Development of intelligent Braking Systems and Runway Overrun Protection for the Airbus 380

Presented by
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AIRBUS


A380
A380 AIRBUS

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Today’s possibilities

- Manual Braking by the pilot, which often leads to big braking asymmetry

- Auto braking systems with different deceleration levels
  - Are blind to present runway position
  - Do not respect the real intent of the pilot to decelerate to taxi speed at a particular runway exit

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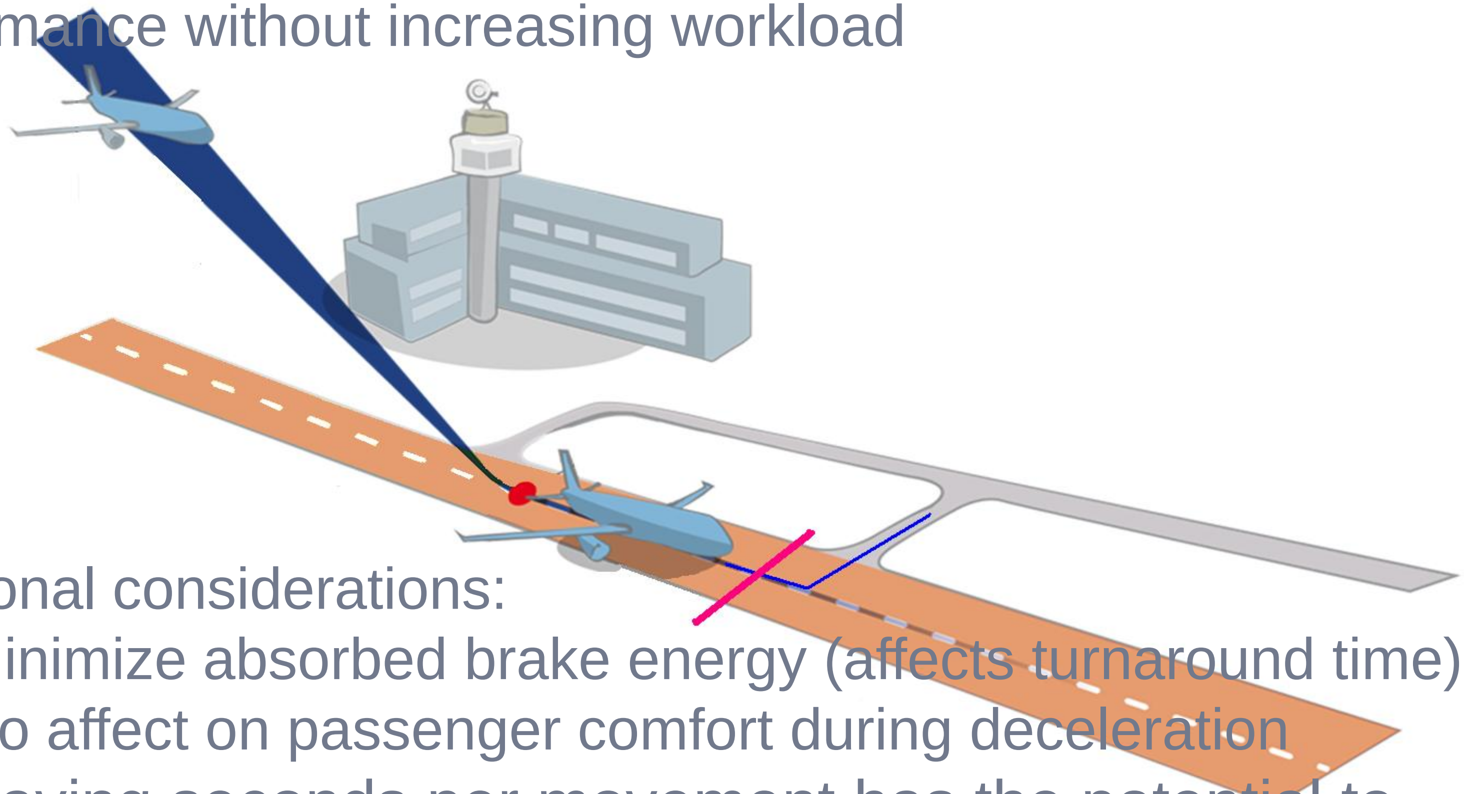
Objective and Concept of (B)rake (T)o (V)acate

Objective: ***Auto brake to a specific speed and to a specific Runway exit***, while increasing pilot awareness of runway performance without increasing workload

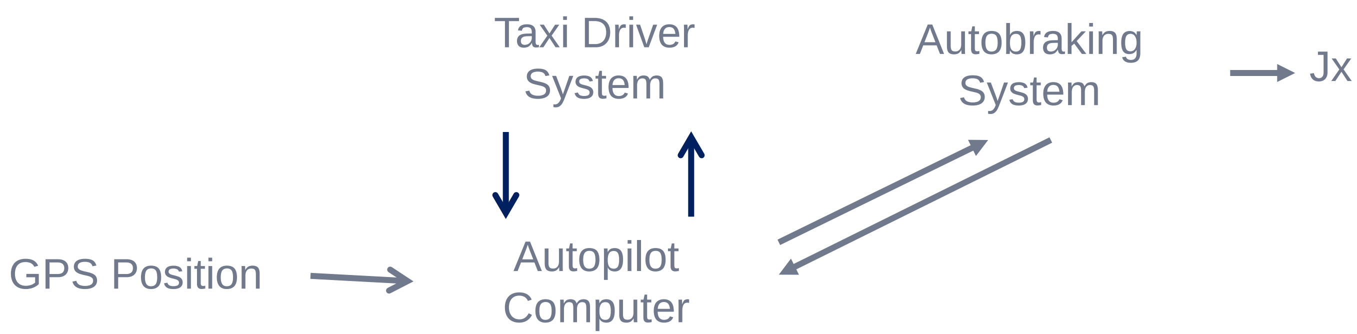


Additional considerations:

- Minimize absorbed brake energy (affects turnaround time)
- No affect on passenger comfort during deceleration
- Saving seconds per movement has the potential to increase capacity

The Initial Concept

- Utilize position information from an Airbus prototype of an airport navigation system displayed on an EFB
  - Taxi Driver System (TDS) was a prototype software application running on a simple PC



- 1st Mod: Braking algorithms and aircraft performance calculations installed in a modified autopilot computer
- 2nd Mod: Autobraking system adapted to accept any variable program that was sent to it

Some Early Decisions

- Provide auto braking symbology on the airport nav display
- Continuously computes ***wet*** and ***dry*** landing performance
  - Approaching the airport: utilizes ***pilot inserted*** environmental data
  - Below 500 feet RA: utilizes ***actual*** data (wind, temp, total energy)
- Exit overrun use existing HI auto brake setting
- Runway overrun predictions = Max braking
- Parallel computations in the Autopilot Computer:
  1. To release at 10 knots at any desired intersection
  2. To release at 0 knots at the end of the runway

- ***Mode reversion when an inconsistency is detected to BRK HI***

BTV selection:

- Cursor on LDG Runway

BTV selection:

- Click on the blue box

BTV selection:

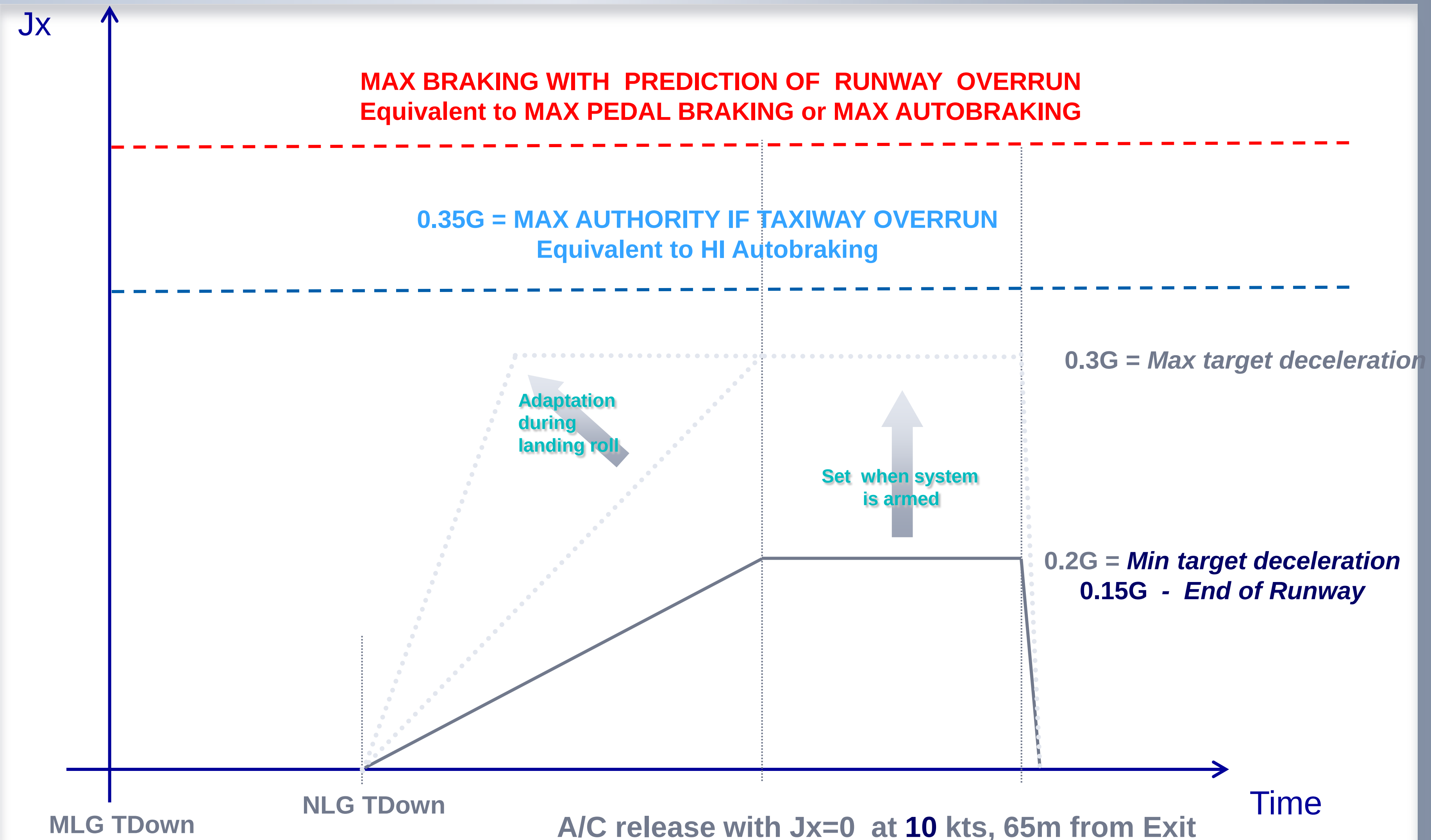
- Select Exit after dry line

BTV selection:

