



GEA Tianjin / 中国民航大学中欧航空工程师学院

Presented by

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Airbus

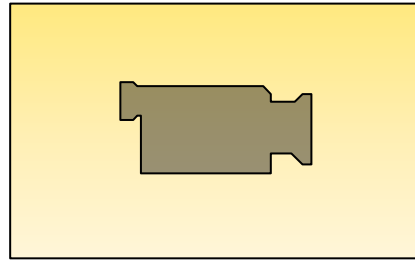
AFS INNOVATIONS

THALES



SUMMARY

- **AP/FD TCAS Mode**
- **BTV / ROPS**
- **Auto Take-off**
- **Taxi Driver System**
- **Auto Pull Up**
- **Other subjects**



SUMMARY

- **AP/FD TCAS Mode**

- **Current TCAS situation**
- **In service feed-back**
- **AP/FD TCAS Operational Concept**
- **AP/FD TCAS Function Description**
- **Examples**
- **New procedure with AP/FD TCAS Mode**
- **AP/FD TCAS Expected Benefits**
- **Architecture**

- **BTV / ROPS**

- **Auto Take-off**

- **Taxi Driver System**

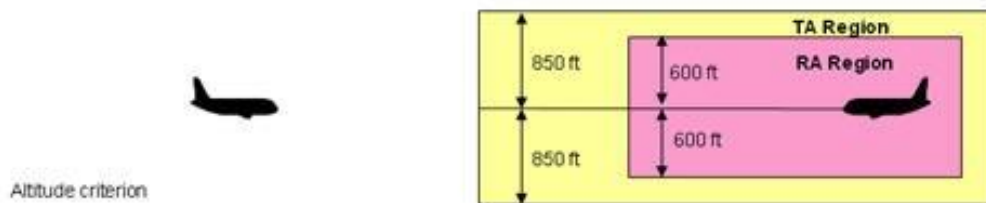
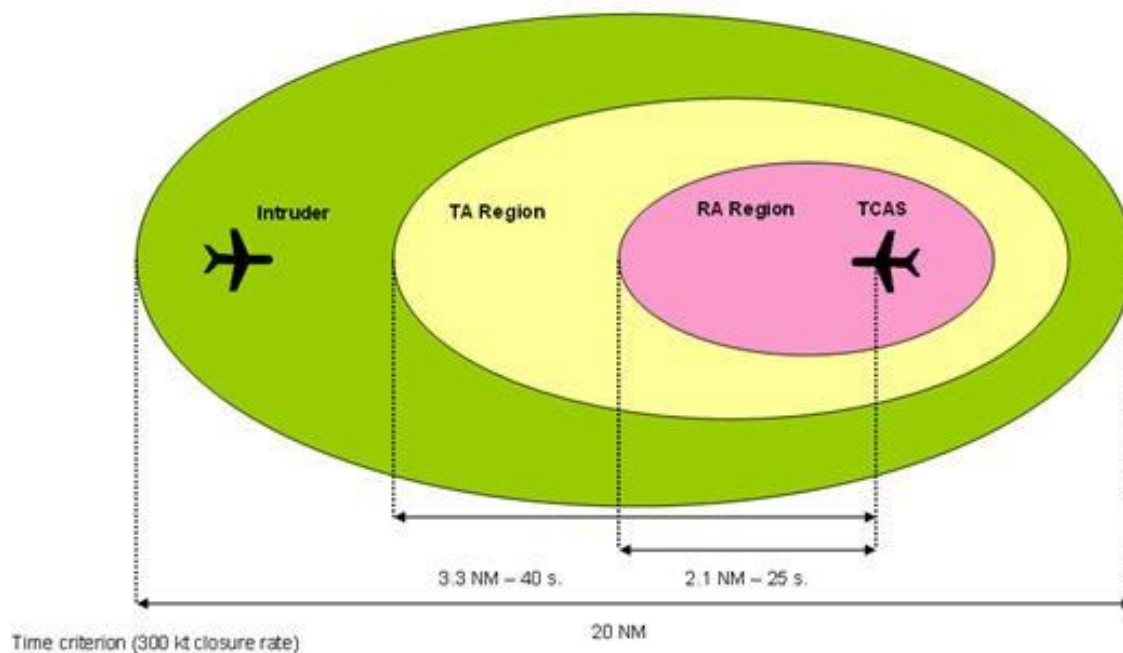
- **Auto Pull Up**

- **Other subjects**

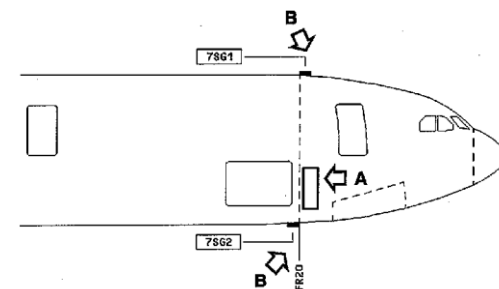
Reminder: current TCAS situation (1/4)

- **TCAS Principles**

- **PROXIMATE:** - white diamond
- **TRAFFIC ADVISORY:** - amber circle -> audio *TRAFFIC TRAFFIC*
- **RESOLUTION ADVISORY:** - red square -> Maneuver required



Example of ACAS Protection Volume between 5000 and 10000 feet



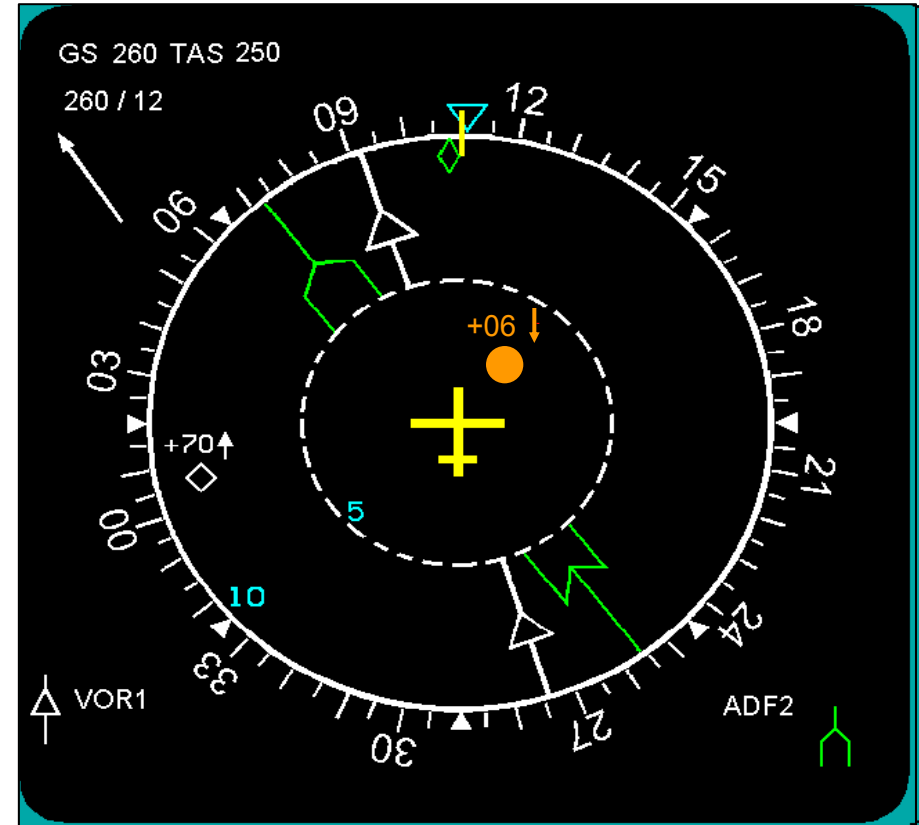
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- **Traffic Advisories (TA)**

- ## ► Audio warning



- ## ► Traffic displayed in amber on ND



- **Operational procedure**

- **No immediate action requested (awareness only)**

Reminder: current TCAS situation (3/4)

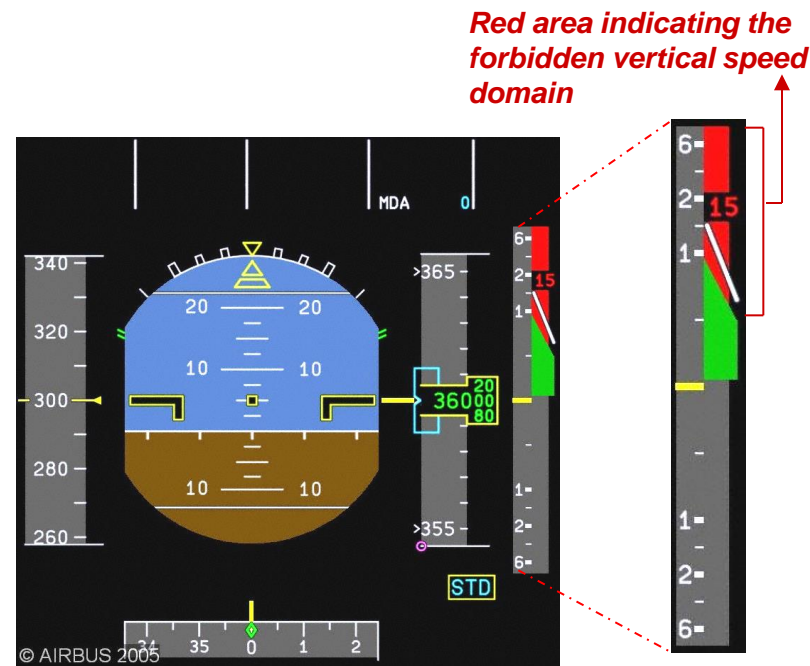
• Resolution Advisories (RA)

- ▶ Different audio warnings, depending on the target



***“Climb”, “Descent”, “Adjust V/S”,
“Maintain V/S”, “Monitor V/S”***

- ▶ Red and green areas on the vertical speed indicator (VSI)
 - Two kinds of RA
 - Preventive RA: initially out of the red
 - Corrective RA: initially in the red



Operational procedure upon TCAS RA

→ ***AP OFF & both FDs OFF***

→ ***Respond promptly and smoothly to an RA by adjusting or maintaining the vertical speed, as required, to reach the green area and/or avoid the red area of the vertical speed scale***

→ ***Notify ATC***

Reminder: current TCAS situation (4/4)

- **End of conflict is notified by a specific audio**



“Clear of conflict”

Operational procedure upon TCAS Clear of Conflict Alert

- *AP / FDs can be re-engaged*
- *Notify ATC*
- *Resume normal navigation in accordance with ATC clearance*

