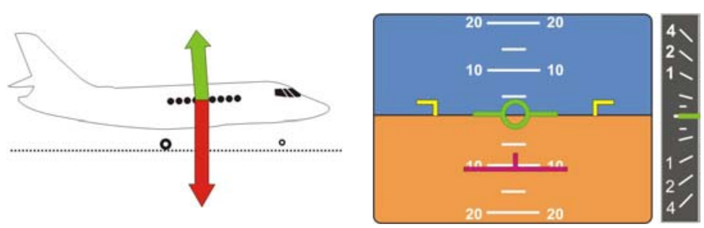
As soon as <Rotate> is called out, the pilot initiates the rotation by pulling on the yoke. This causes the ROS to rise up from the bottom of the ADI. Then the pilot controls the rotation by bringing the ROS to the horizon reference line in the ADI. By doing that, the pilot gives the airplane the appropriate angle of attack to generate the necessary lift to lift up and climb.

As soon as the airplane is airborne, the FPS rises off from the horizon reference line where it was stuck during the rolling and rotation phases. Three seconds after lift up, the ROS disappears and FPS naturally becomes the primary mean of flight path control for the pilot.

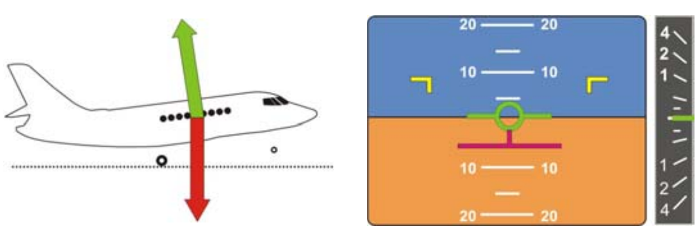


- The airplane is rolling on the ground (pitch and flight path angle are null)
- Lift (created by speed only) does not compensate for the airplane weight yet
- ROS is at the bottom of the ADI
- <Rotate> is called out

ROTATION PHASE PART 1

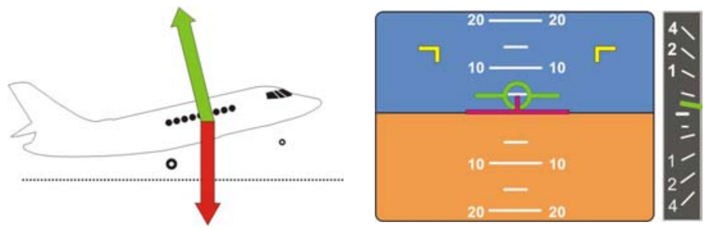


- The pilot is pulling on the yoke to set the ROS on the horizon reference line, which causes the pitch symbol to rise up too, but not the FPS
- The airplane rotates while still rolling on the ground. However, the combination of speed and angle of attack does not create lift enough for lift up

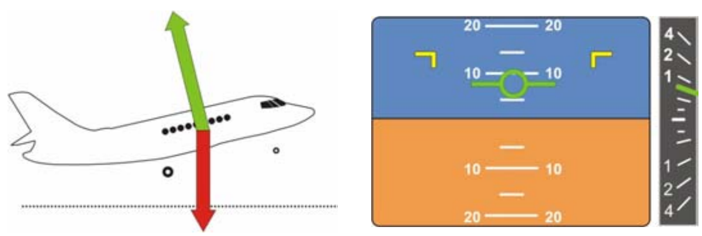


- The pilot keeps on pulling on the yoke to set the ROS on the horizon reference line, which causes the pitch symbol to rise up too, but not the FPS
- The airplane keeps on rotating while rolling on the ground. However, the combination of speed and angle of attack does not create lift enough for lift off

ROTATION PHASE PART 2



- The pilot has set the take-off attitude by keeping the ROS on the horizon reference line until it disappears, which causes the FPS to climb above the horizon line reference
- The combination of speed and angle of attack now creates lift enough to lift off the airplane



- 3 seconds after lift off, the ROS disappears and the pilot flies the FPS to climb

Legend:

Pitch symbol on EASy | Flight Path Symbol (FPS) | Vertical speed indicator | Airplane weight | Lift

CONCLUSION

The ROtation Symbol (ROS) is a symbol providing the pilot with valid flight information to control the rotation phase up to three seconds after lift off. It helps the pilot to measure out how much input he / she must give to the yoke to perform the rotation by reaching the appropriate angle of attack, in safe and comfortable conditions.

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