- Check ROT and Turnaround Time

ACTIVATE BTV

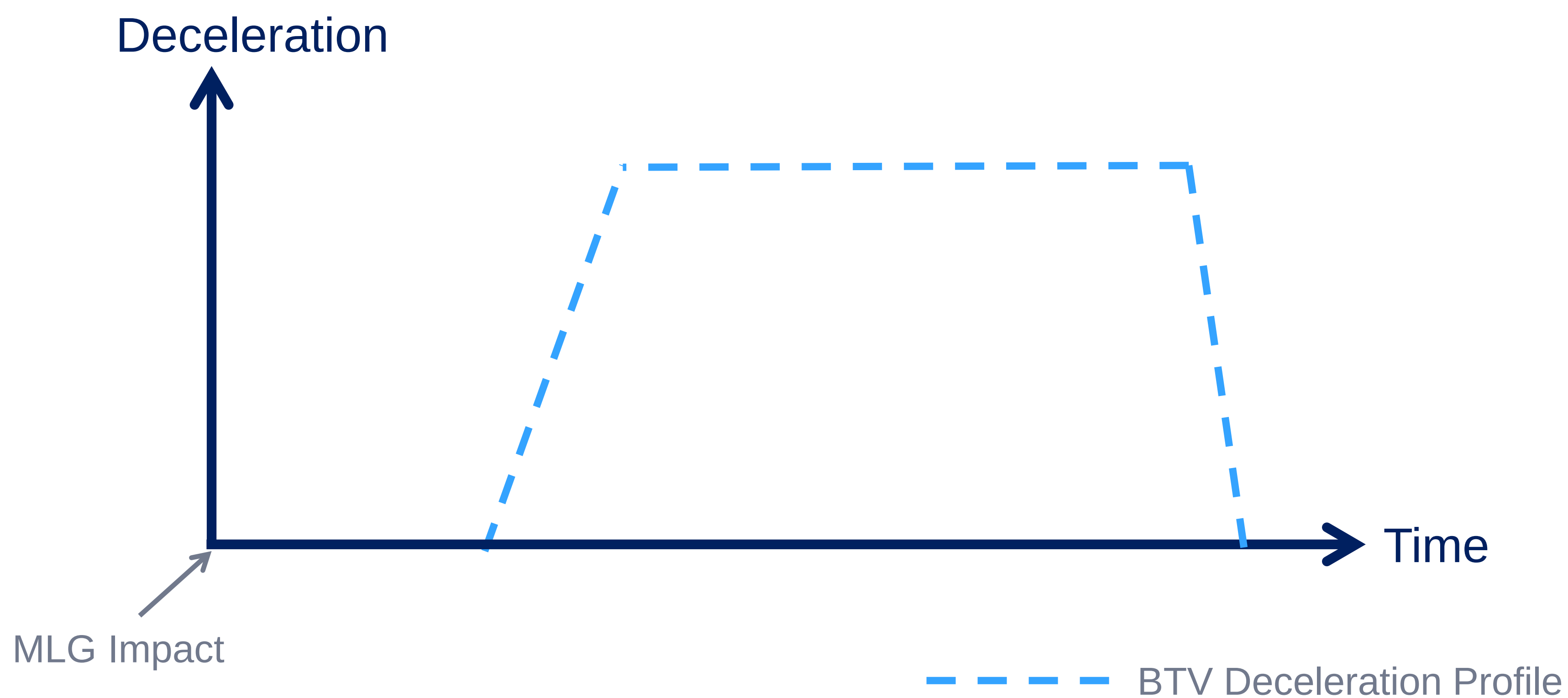
Braking Control Law Principle



How to use BTV?

How does BTV manage the braking applications? (cont'd)

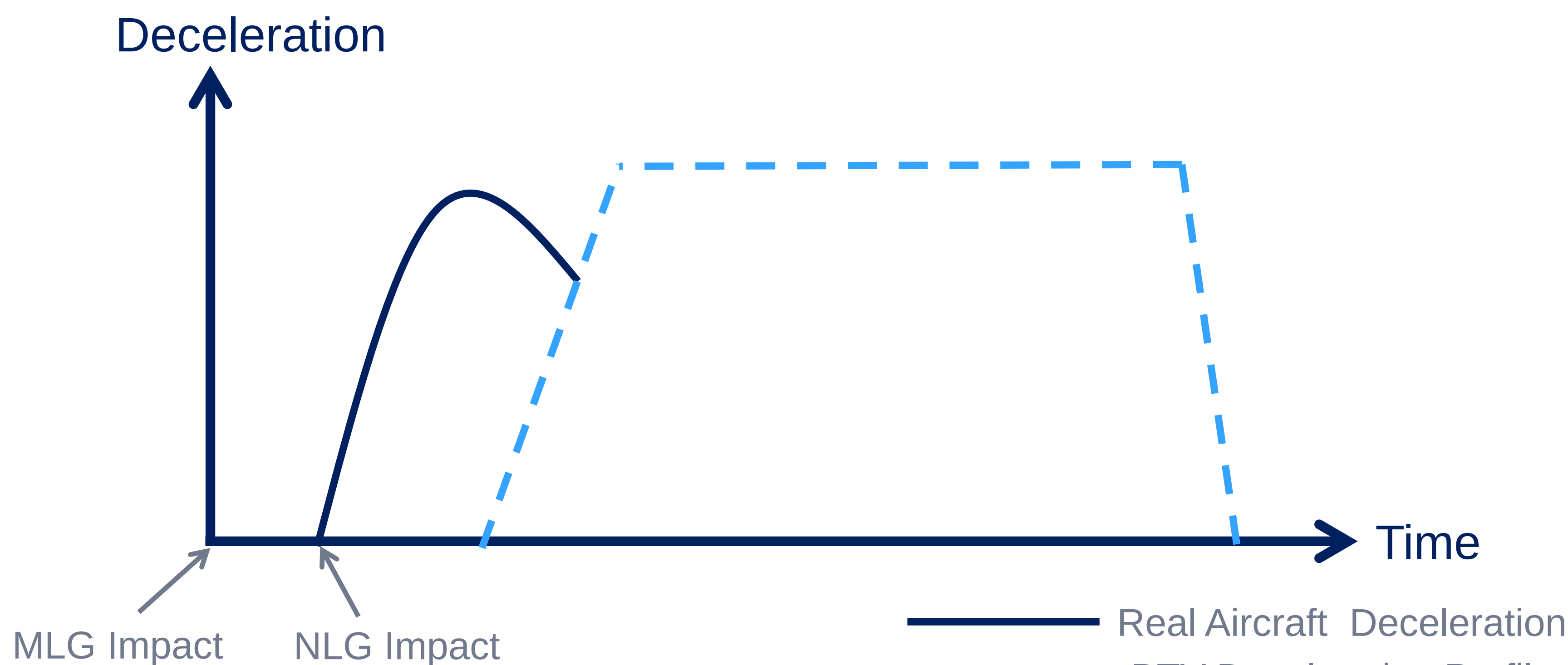
- BTV deceleration profile



How to use BTV?

How does BTV manage the braking applications? (cont'd)

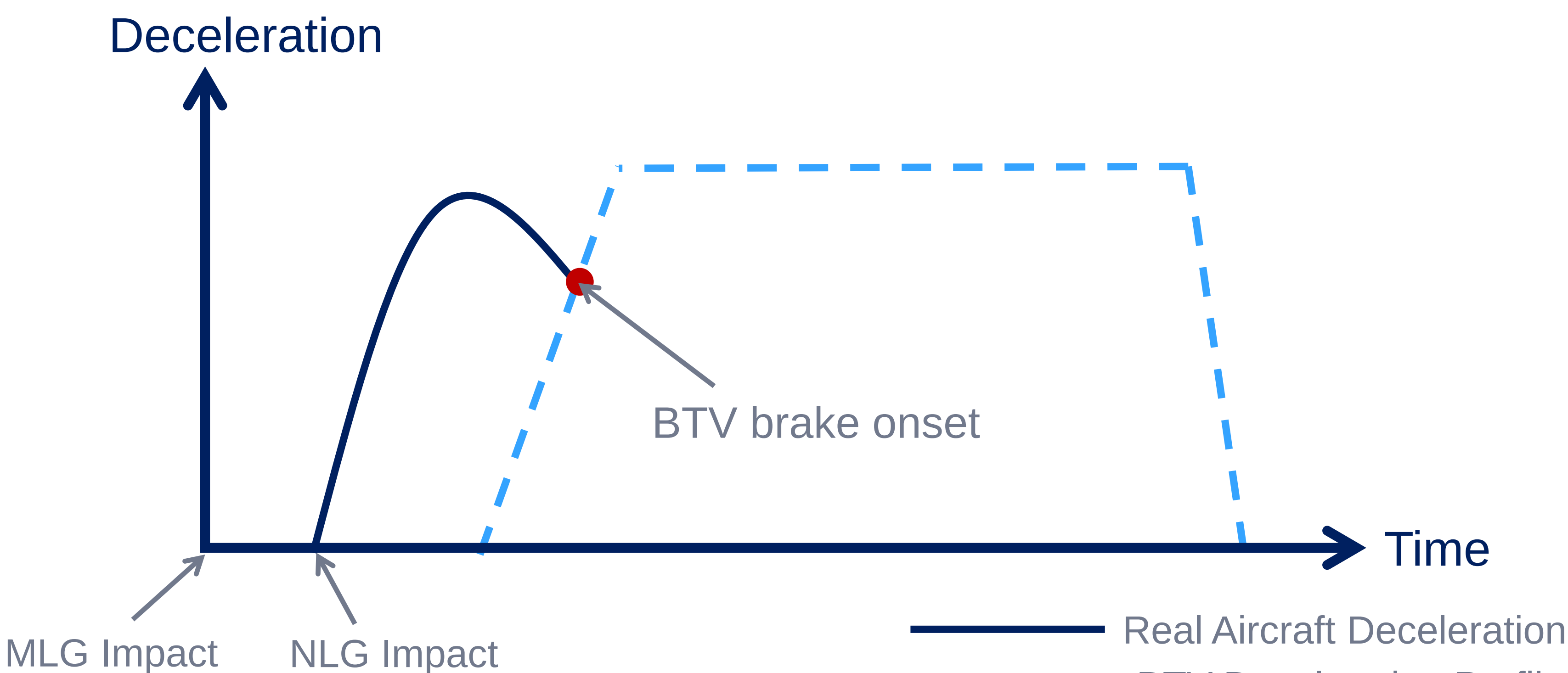
- At aircraft touchdown, the aircraft decelerates thanks to aerodynamic drag, and thrust reversers



How to use BTV?