In service feedback : Over-reactions

- **Over-reactions**

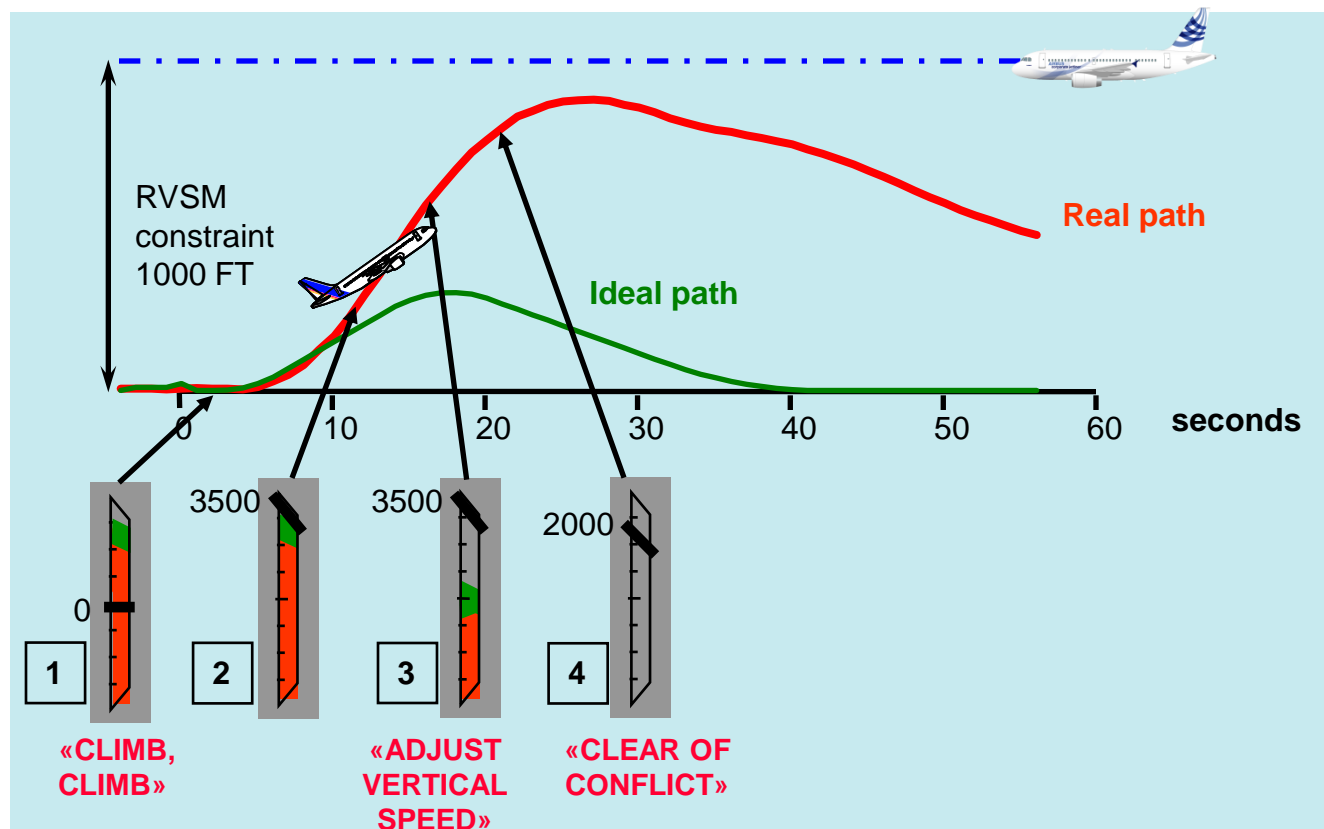
- **Excessive load factor**

- Cabin discomfort, injuries

- **Excessive vertical deviation (greater than the expected 300ft)**

- Perturbation of traffic

- Generation of other RA



1 - “CLIMB” RA requires a $V/S > 1500 \text{ fpm}$

→ Pilot flies a $V/S = 3500 \text{ fpm}$ ($\gg 1500 \text{ fpm}$)

3 - “ADJUST V/S” RA : pilot can reduce V/S before the Clear of Conflict

→ Not followed

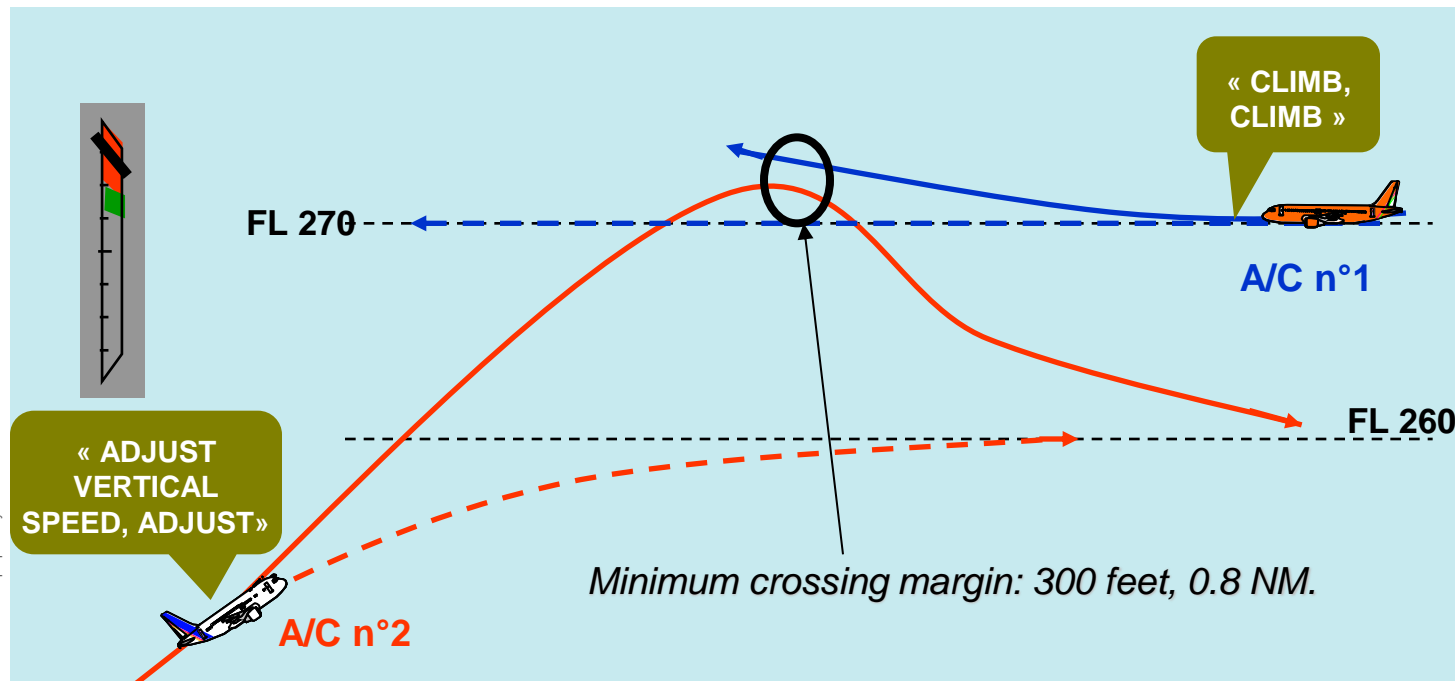
In service feedback : Inverse corrections

- **Inverse corrections**

- Mainly upon “ADJUST VERTICAL SPEED, ADJUST” RA

→ Ambiguous call-out: not intuitive, does not indicate the sense of correction

- ~ 5% of inverse reaction reported by AFR and DLH



- A/C n°1: cruising FL270
- A/C n°2: in climb at 3000ft/min, approaching FL260
- A/C n°2: “ADJUST VERTICAL SPEED” (V/S <1000ft/min)
- A/C n°2: Wrong interpretation of TCAS RA indications on VSI: pilot increases V/S rather than reducing it.
- A/C n°1: “CLIMB, CLIMB” RA.

In service feedback : Lack of reaction

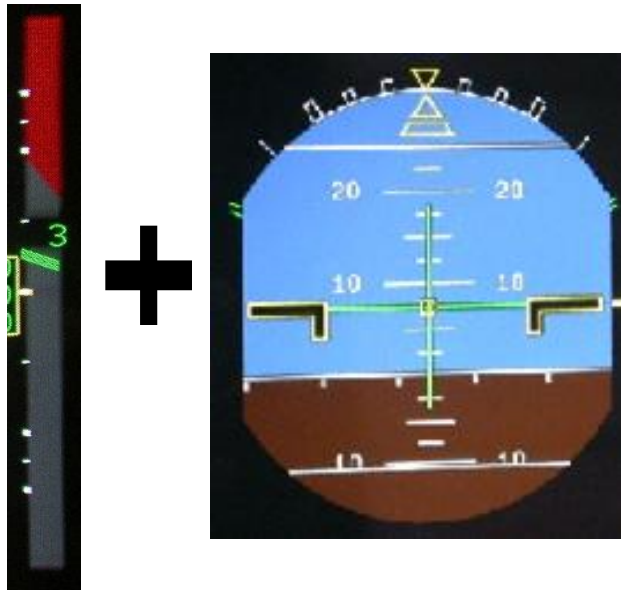
- **Lack of reaction**

- **In Europe*:**

- About 30% of non response below FL50
 - About 10% of non response above FL50

*Source: SIRE+ project (Eurocontrol project for TCAS performance improvement). Data based on observation of major TMA in Europe.

Operational concept (1/2)

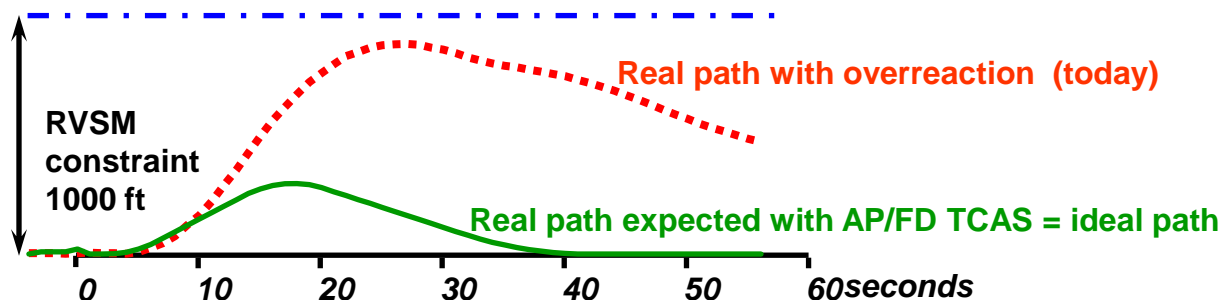


- ☐ TCAS provides a V/S target to follow on the Vertical Speed Indicator (VSI)
- ☐ The Auto Flight System (AFS) provides a V/S guidance through AP/FD orders

AP/FD TCAS concept is to combine AFS with TCAS to provide a V/S guidance using TCAS target.

Main design drivers

- Provide a TCAS guidance through Auto-Flight System
 - FD guidance if AP OFF
 - Automatic maneuver if AP ON
 - In all cases of TCAS RA
 - In addition to Vertical Speed Scale indications
- Design this guidance to
 - Minimize deviation from initial trajectory
 - Let the A/C in a safe configuration after Clear of Conflict
- Operate the TCAS RA with a simple procedure
 - No FCU action
 - Current flying technique maintained (no change of AP/FD engagement status)



Airbus AP/FD TCAS – Function description

When a TA is triggered



“Traffic, traffic”

- **TCAS mode is armed**

- To warn pilots that TCAS mode could engage if the TA is followed by an RA
- On FMA 3rd line (in blue)
- Even if AP/FD OFF
- Other modes initially armed are kept armed and displayed on FMA 2nd line

OP CLB
ALT
TCAS

ALT
TCAS

Note: when TA alert disappears, TCAS mode is disarmed

When a RA is triggered

- **TCAS mode engages immediately**

- On FMA 1st line (in green)

- Controls the a/c V/S

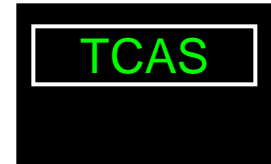
- **Corrective RA:** V/S guidance with internal target «200 ft/mn within the green TCAS VSI zone» and a load factor increased up to 0.3g
 - **Preventive RA:** V/S guidance on current A/C V/S

- **Armed modes disarmed, except ALT if level-off compliant with the TCAS advisory**

- If altitude capture is compliant with the TCAS advisory (e.g. **“Adjust” RA** and **“Monitor” RA**), TCAS mode will perform the altitude capture when conditions are met.