How does BTV manage the braking applications? (cont'd)

- BTV starts to command brake application, when the real aircraft deceleration reaches the deceleration profile



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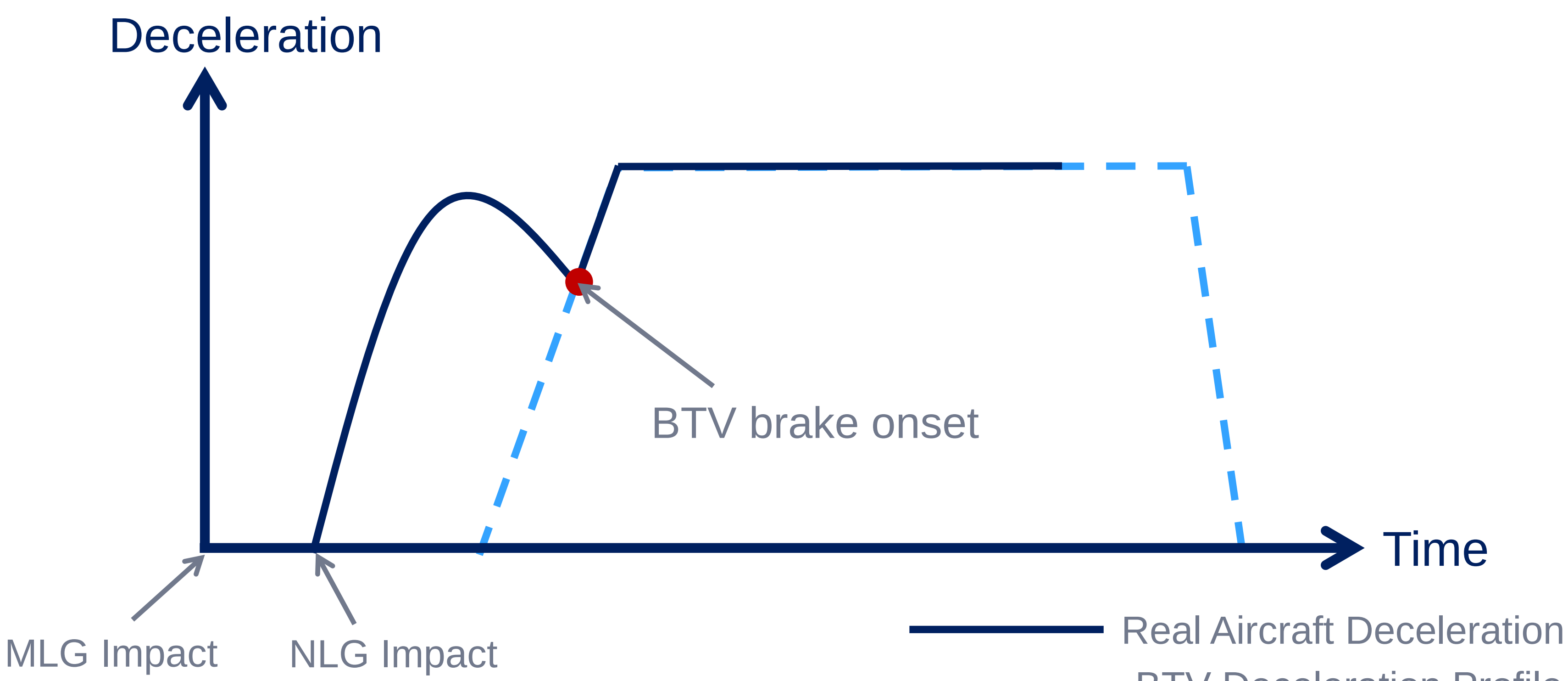
How to use BTV?

How does BTV manage the braking applications? (cont'd)

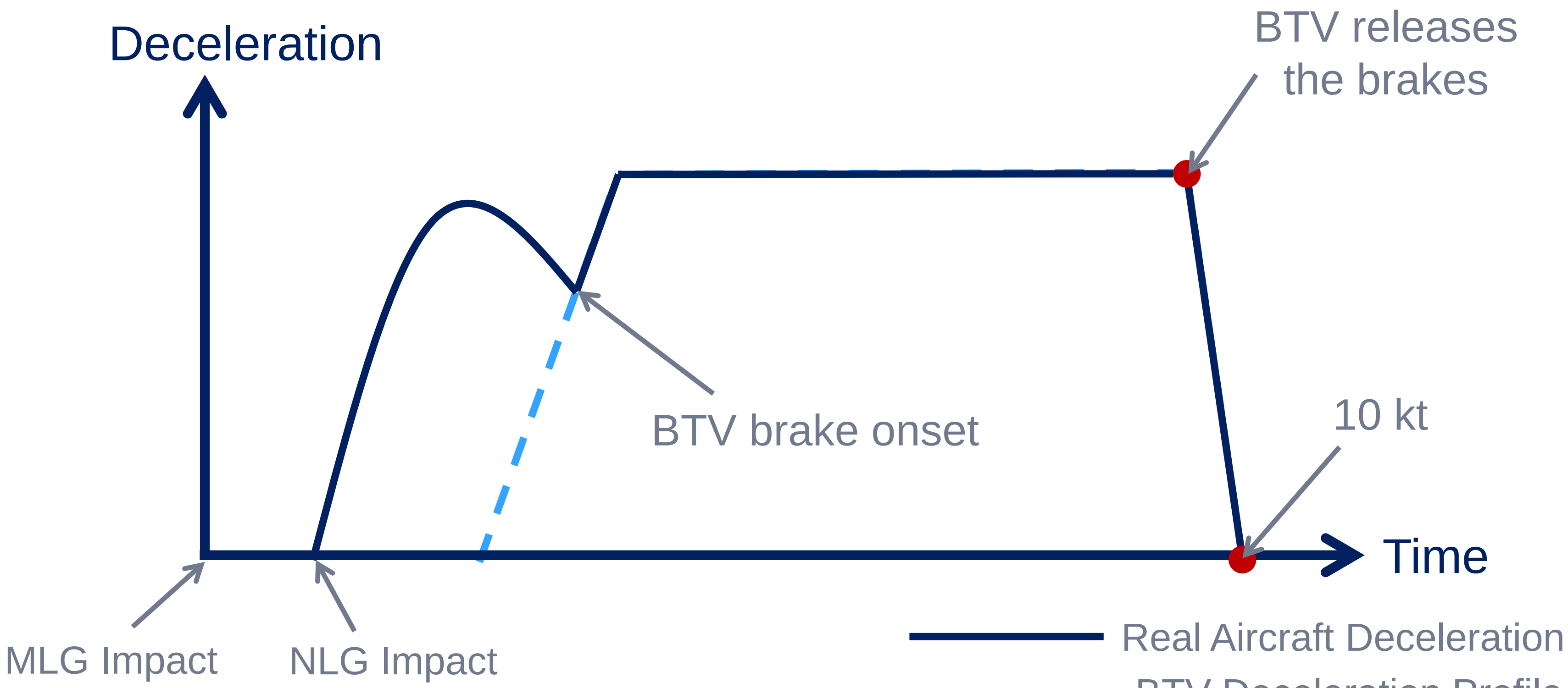
- From the intersection point, the aircraft deceleration follows the BTV deceleration profile



How to use BTV?

How does BTV manage the braking applications? (cont'd)

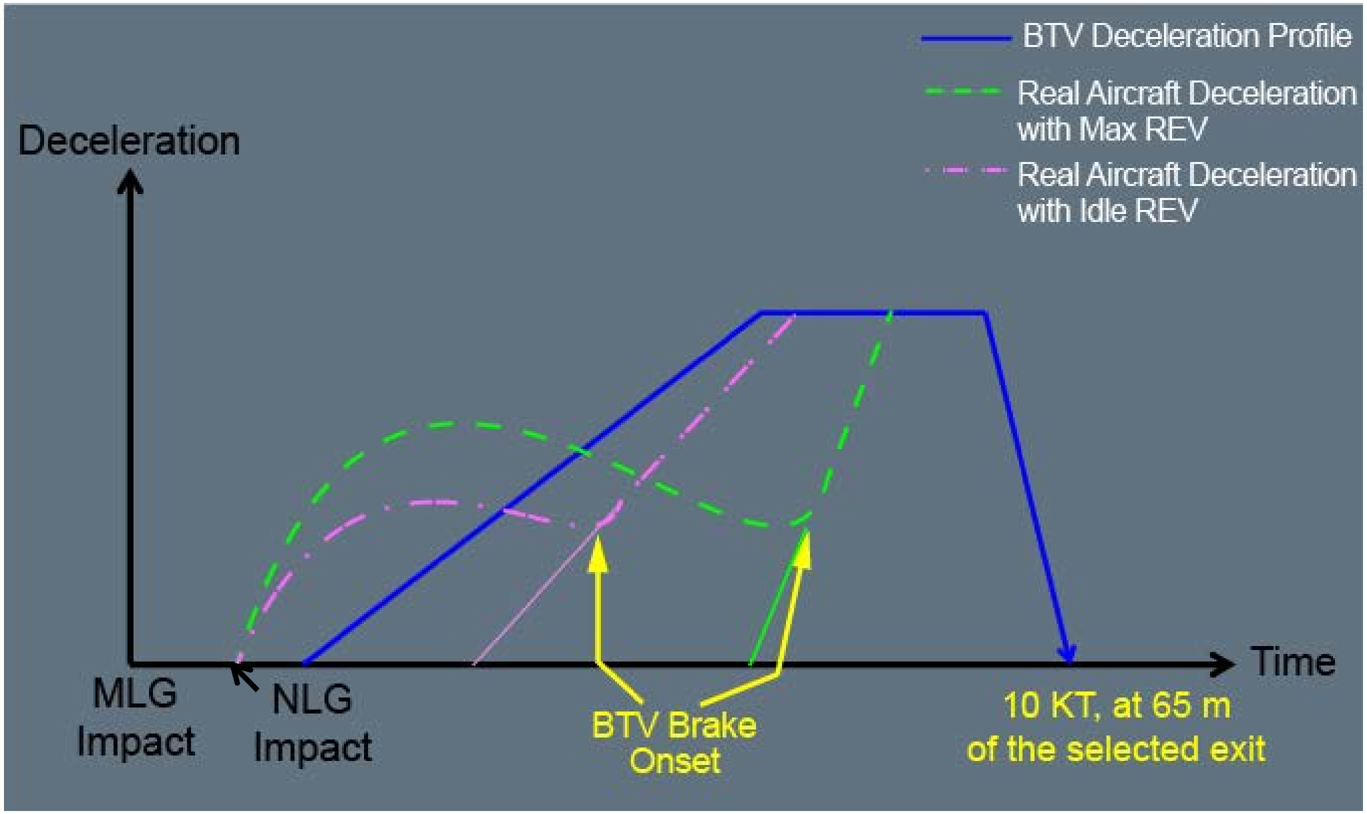
- Brake release at 10 kt, at 65 meters from the selected exit



How to use BTV?

How does BTV manage the braking applications? (cont'd)

- Deceleration profile computed in real time during the landing roll, to take into account:
  - Ground speed, aircraft deceleration, aircraft position

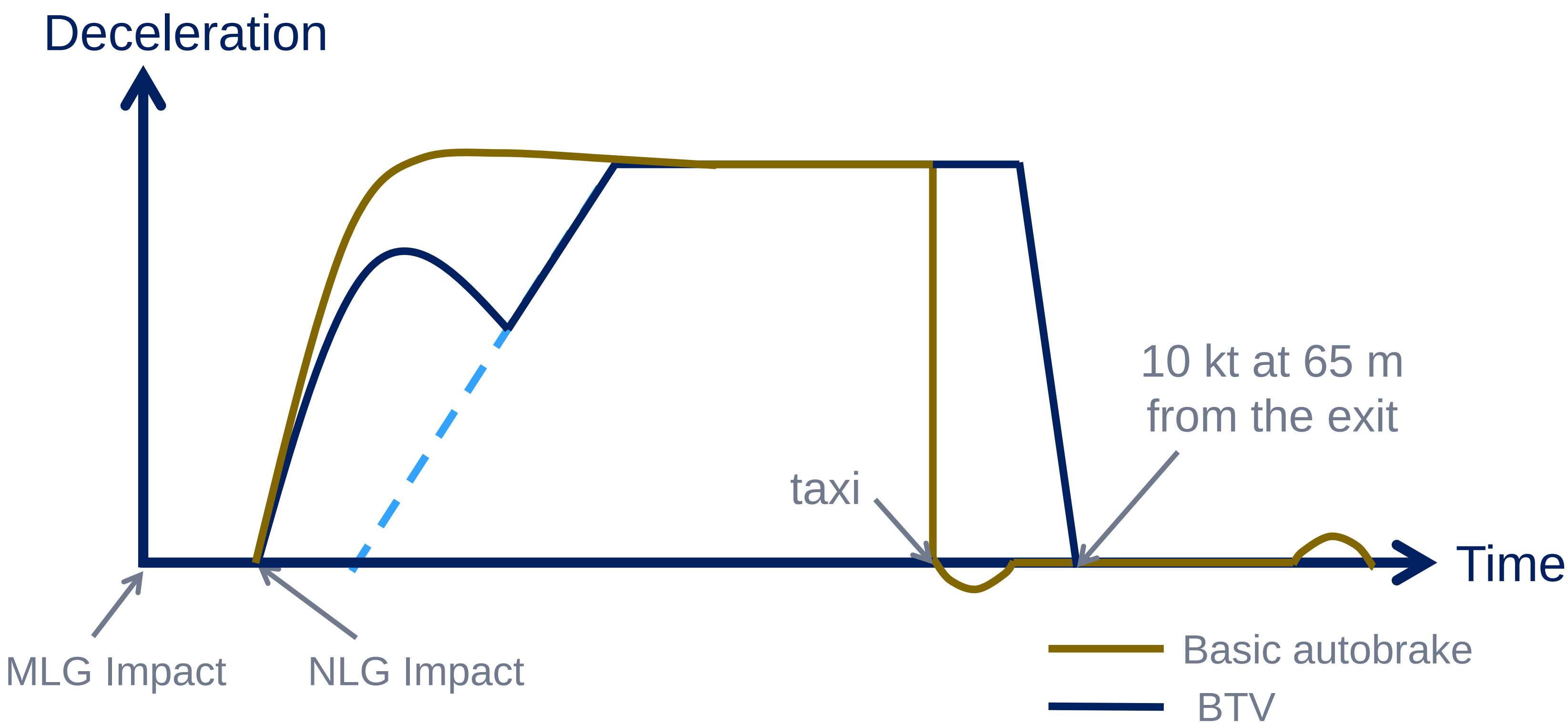


How to use BTV?

How does BTV manage the braking applications? (cont'd)

Comparison with basic autobrake mode

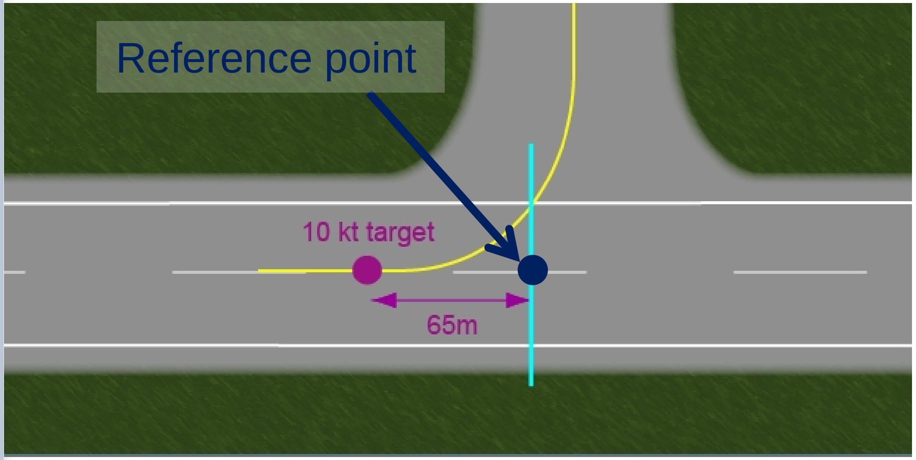
- In basic autobrake mode, at NLG touchdown, the autobrake targets a constant deceleration profile



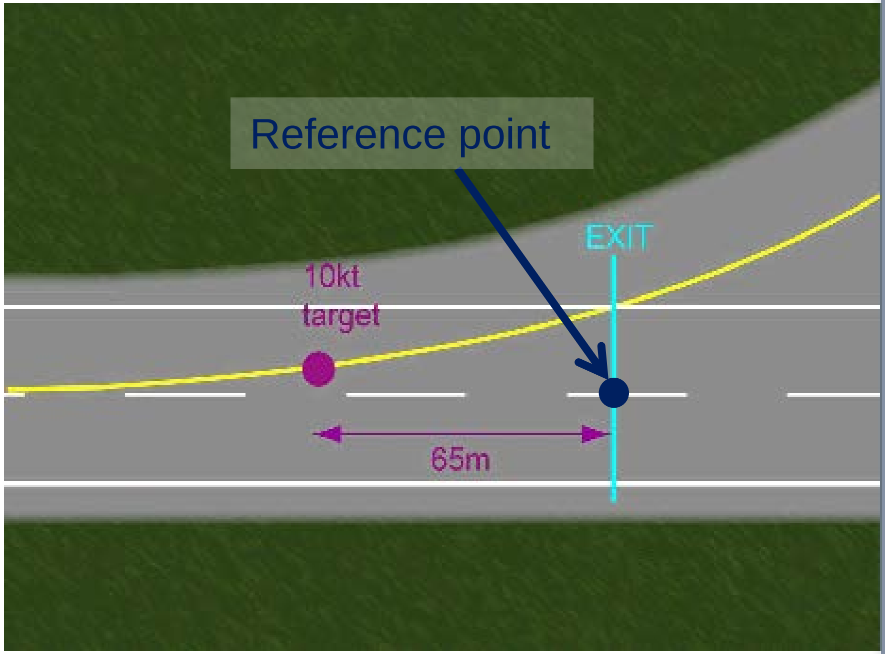
How to use BTV?

How to manage a high speed turn-off

- BTV targets 10 kt at 65 m from the exit, whatever type of exit



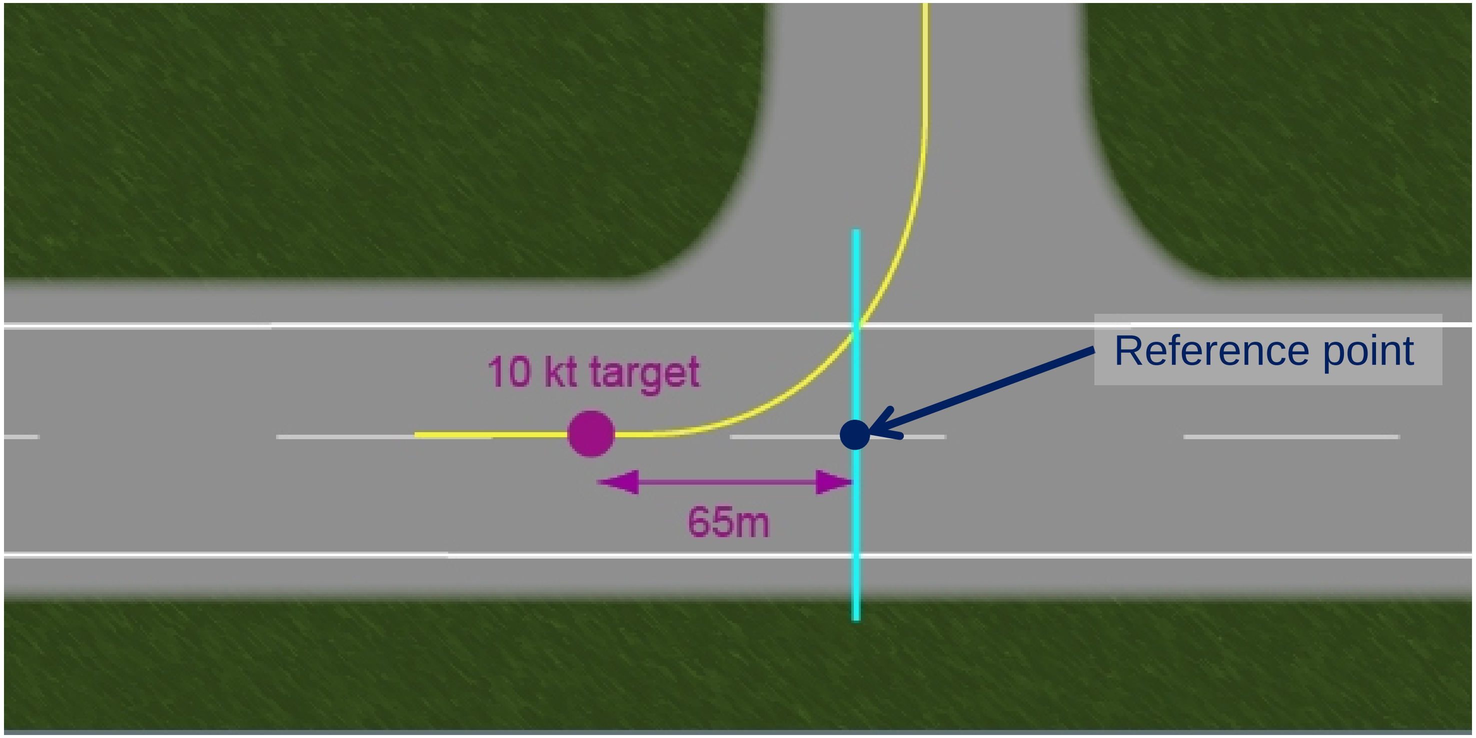
90° exit



High speed turn-off

How to use BTV?