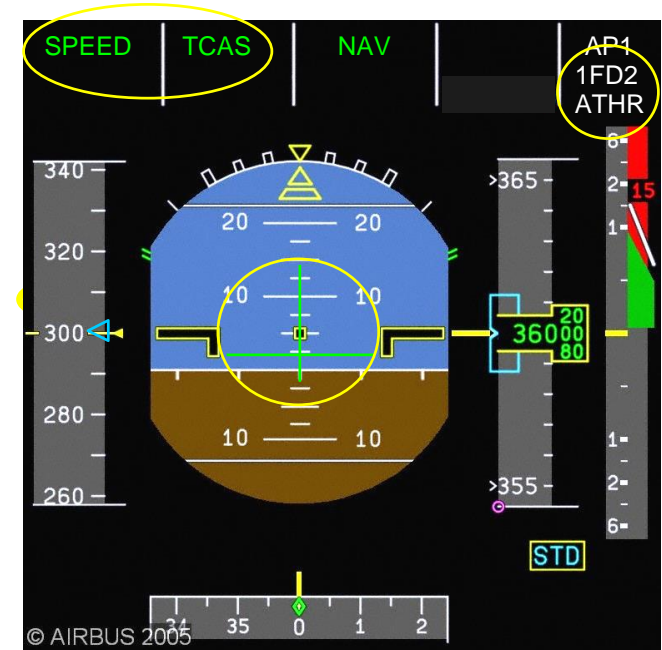


*“Climb,
Descent,
Adjust V/S,
Maintain V/S,
Monitor V/S ”*



When a RA is triggered

- **AP/FD/ATHR**
 - No change in AP engagement status
 - FDs automatically engage if initially OFF (with cross-bars display)
 - ATHR automatically engages/reverts in SPEED/MACH mode
 - Speed target (selected) = current speed at the time of the RA
- **Lateral trajectory unchanged**
 - The lateral trajectory is maintained during the RA (NAV, HDG)
- **Crew can override the automatism at any time**



PFD figuration during a TCAS RA

Clear of Conflict



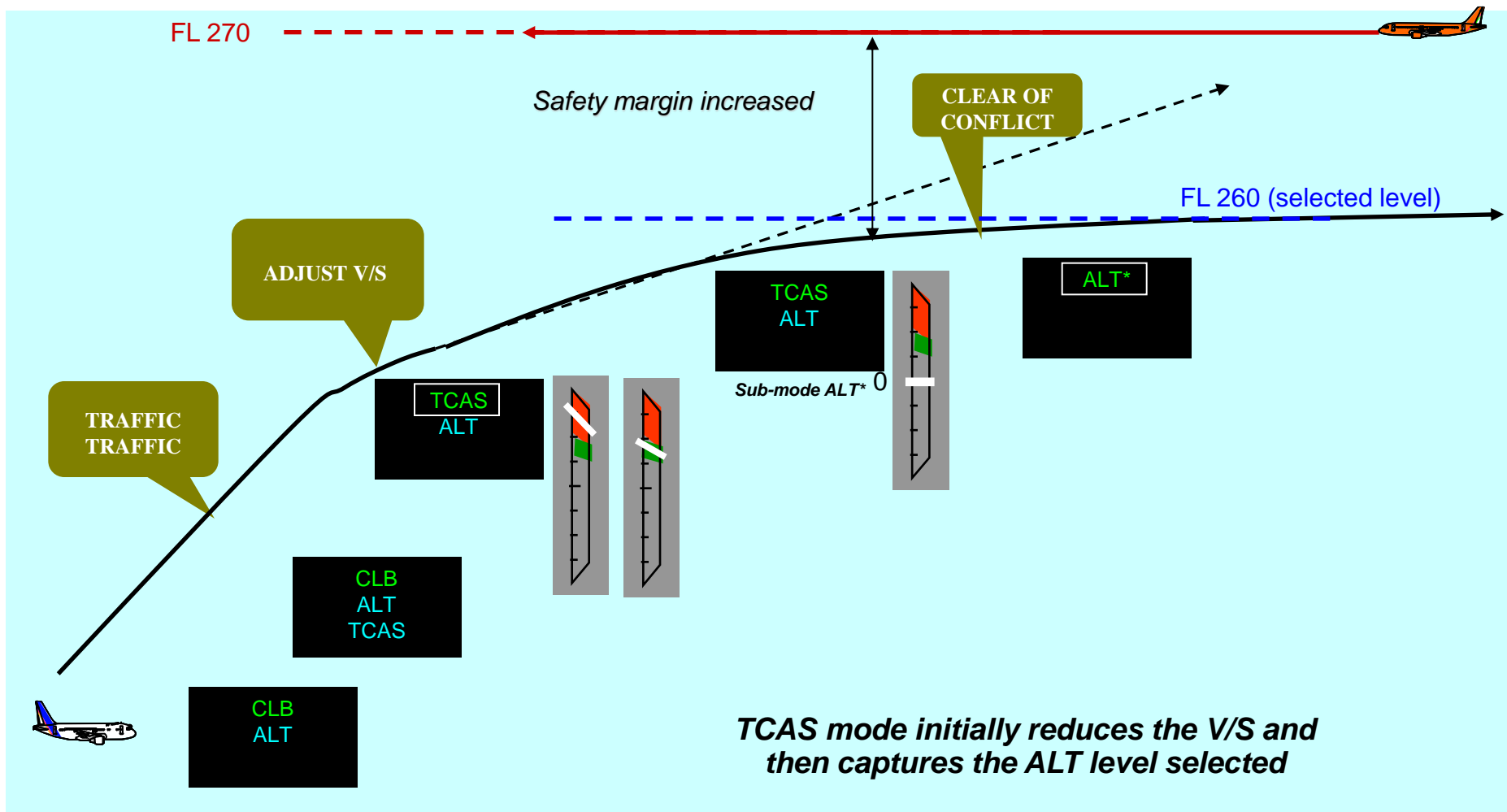
- **Reversion to V/S mode**
 - Smooth value (<1000ft/min) toward FCU altitude
 - ALT mode is armed
- **Reversion to ALT* or ALT mode if altitude capture performed by TCAS mode during the RA**

HMI

- **Usual HMI AFS logics apply**
 - **Flight Mode Annunciator: white Boxing at TCAS mode engagement and V/S engagement at CoC**
- **Altitude alert inhibited when in TCAS mode**
 - **Judged disturbing in addition to the RA aural**

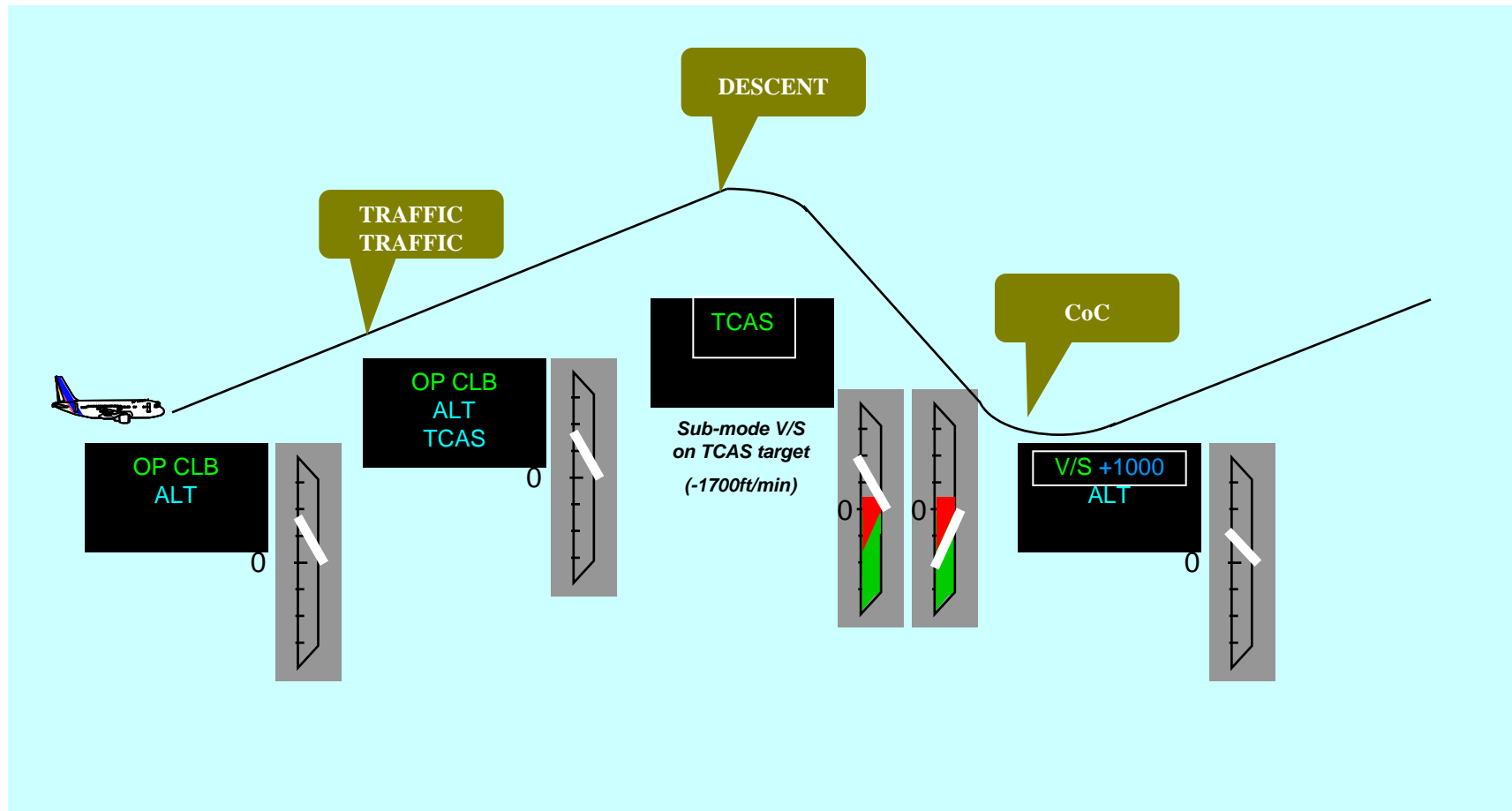
AP/FD TCAS Function Description – Example 2

- “Adjust” RA during CLB with ALT mode armed



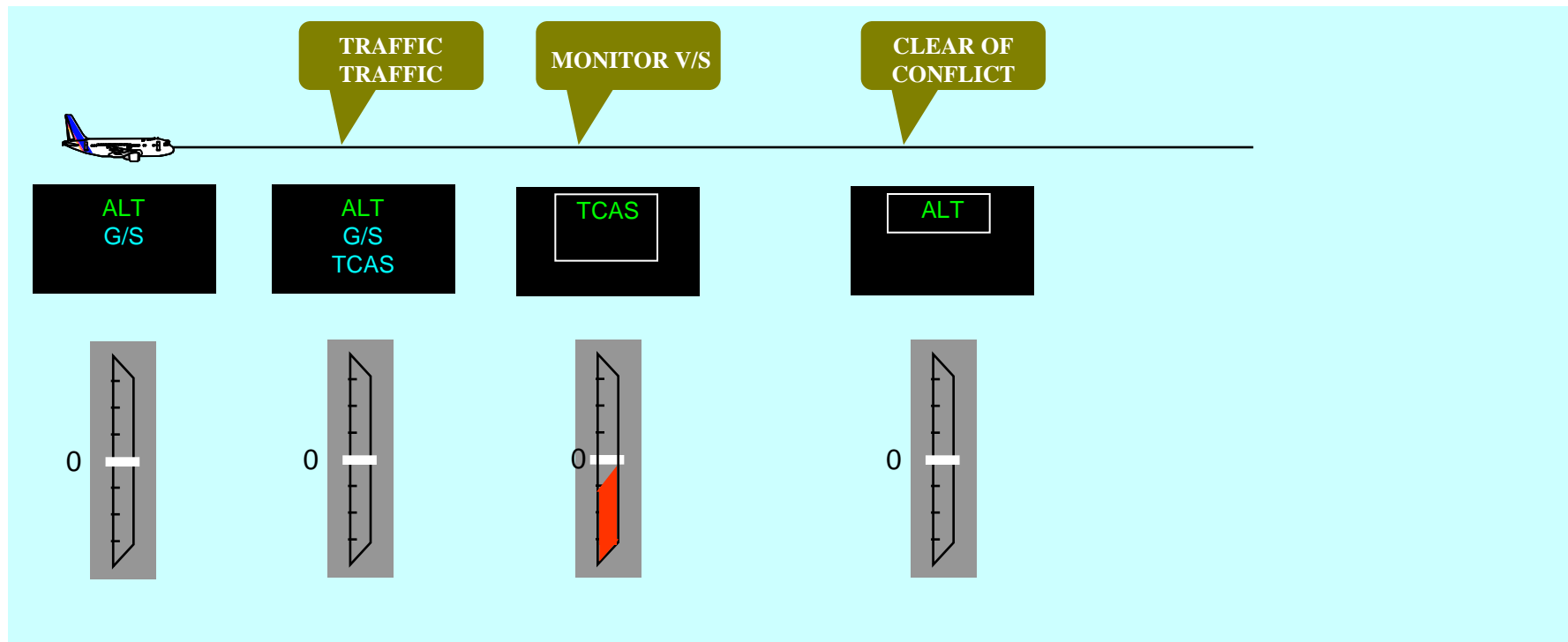
AP/FD TCAS Function Description – Example 3

- “Descent” RA during OPEN CLB with ALT mode armed



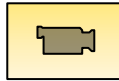
AP/FD TCAS Function Description – Example 4

- “Monitor” RA during ALT hold with G/S mode armed



AP/FD TCAS Function Description – Cockpit Examples

- **TCAS arming during an approach**



- ***TCAS engagement in NAV – ALT in turn***



- ***FD manoeuvre during descent***



Airbus AP/FD TCAS - Expected Benefits (1/2)

- **Ease TCAS RA piloting**

- ▶ **Pilot flies the FD (or AP).**

- No more direct piloting of the VSI parameter

- ▶ **Respond correctly and quickly to the TCAS alert**

- Fully deals with inverse reaction issue

- ▶ **Maintain a moderate load factor during the maneuver**

- Avoid passenger discomfort and risk of injuries

- ▶ **Consistent with usual cockpit interfaces**

- Consistent with Auto Flight System philosophy: can be flown manually (FD) or automatically (AP)
 - Not a new type of display
 - Continuous transitions upon RA and upon Clear of Conflict

- ▶ **Maneuver only to the extent necessary to avoid the intruder A/C**

- Fully deals with over-reaction issue
 - Prevent from new RA triggering with other a/c
 - Avoid level crossing when ALT capture is safe

Airbus AP/FD TCAS - Expected Benefits (2/2)

- **Reduce the workload and stress associated to TCAS alert**
 - Crew has more time available for appropriate ATC communication and maneuver monitoring.
- **Simple procedure**
 - Maintain the current flying technique with AP or FD
 - Procedure just consists in
 - Following AFS guidance
 - Monitoring path deviation on the VSI
- **Simple training**
 - Intuitive function, consistent with usual cockpit interfaces

SUMMARY

- AP/FD TCAS Mode
- **BTV / ROPS**
 - Background
 - Functions presentation
 - Cockpit overview
 - Architecture
 - Project Benefits
 - Illustration on a real accident
- Auto Take-off
- Taxi Driver System
- Auto Pull Up
- Other subjects

ROPS benefits: *Value for Airlines, IATA view*

The IATA Safety Report 2009 presents analytical findings of accidents that occurred in 2008.

Highest Occurrence

- The first issue raised in the Safety Report 2008 is: **Runway Excursion**
- Runway excursions can occur during both takeoffs and landings.
- **42% occurred on non-dry runways**



High Consequences

- Over half (57%) of these events in 2008 resulted in hull losses.
- Half (48%) of cabin damages comes from runway excursion.

Runway Overrun Prevention System (ROPS)

ROPS is a runway overrun risk mitigation mean to:

- help the crew in the decision making process in flight,
- assist and warn the crew during the ground phase on the required action to limit the risk of runway overrun risks or limit the overrun speed.

Brake To Vacate (BTV)

BTV is a function to improve pilot's management of approach and landing phases:

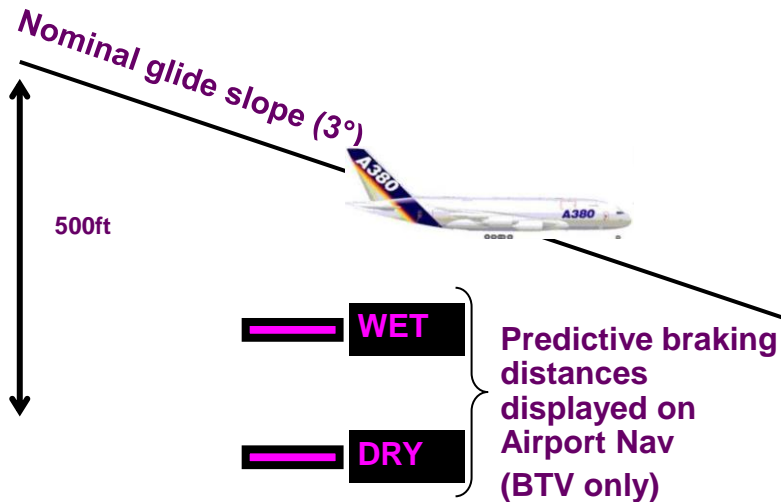
- to help the crew to select an appropriate runway and exit during approach (with OANS)
- On ground, to monitor and pilot braking so as to reach selected exit in an optimum manner.

ROPS function is a pre-requisite for BTV.

A380/A320/A330/A340 ROPS: Safety function

ROW (Runway Overrun Warning)

It is Go Around-minded



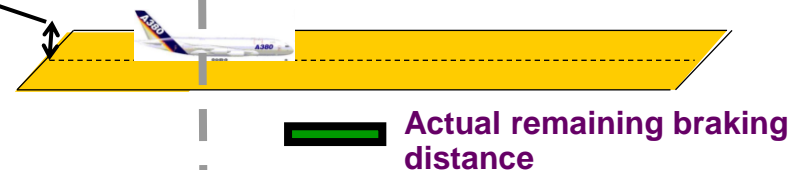
WET case: amber message on PFD
DRY case: red message on PFD + audio

ROP (Runway Overrun Protection)

It is stop-minded

Autobrake activation
(Nose Landing Gear down or five seconds after Main Landing Gear down)

50ft



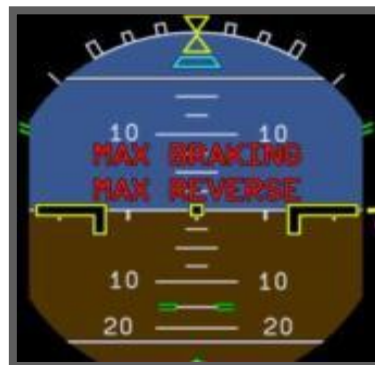
ROP alerts (Pedal braking)

ROP
(Runway Overrun Protection)

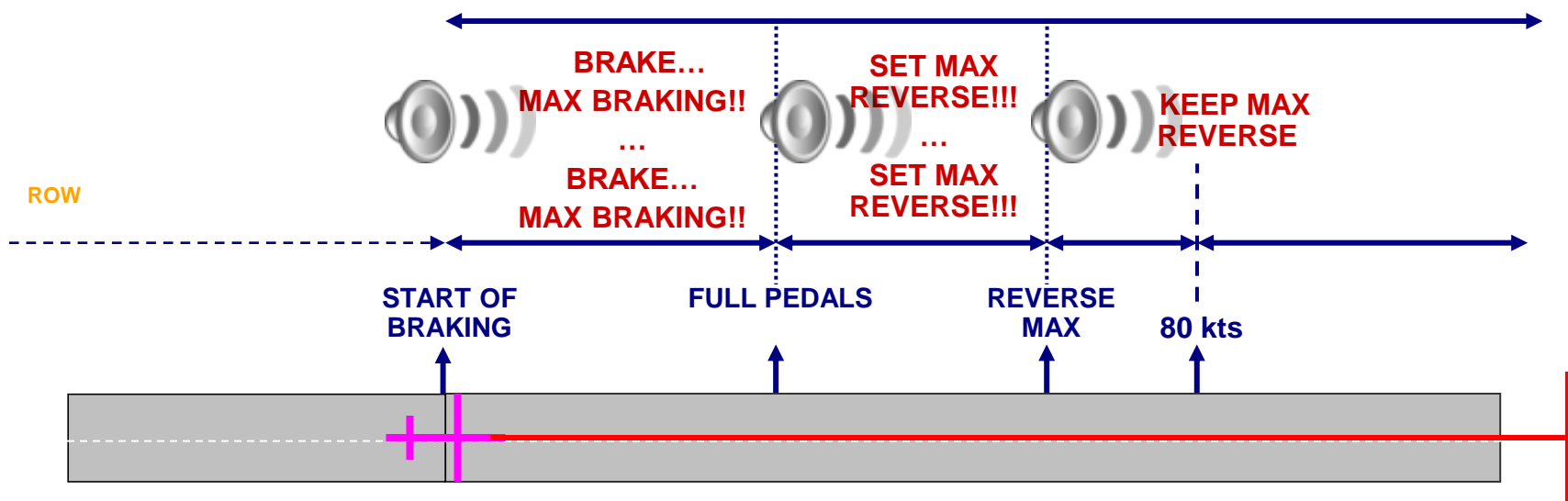
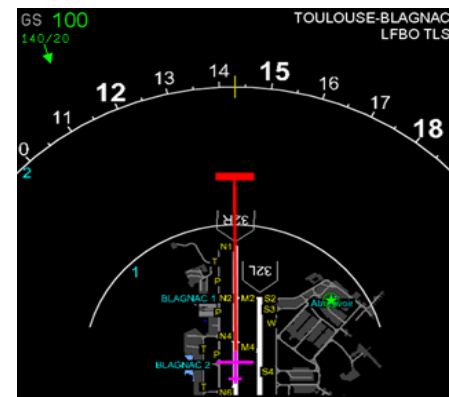
Pedal braking



Flashing



Stop bar pulsing



ROPS Overview on phase air

- Warnings on PFD
- Warning on HUD



ROPS Overview on phase air

- Warnings on PFD
- Warning on HUD



« RWY TOO SHORT »



ROPS Overview on phase air

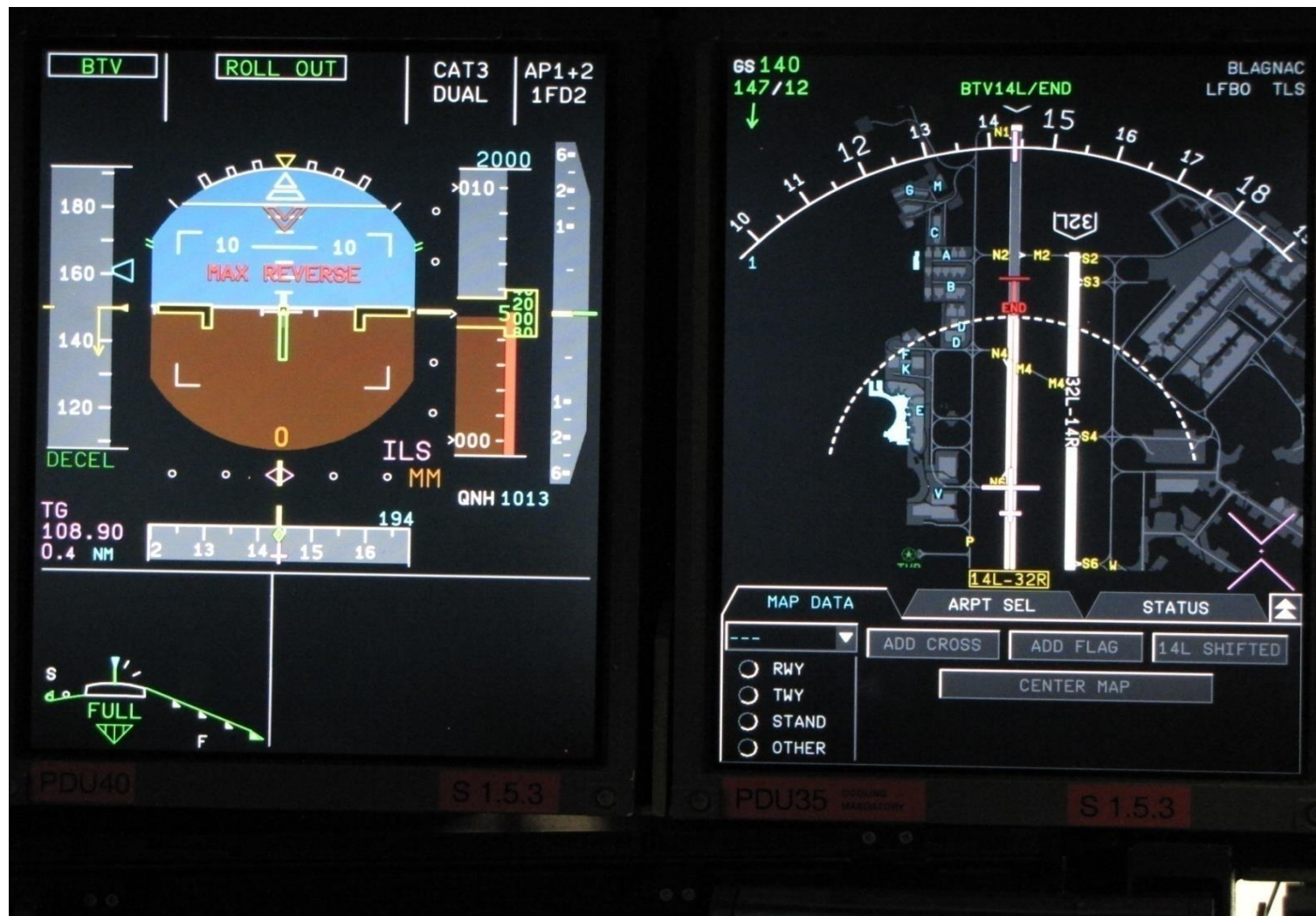
- Warnings on PFD
- Warning on HUD



« SET MAX REVERSE »



« KEEP MAX REVERSE »