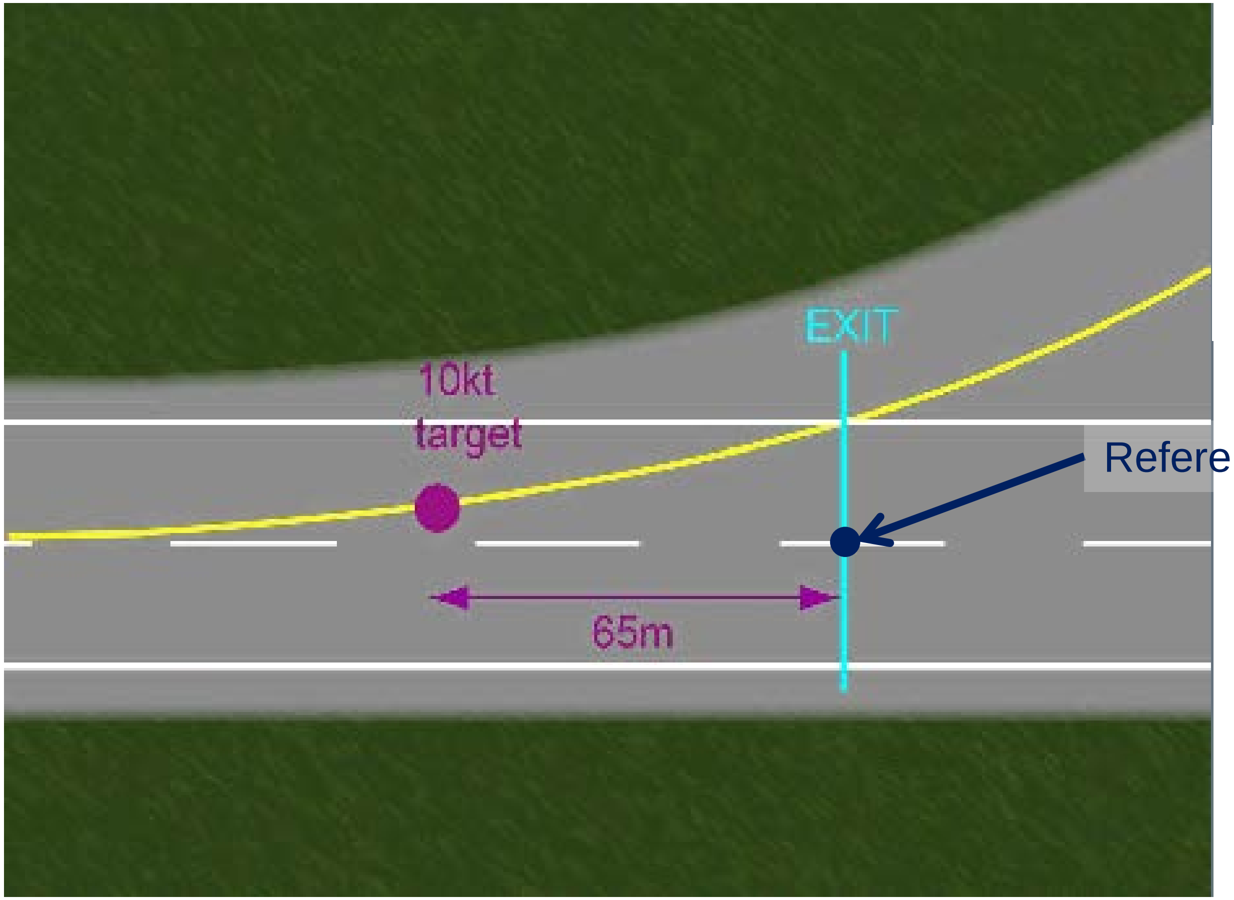
How to manage a high speed turn-off (cont'd)



90° exit

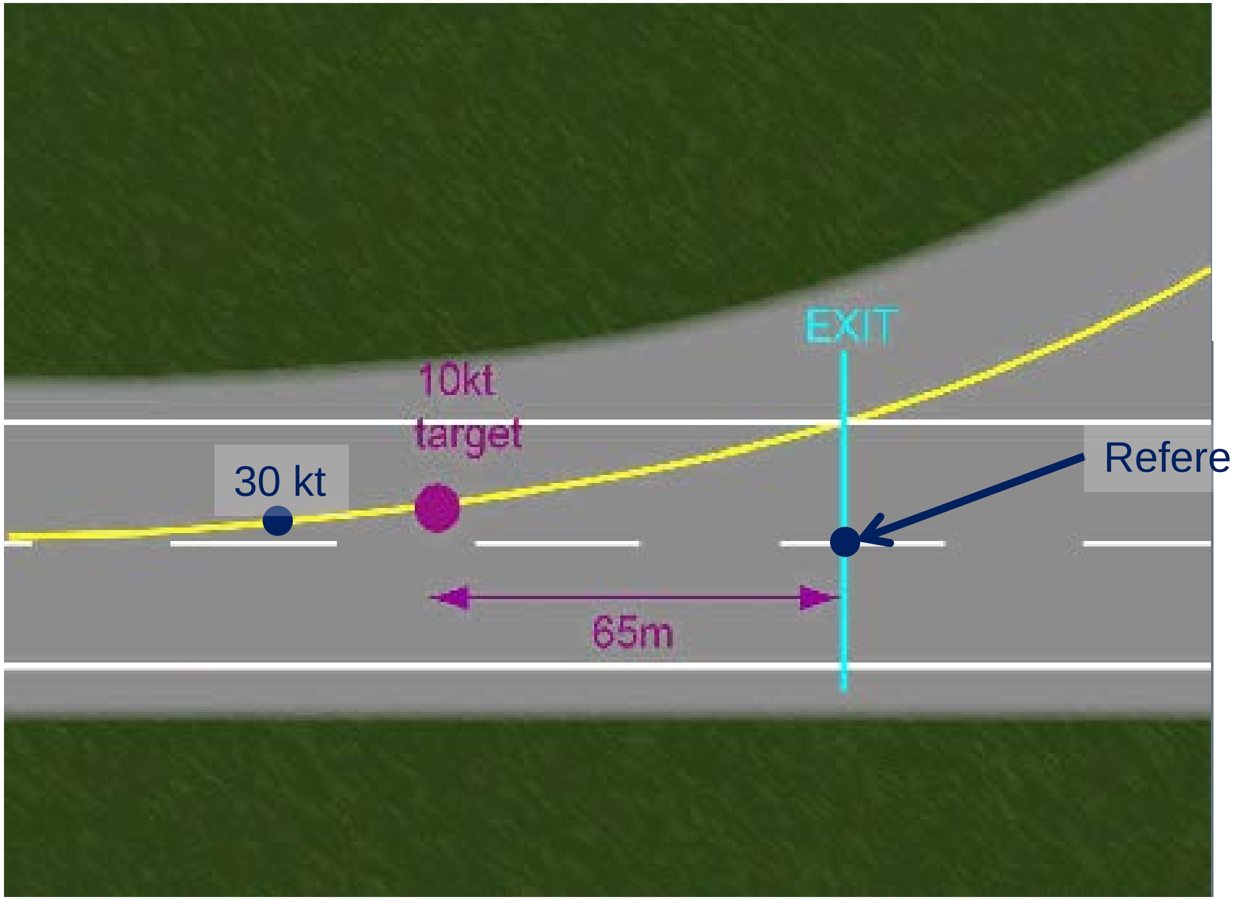
How to use BTV?

How to manage a high speed turn-off (cont'd)



High speed turn-off

How to use BTV?
How to manage a high speed turn-off (cont'd)



High speed turn-off

How to use BTV
Management of missed exit

- If BTV detects that the exit will be missed:
  - BTV targets 0.35 g
  - If exit missed confirmed: EXIT MISSED on FMA

  - In order to avoid strong braking (and if long runway):
    - The flight crew can deactivate BTV
    - Apply manual braking to next exit.

Runway Modifications in the OANS

- ***Runway can be shortened for LAHSO or NOTAMed closures***

The Maximum Overweight Landing Demonstration

22 December 2008

Ramp Weight: 604.3t
ZFW: 345.7t , incl 40t water ballast
Fuel: 258.6t
Takeoff : 603.5t
Landing : 596.3t Normal Max Landing Weight: 391t

Development Timeline

A340-600 prototype:

- 10 major iterations of the control software
- 5 major iterations of the interface through TDS (EFB with moving map + touch screen)
- 120 landings from minimum weight to above MLW

Principle then simulator studies

04/2004:
1st flight on A340-600 prototype

03/2005:
flight to CDG braking demonstration with top A380 program managers **=> *decision to launch on A380***

07/2007:
last and 21st flight on A340-600 proto

05/2008:
1st flight on A380

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12/2008:
Maximum overweight landing with EASA test pilot

9/2009 Certification

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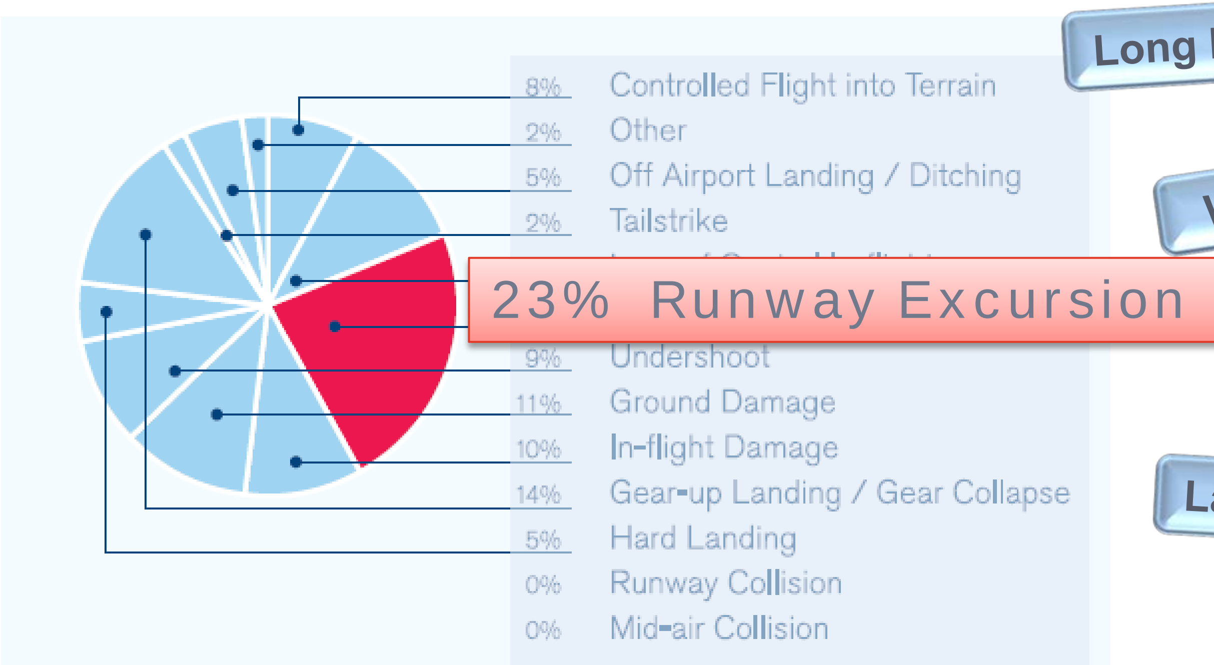
Reducing runway excursion: a safety priority

IATA Safety Report 2010
Breakdown per Accident Category



- Non-Stabilized approaches
- Long Flare /Long Derotation
- Wind shift at low altitude
- Contaminated Runways
- Late selection of reversers
- Late Manual braking

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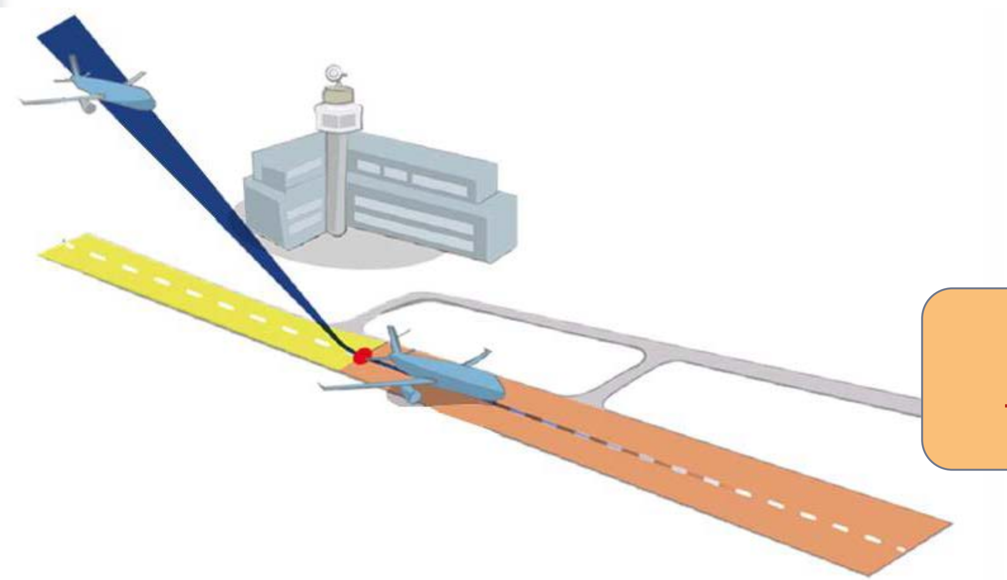
ROPS Principle

ROPS

Runway Overrun Prevention System



HELPS

CREW DECISION MAKING

WARNS

THE CREW IF RUNWAY TOO SHORT

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ROPS Principle

TAWS

Runway data and Aircraft position

ROPS
Runway Overrun Prevention System

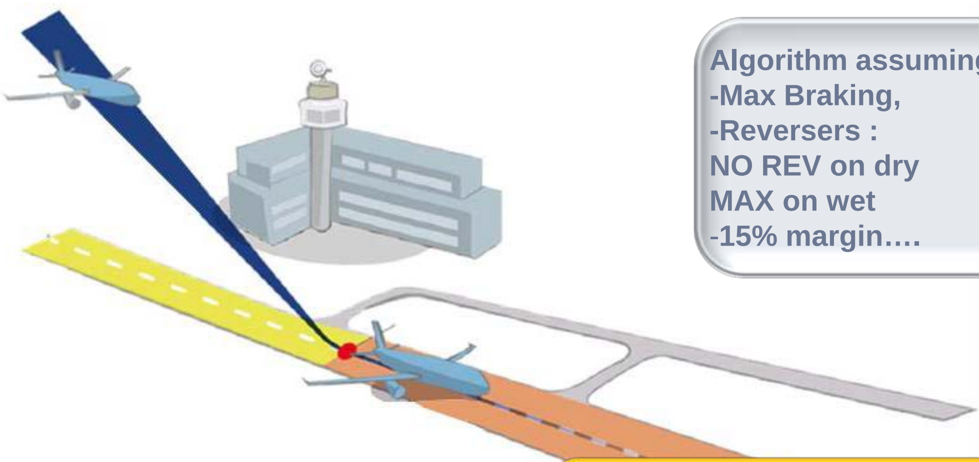
Ground Speed

Vertical Speed

Landing Configuration

Wind

Algorithm assuming :
-Max Braking,
-Reversers :
NO REV on dry
MAX on wet
-15% margin….



- Landing Distance computation on DRY & WET runways
- Comparison with the runway length

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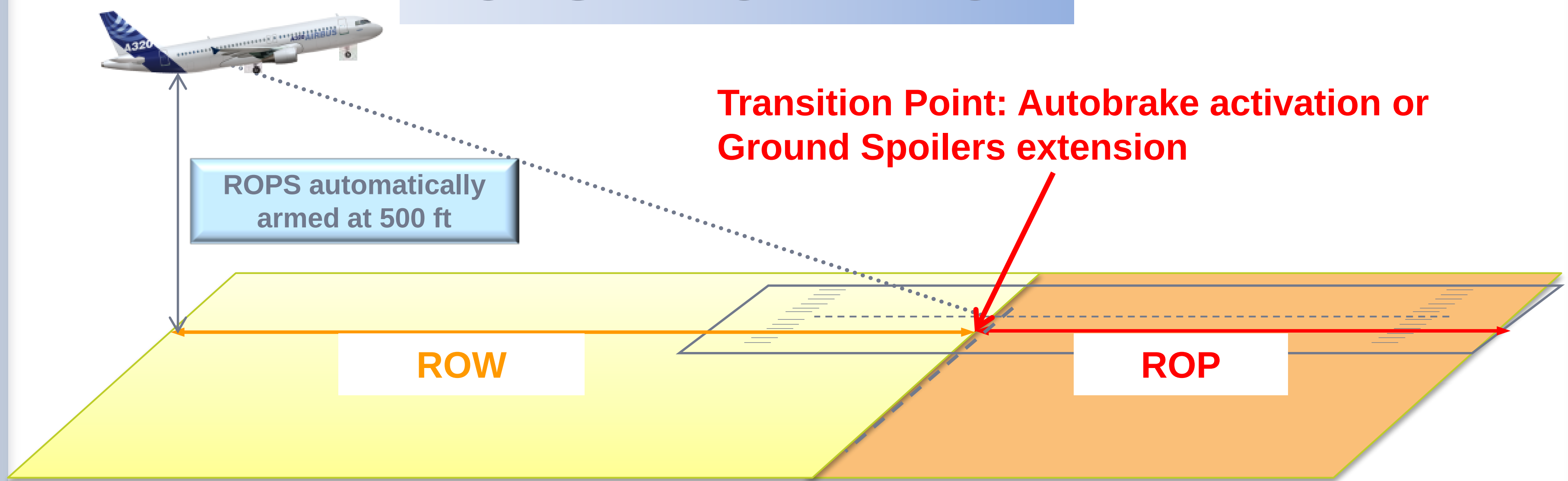
ROPS Principle

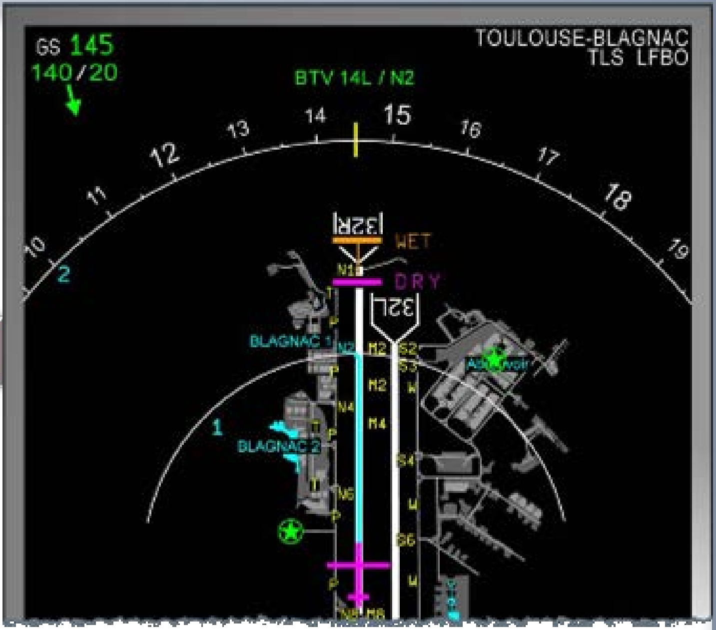
ROPS = ROW + ROP



Runway end Overrun Warning
GO-AROUND

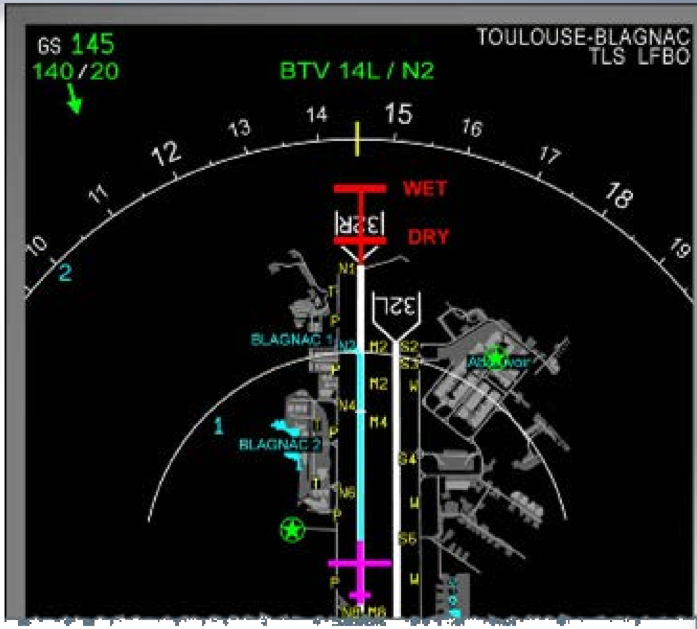
Runway end Overrun Protection
STOP

How does ROW work? Before the Transition point: ROW Alerts



PFD (Below 500 ft)	Audio (Below 200 ft)	Pilot Action (Below 500 ft)
	None	Go-Around Decision If Runway Condition is not DRY