ROPS in pedal braking



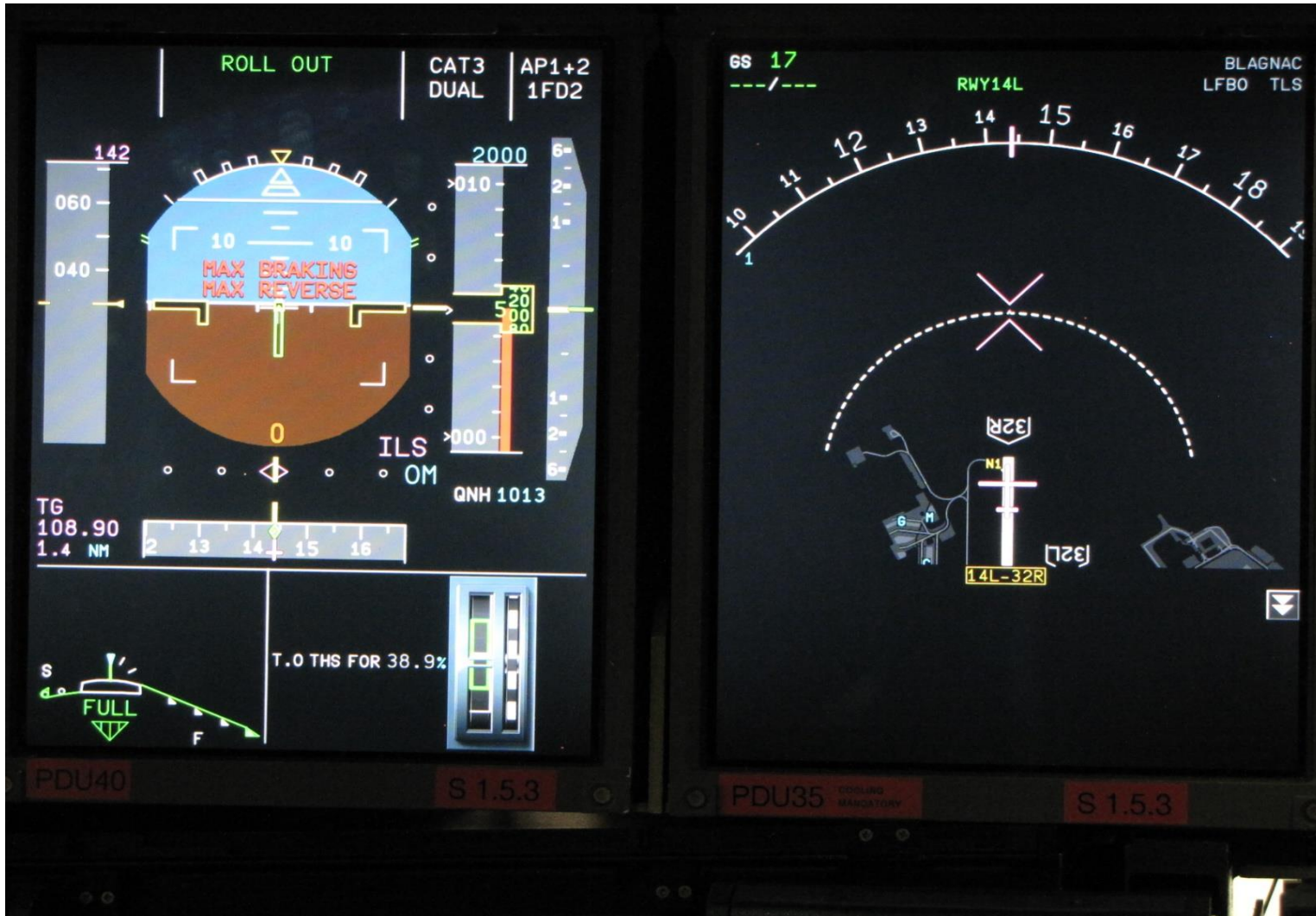
« MAX BRAKING »



« SET MAX REVERSE »

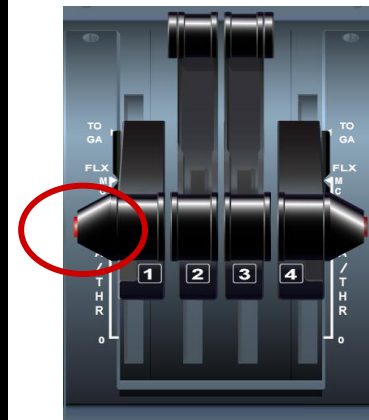
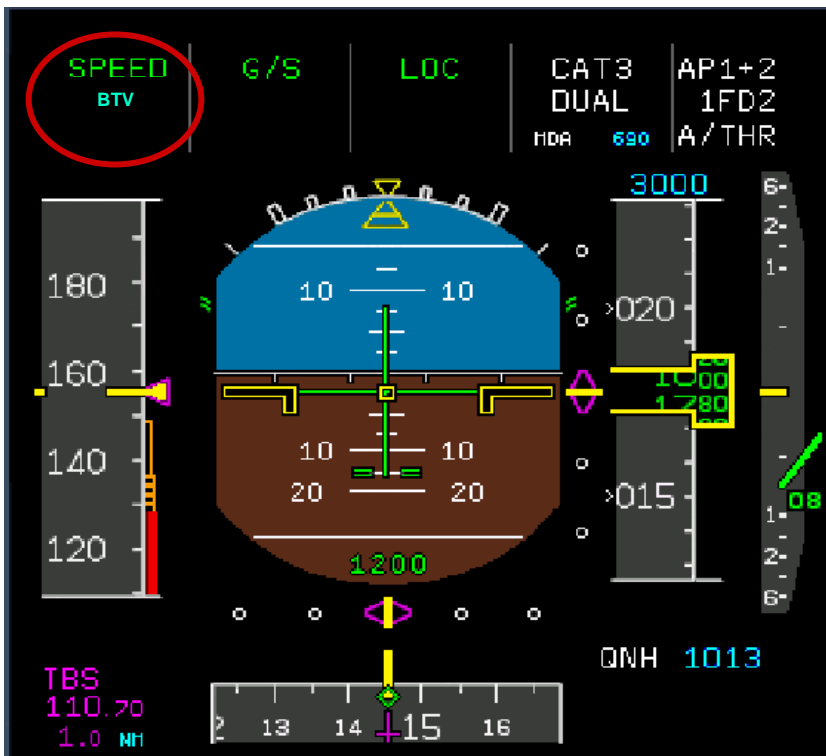


« KEEP MAX REVERSE »



A380 BTV Overview

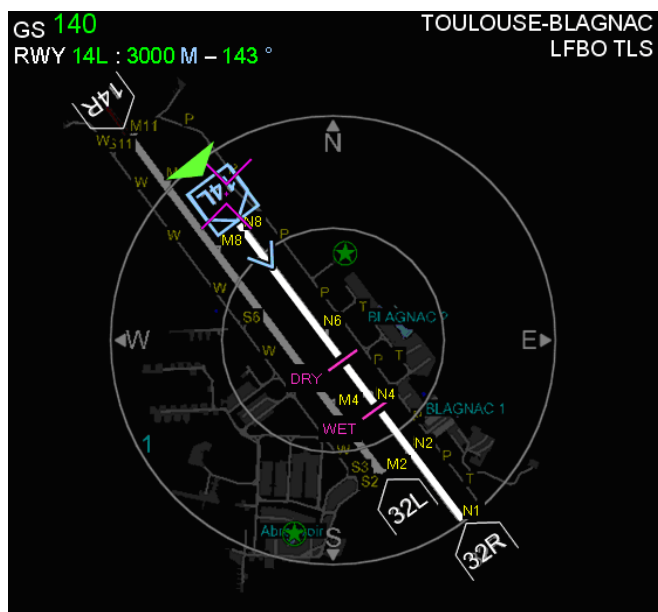
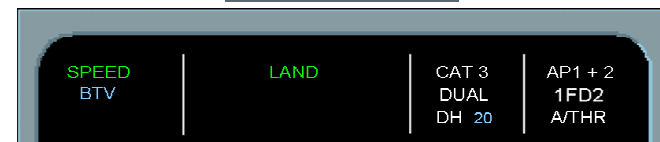
- ▶ Selection of RWY & TWY using OANS interface and KCCU
- ▶ Engage/Disengage function
- ▶ Display BTV status on PFD using FMA display area



- Warnings and ECAM
- HUD

A380 BTV Overview

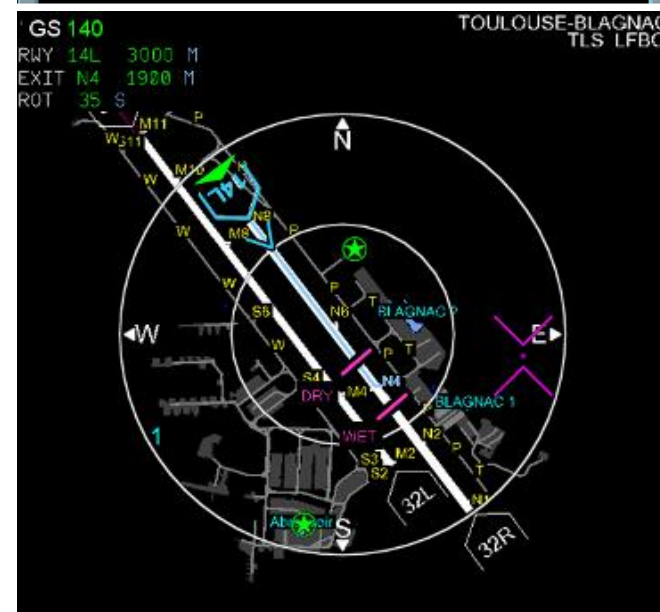
BTV selection in PLAN Mode



1 : Runway selection
Grey mode +
Display of dry and wet bars



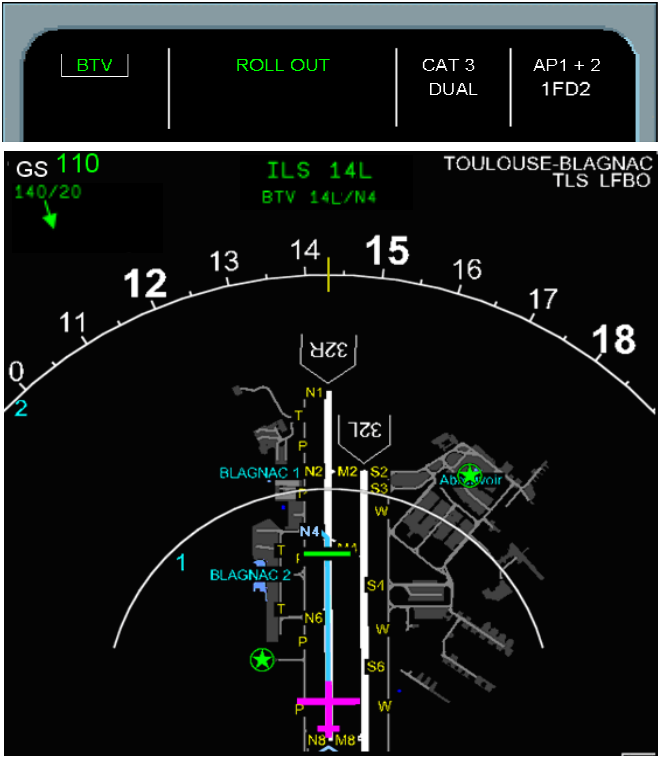
2 : Exit selection



3 : BTV arming with Auto-Brake rotary switch

A380 BTV Overview

BTV normal operations



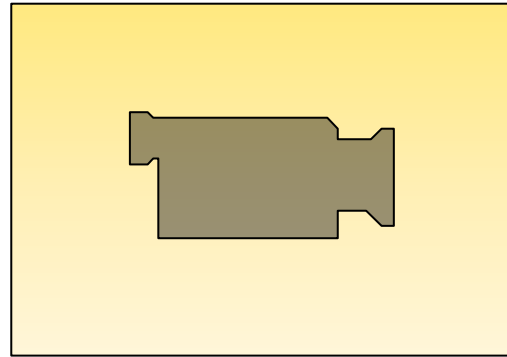
BTV armed
Below 500 ft DRY/WET bars are "alive".