How does ROW work?
Before the Transition point: ROW Alerts



PFD (Below 500 ft)	Audio (Below 200 ft)	Pilot Action (Below 500 ft)
	**"RWY TOO SHORT !"**	Go-Around Decision Whatever Runway Condition

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How does ROP work?
After the transition point: ROP Alerts

PFD	Audio	Pilot Action
	**“BRAKE…MAX BRAKING…MAX BRAKING”** - If Max Braking applied and Max Reverse not selected, **"MAX REVERSE"** **"KEEP MAX REVERSE"**	Max Braking Max Reverse

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Highlights

- Braking control law – Perfect from day one
- Speed at disconnect – set at 10 knots
  - Smooth, symmetrical disconnect
  - Need to fine-tune the distance to the exit (GEO)
  - Need to rethink the brake onset philosophy
- Need to improve management of high speed turnoffs
- Margins when runway end is selected
  - Biggest problem: making pilots comfortable with the braking profile when approaching the runway end

Robustness

During Test's our engineers require us to do "grazy" things

- Steep approaches
- Flat approaches
- Side step landings
- Long Landings
- Bounced Landings
- Reverse manipulations
- Fast Landings
- Overweight Landings
- And approach the **runway end** at high speed to see whether the ROPS is intrusive

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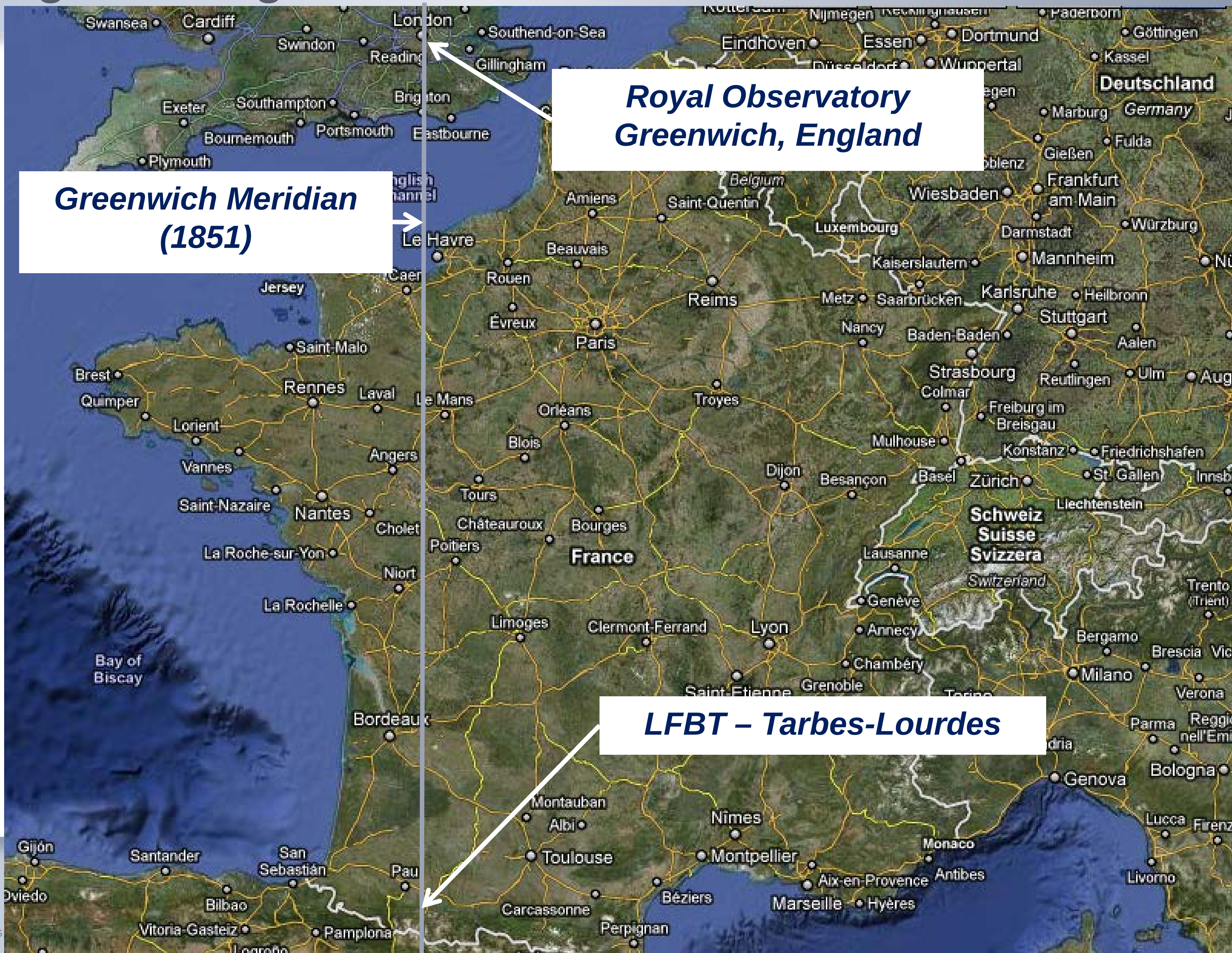
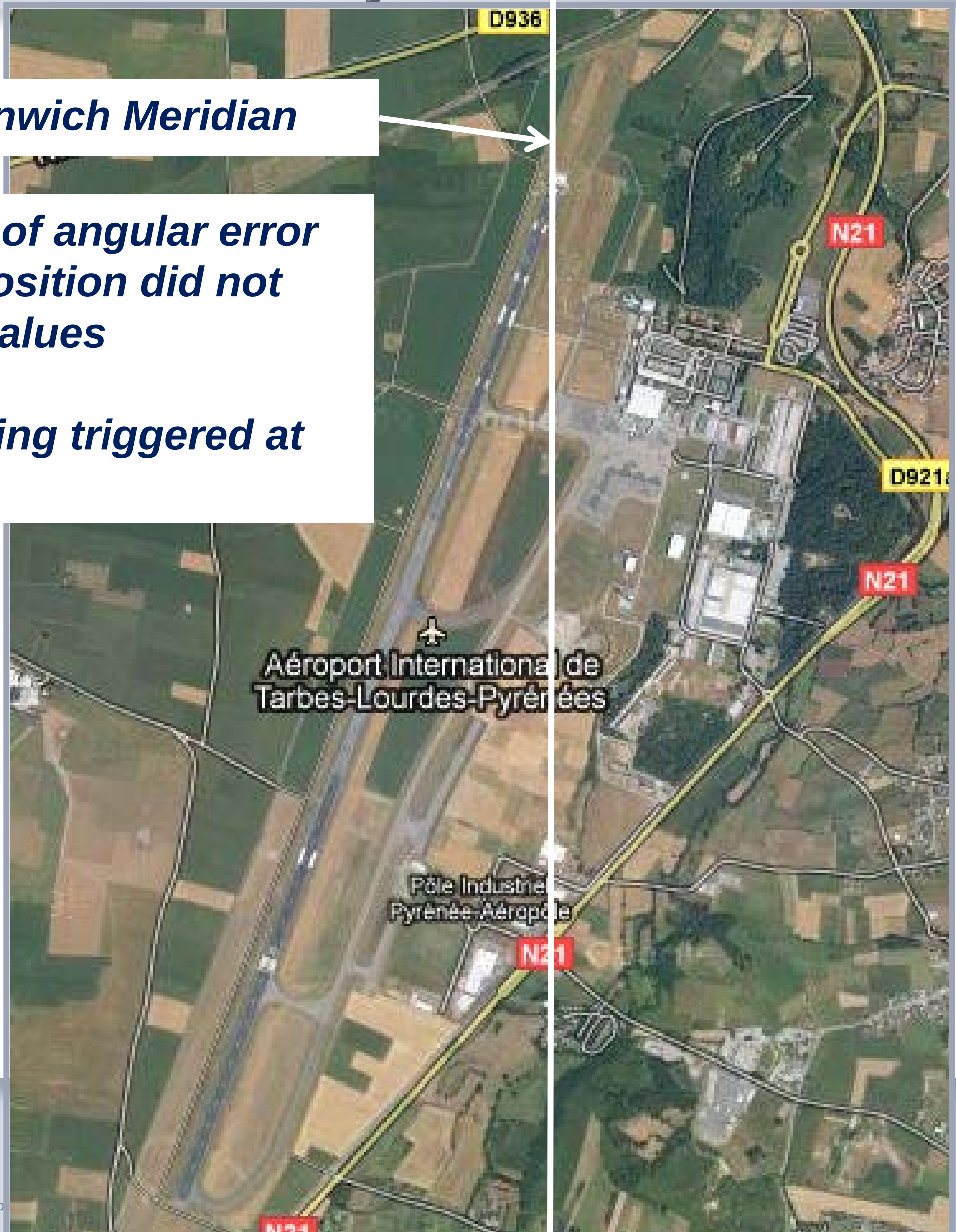
Selecting the Brake Release Point