BTV activation
DECEL on PFD

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ROPS demonstration



ROPS benefits: *Runway Overrun Factors*

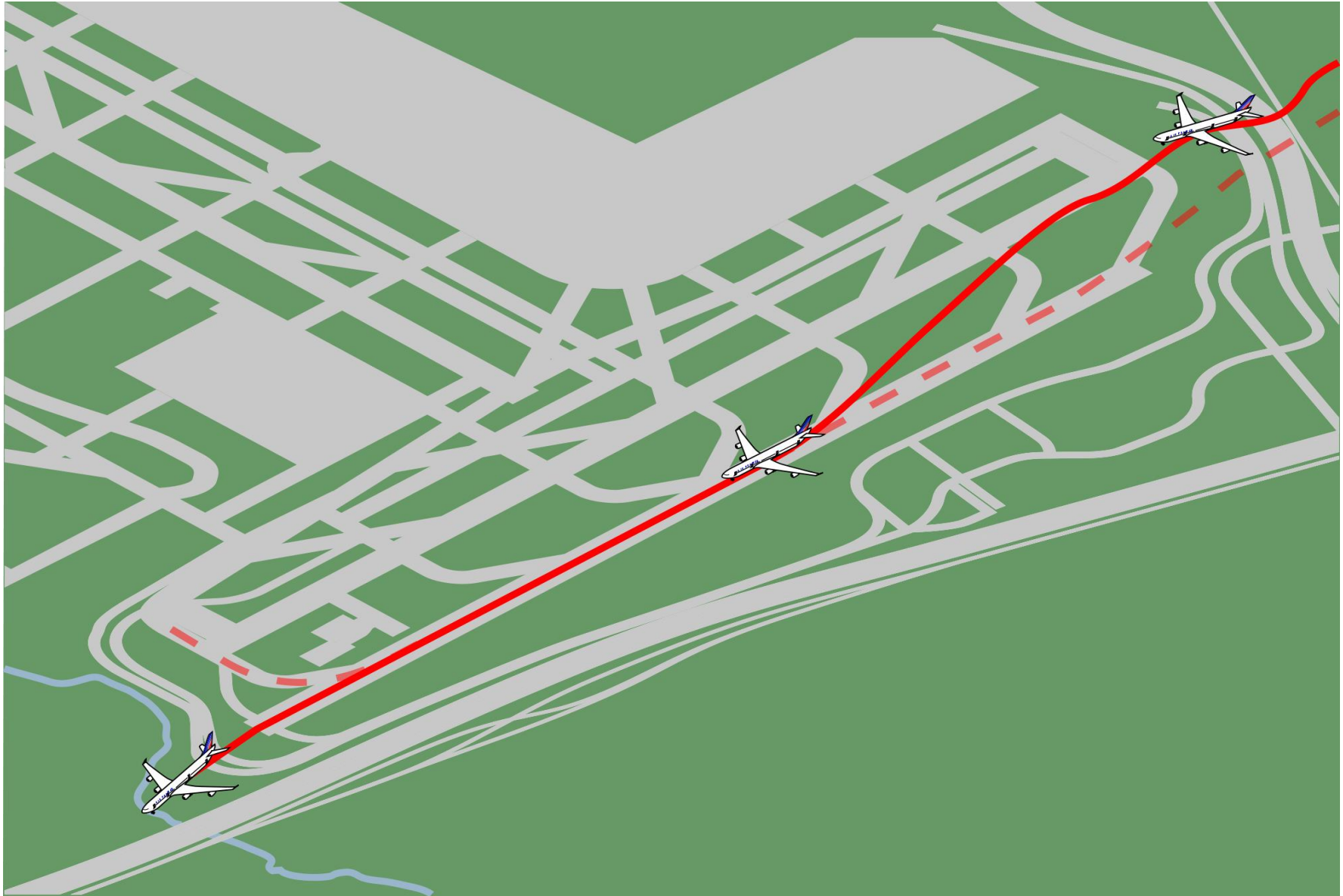
Safety Risk Management allowed by ROPS

Main factors of Runway Overrun at landing

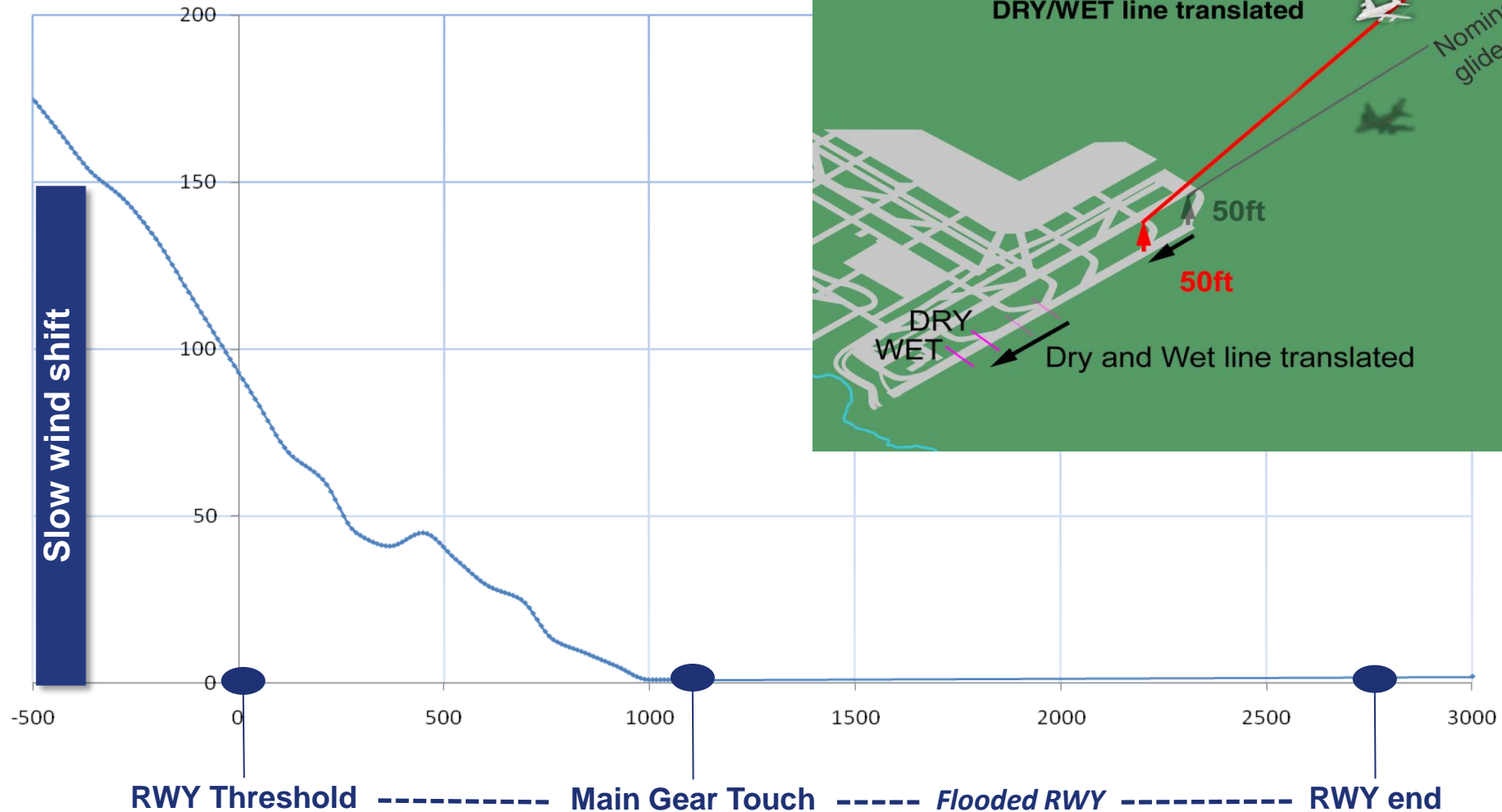
- Landing with reduced margins on DRY & WET runways
- Stabilization not achieved at 1000/500 ft
- Wind shift at low altitude
- Approach becoming unstable at low altitude
- Long flare
- Long derotation
- Late selection of engine thrust reversers
- Runway friction coefficient lower than expected
- Cancellation of reversers at 70kts
- Late/weak manual braking
- Failure affecting the landing distances
- Landing with reduced margins on contaminated runways: snow, ice
- ...



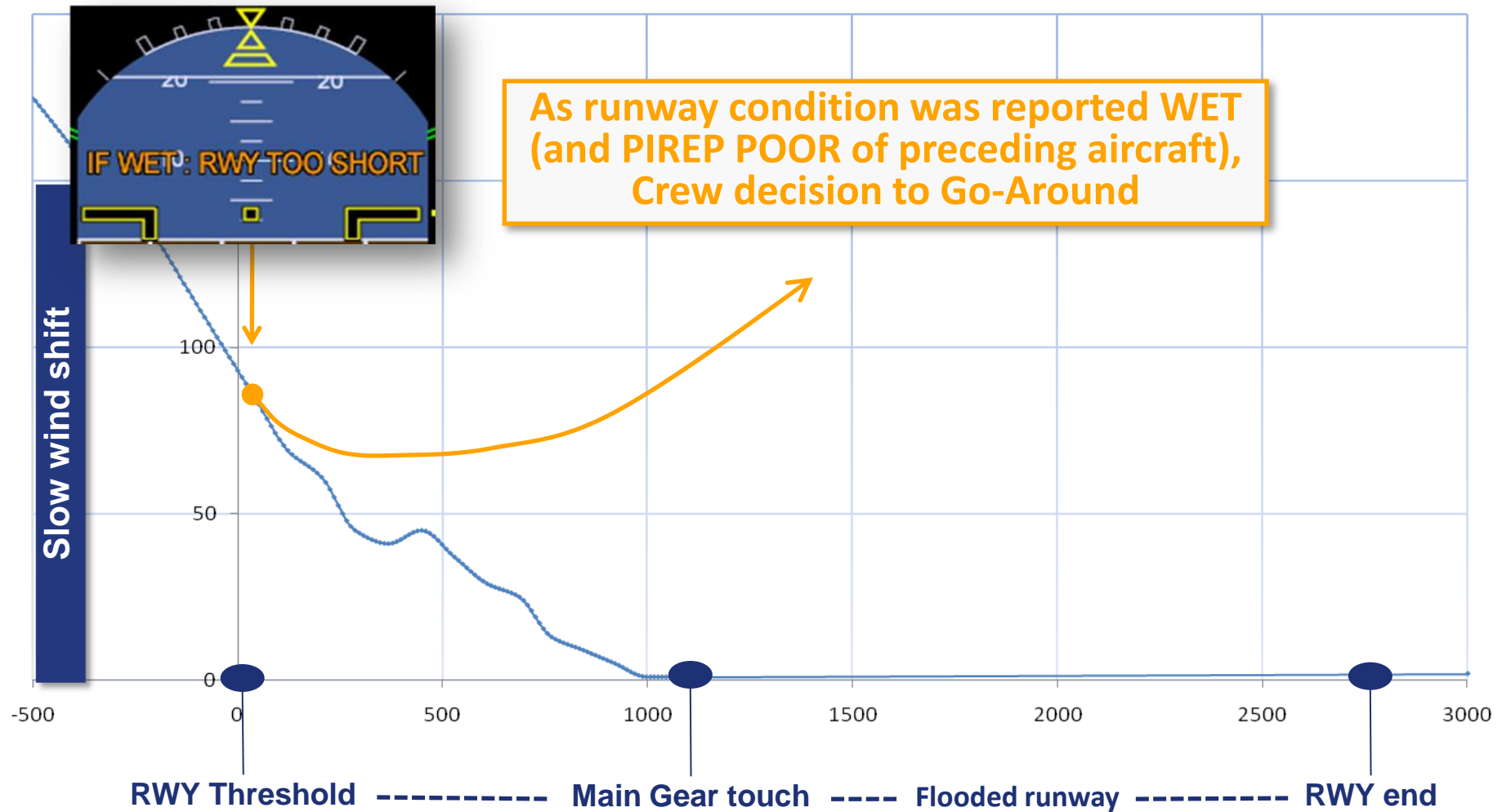
ROPS illustration on a Real Accident Scenario (1/5)



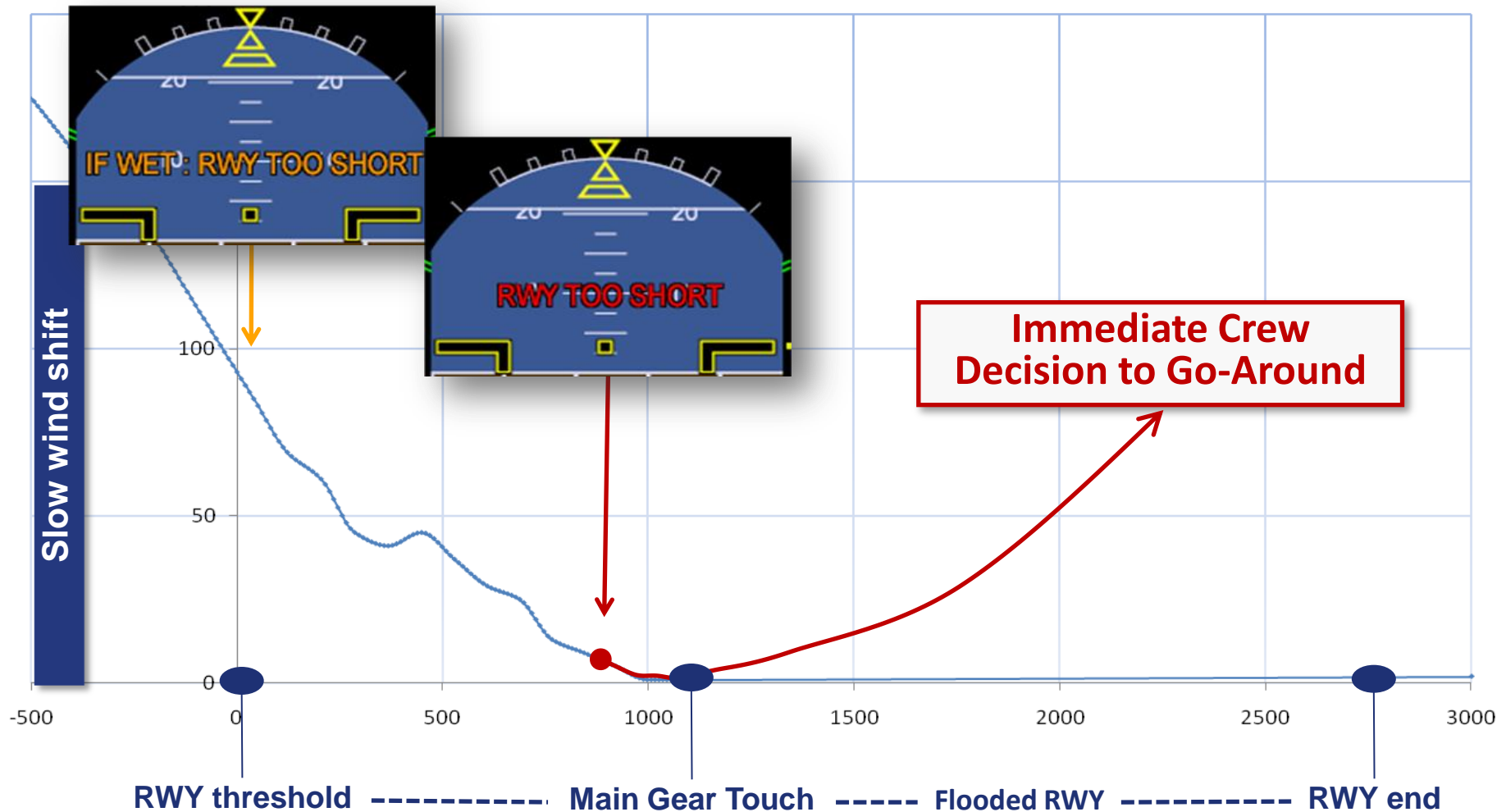
ROPS illustration on a Real Accident Scenario (2/5)



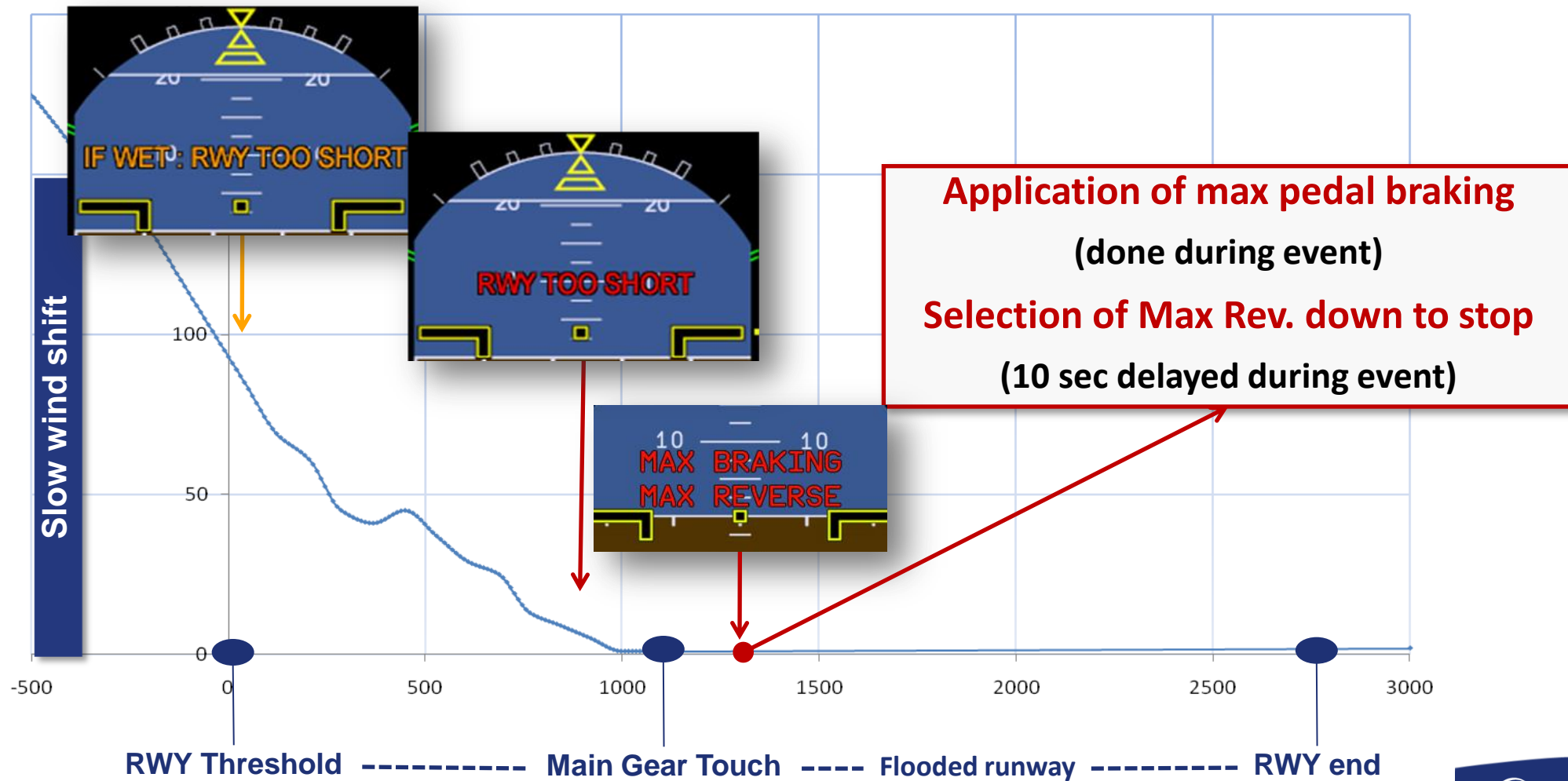
ROPS illustration on a Real Accident Scenario (3/5)



ROPS illustration on a Real Accident Scenario (4/5)



ROPS illustration on a Real Accident Scenario (5/5)



SUMMARY

- AP/FD TCAS Mode
- BTV / ROPS
- **Auto Take-off**
 - Automation principle
 - Description and operating process
 - System Architecture
 - HMI - FMA, FD and TDS
- Taxi Driver System
- Auto Pull Up
- Other subjects

Automatic Takeoff Function : Automation Principle

Tasks breakdown for takeoff manoeuvre (until V2)

- **After Thrust Power Setting, without crosswind:**
 - **On ground**
 - Control directionally the aircraft to track runway axis
 - Monitor speed evolution until decision speed
 - **From ground to flight**
 - At rotation speed, rotate the aircraft while controlling pitch angle
 - Control directionally the aircraft to track runway axis
 - Monitor speed until V2
 - **In case of major failure before decision speed**
 - Stop the aircraft (thrust reduction and reversers, RTO automatic braking)
 - Control directionally the aircraft to track runway axis
 - **Speed Control/Monitoring and Takeoff rejection decision are under pilot responsibility**

Automatic Takeoff Modes Presentation (1/3)

- **New AP modes available for takeoff phase in addition to SRS vertical mode and RWY lateral mode**
- **2 new modes for aircraft automatic control during takeoff**
 - AUTO TO for the vertical control
AUTO TO mode → Optimal pitch profile tracking (from Vr speed)
 - AUTO RWY for the lateral control
AUTO RWY mode → Takeoff runway axis tracking during takeoff course (up to lift-off)
- **Available during the takeoff run and initial climb on the AP/FD**
- **3 takeoff configurations for 3 modes combinations**
 - SRS and RWY: manual takeoff (as today)
 - AUTO TO and RWY: semi automatic takeoff
 - AUTO TO and AUTO RWY: full automatic takeoff

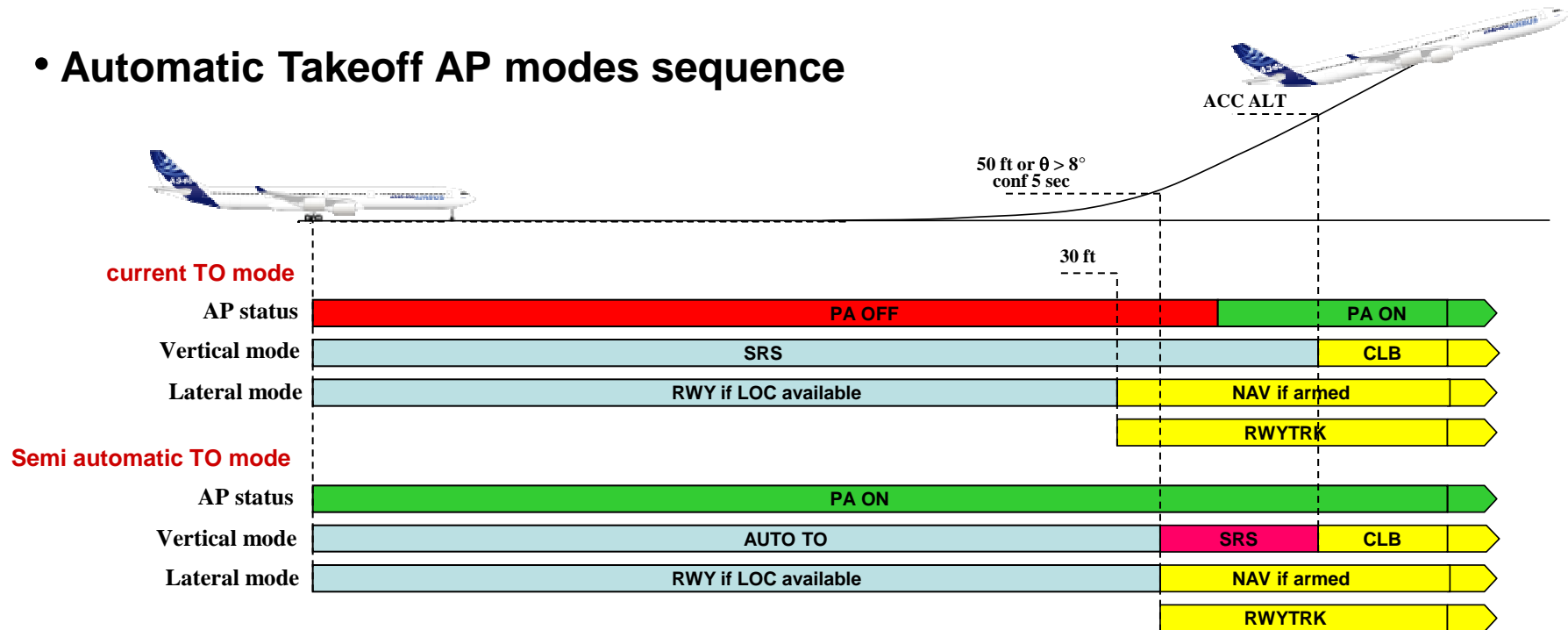
Automatic Takeoff Modes Presentation (2/3)

- **Guidance principle**

In AUTO TO mode, the aircraft follows the pitch profile defined during takeoff preparation according to takeoff parameters. The guidance law also includes a pitch angle protection to cover tailstrike risks.

Today, pitch profile is computed according to a « performance » profile.

- **Automatic Takeoff AP modes sequence**

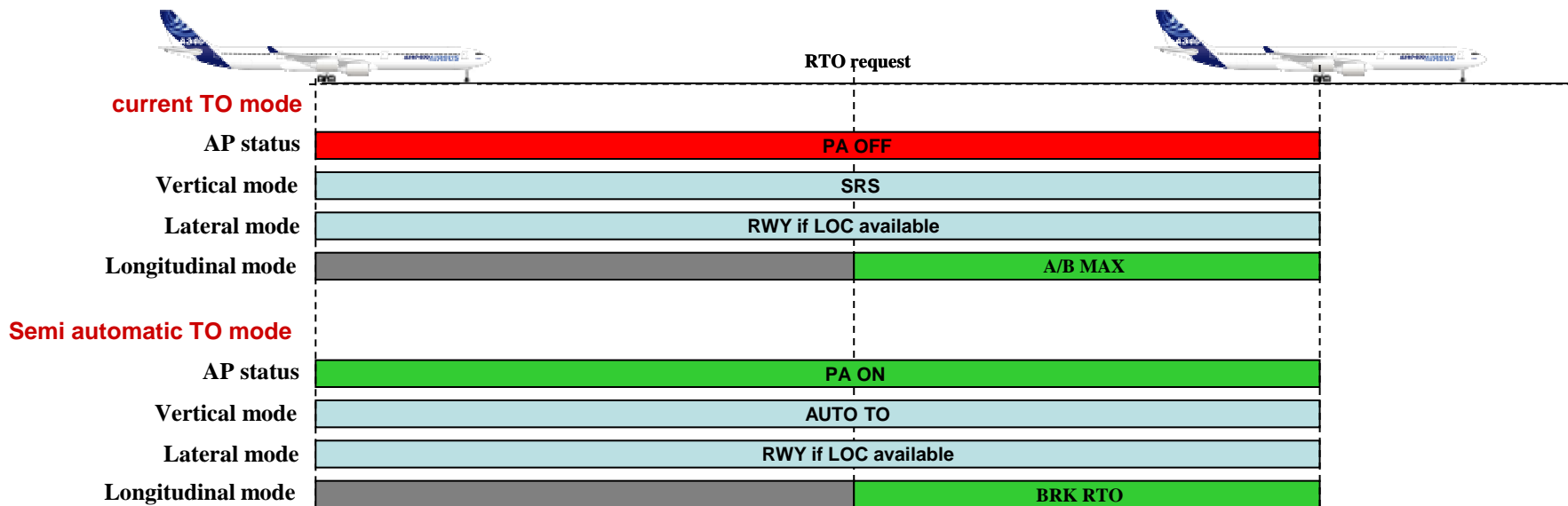


Automatic Takeoff Modes Presentation (3/3)

- **Guidance principle**

In RTO mode, the aircraft follows the current pitch attitude until aircraft stop

- **Rejected Takeoff AP modes sequence**



Automatic Takeoff : Operating procedure

• AUTO TO mode operating process

Arming conditions

AUTO TO mode is armed if the following conditions are met :

- . Performance condition : TO speeds and pitch profile are available
- . Configuration condition : Slats are extended
- . System condition : AP is engaged by means of AP pushbutton on the FCU

Engagement conditions

AUTO TO mode is engaged on thrust power setting (crew action).

Disengagement conditions

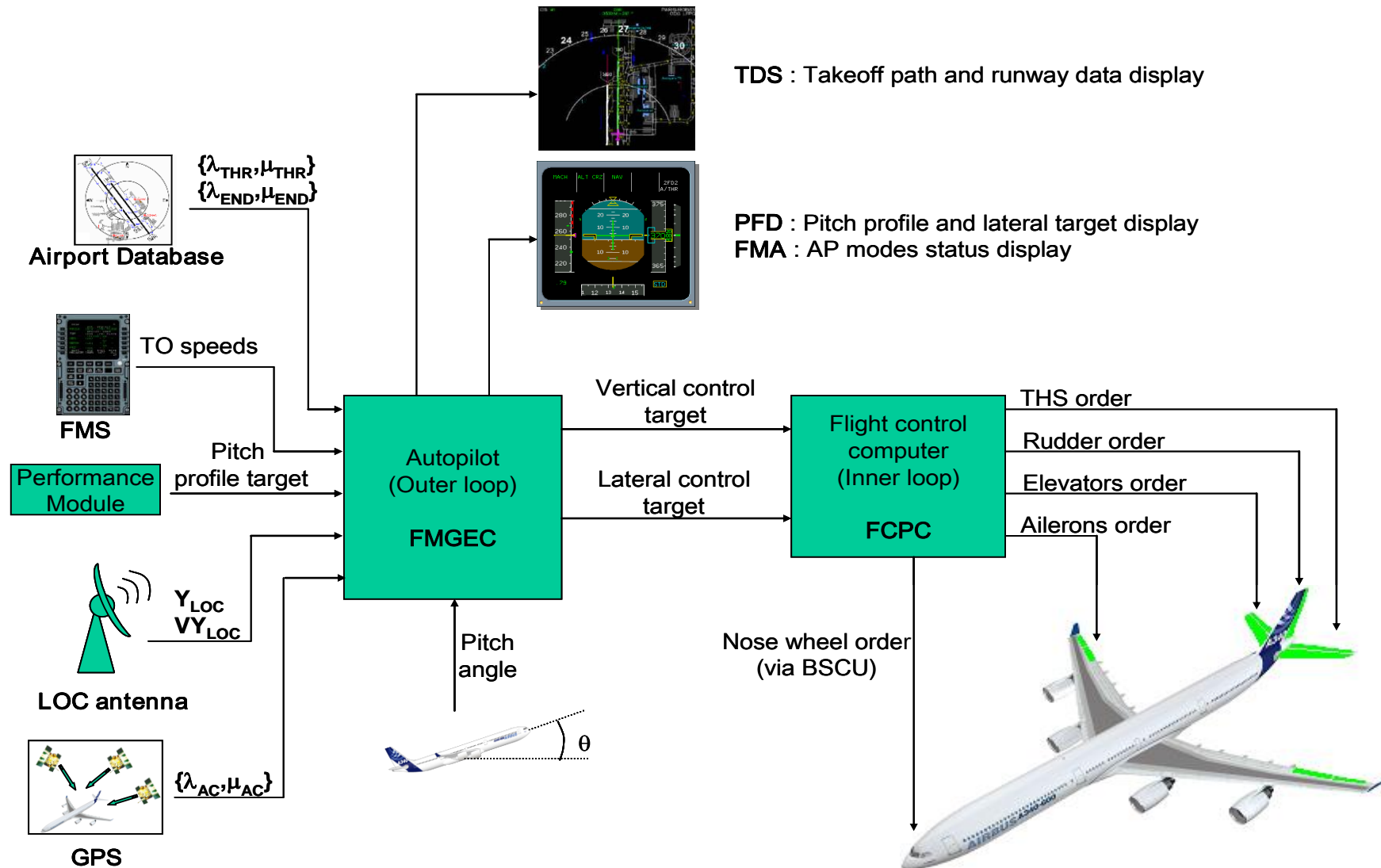
AUTO TO mode is disengaged by two means :

- . Manually if the pilot disengages the AP by:
 - . Pressing the AP pushbutton on FCU
 - . Pressing the takeover pushbutton on the side stick
 - . Pushing on the side stick harder than a certain threshold
- . Automatically if :
 - . Another vertical mode engages (SRS mode) or
 - . Loss of system or performance conditions (AP is disengaged only in this case)

In all AP disengagement cases, AUTO TO reverts to SRS (FD mode)

System Architecture

• Full automatic takeoff system architecture



SUMMARY

- AP/FD TCAS Mode
- BTV / ROPS
- Auto Take-off
- **Taxi Driver System**
- Auto Pull Up
- Other subjects

Taxi Driver System

- Ground control next step: 2D Taxi Control Function

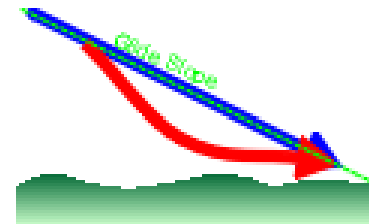
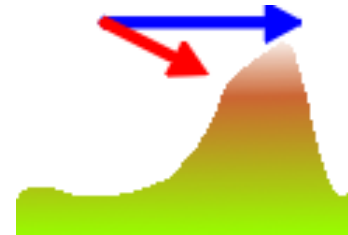


SUMMARY

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- **Auto Pull Up**
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TAWS (Terrain Awareness and Warning System) principle:

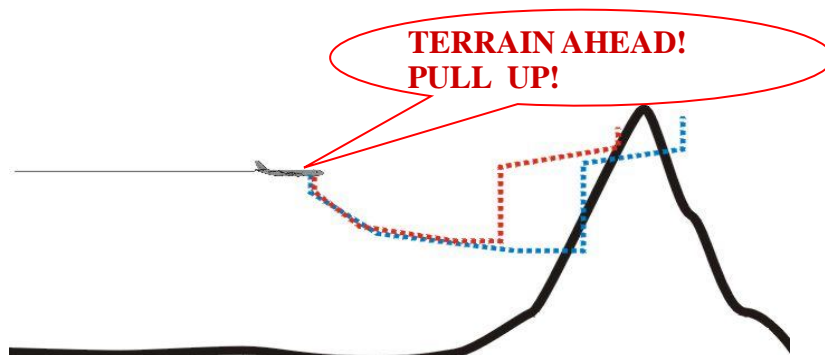
- The TAWS purpose is to alert and display the terrain (on the ND) to warn the pilot about a potential collision with terrain.
- The EGPWS monitoring is done thanks to:
 - Parameters coming from aircraft systems:
 - RADIO-ALTI
 - ADIRS
 - ILS
 - FCU
 - AFS
 - Mundial terrain Database (including high buildings)



Auto Pull Up

- Auto Pull up

- Main driver: CFIT prevention
 - ➔ in the past 8 years, 1/5 of total commercial jet a/c accidents is a CFIT
- Coupled with TAWS for terrain avoidance

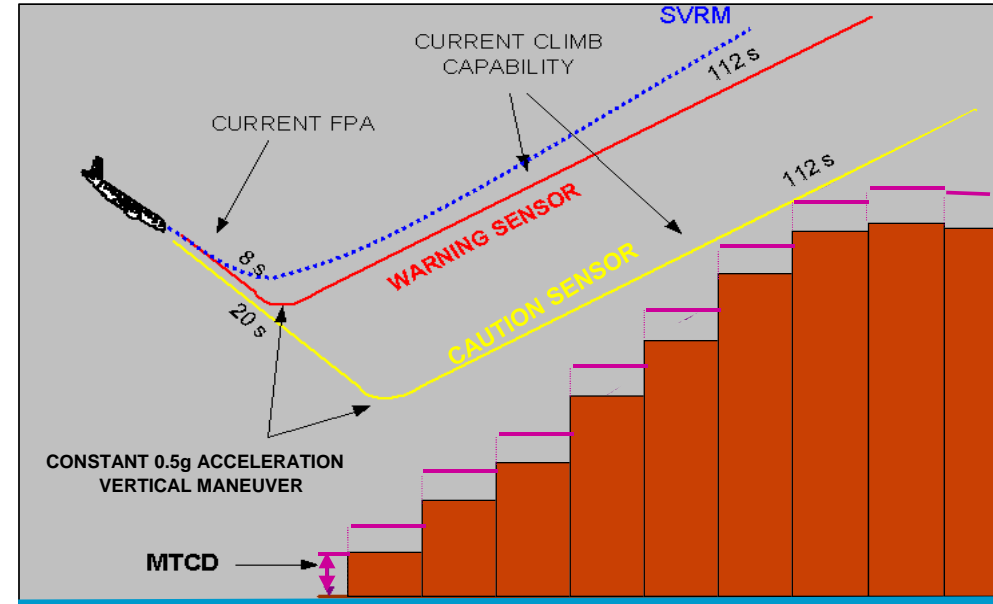


TOGA LK

PULL UP

HDG

AP1
1FD2
A/THR



SUMMARY

- AP/FD TCAS Mode
- BTV / ROPS
- Auto Take-off
- Taxi Driver System
- Auto Pull Up
- **Other subjects**

- **TCAP: altitude capture to avoid RA**
- **Manual AP protection: no more AP disengagement in normal law (A350)**
- **Alternate AP: provide AP-FD-A/THR without speed information**
- **Alternate VCAS: provide AP-FD-A/THR with a speed information built based on engine pressure sensors (A350 / NEO)**
- **No AP loss: « minimal » AP in SEC computers**
- **Autoland on runways with strong slope: +/- 2° instead of +/- 0.8° today (SA)**



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