Programming



The Greenwich Meridian Crosses the Tarbes-Lourdes Runway 20 Threshold



Greenwich Meridian

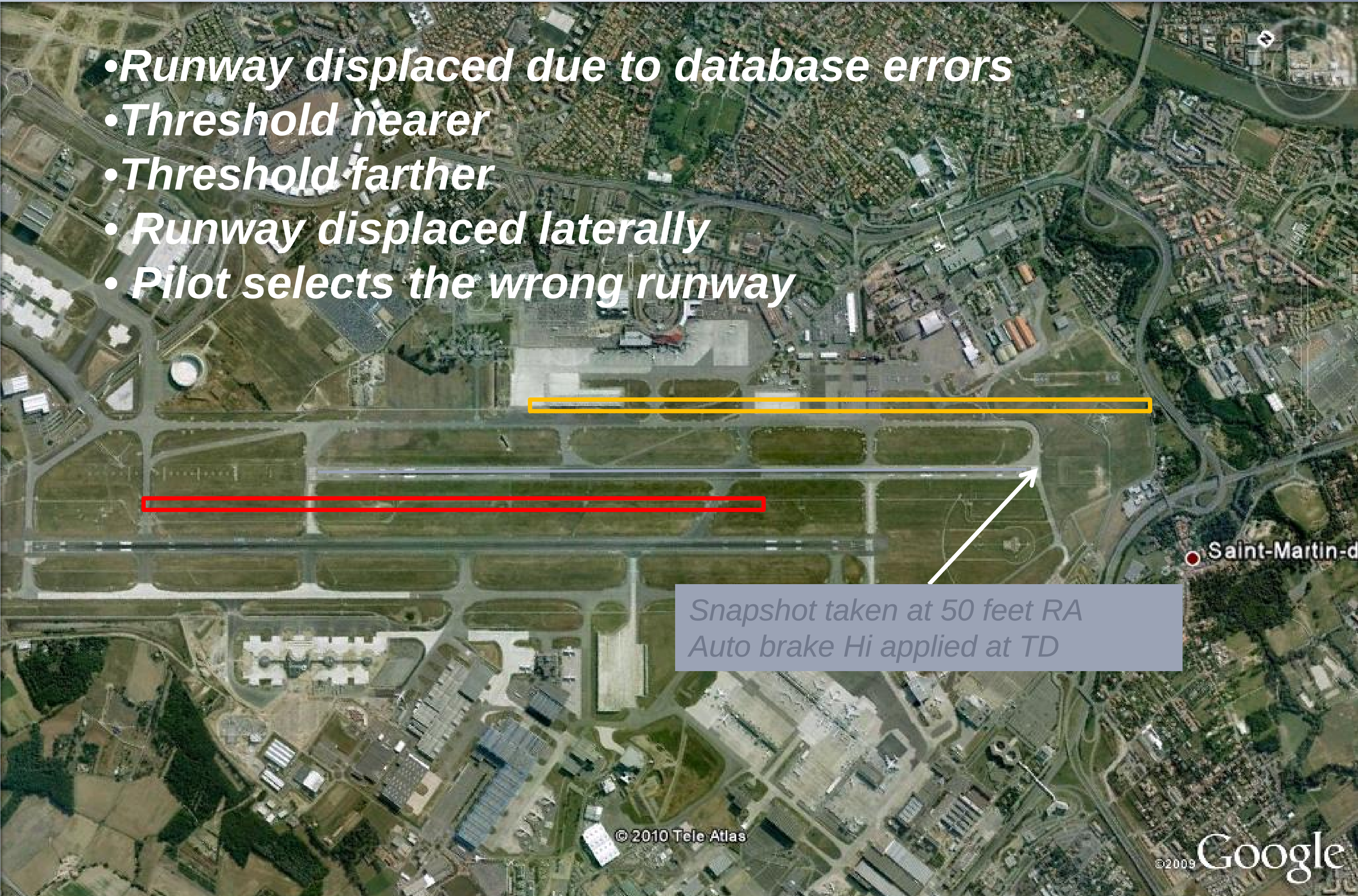
- ***Simple calculation of angular error from a coded x, y position did not consider negative values***

- ***Auto brake HI braking triggered at touchdown***

LL3

Possible Trap: Runway Errors

- *Runway displaced due to database errors*
- *Threshold nearer*
- *Threshold farther*
- *Runway displaced laterally*
- *Pilot selects the wrong runway*



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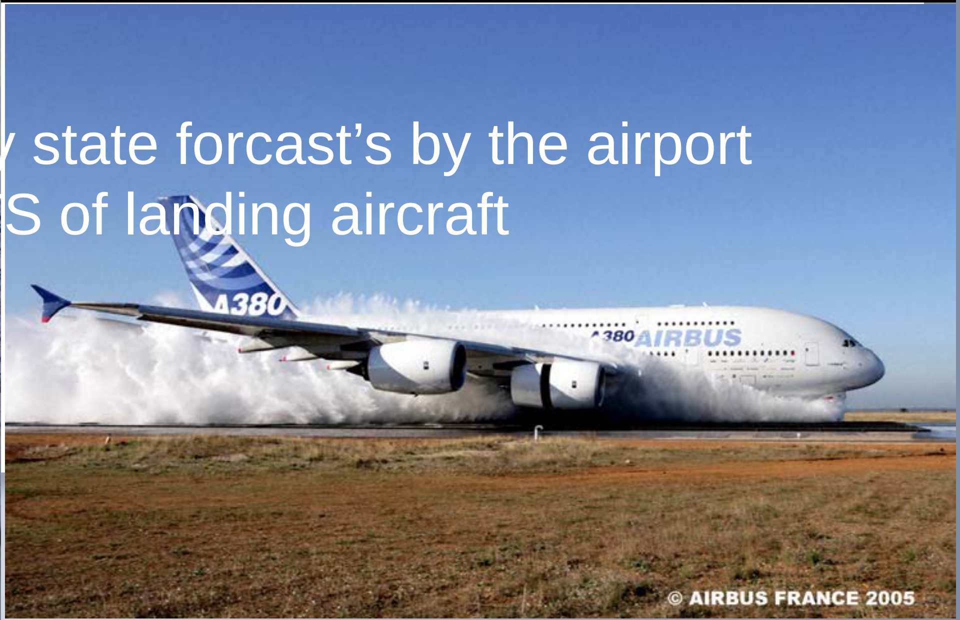
WAY FORWARD

Braking System for all different Runway states



Requirements:

- Reliable Runway state forcast's by the airport
- PILOT REPORTS of landing aircraft

BTV on Contaminated Runways

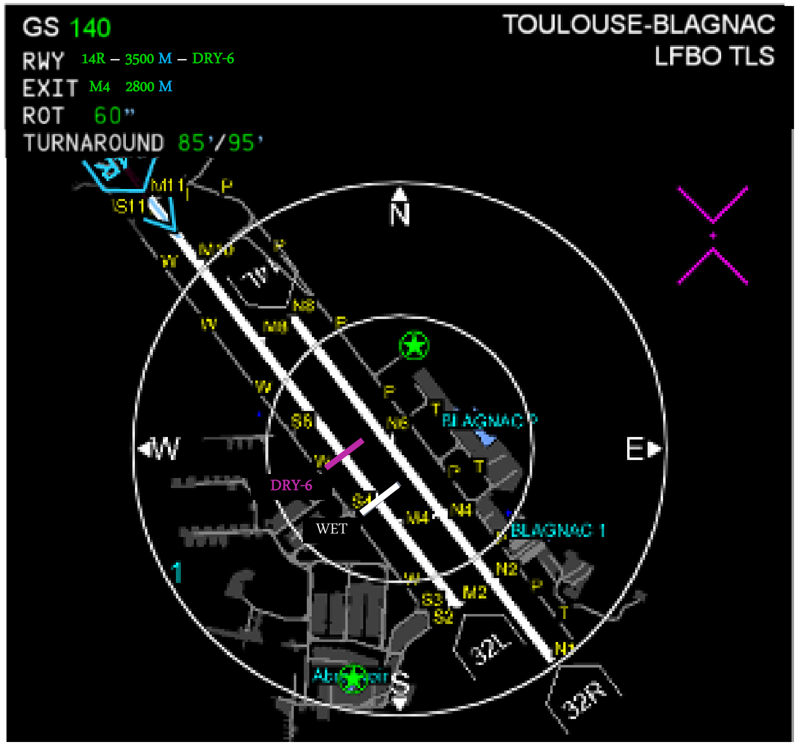
BTV control law will obviously **not delay braking** on contaminated runways.

With selection of a contaminated RWY condition,
BTV will act at high and medium speed as A/BRK MED, to ensure maximum braking limited by anti-skid without delayed braking onset: it will be optimized for **safety**. There might be a low speed progressive release to join the EXIT if this is validated as not misleading in terms of pilot perception during development.

A prototype is currently under development on A380 to anticipate A350 BTV design.

A 350 Interface

- WET bar in white color
- No associated alert
- Disappears when ABRK or BTV armed
- Disappears in case of RWY TOO SHORT conditions detected



A 350 BTV Step 3

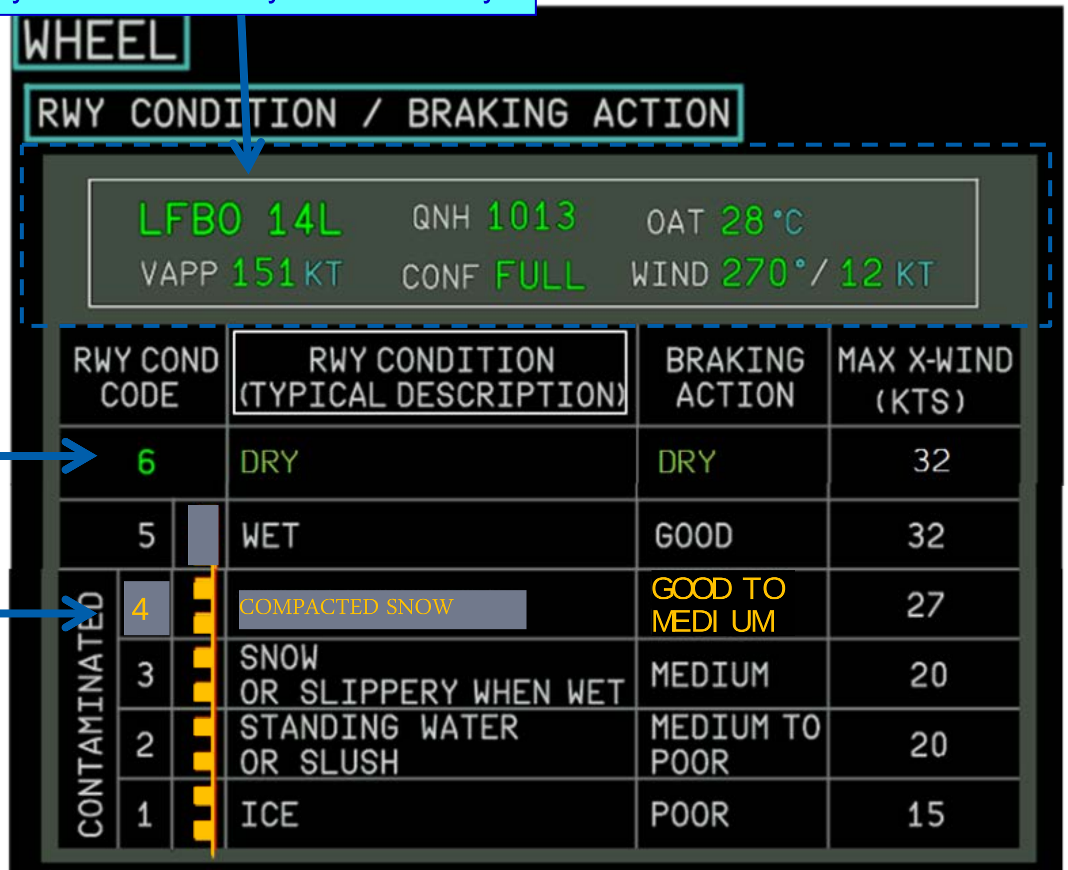
Runway condition Matrix - Content

Dest. Airport code + LDG runway
(cyan if LDG runway ≠ FMS runway

PERF APPR data
If the RWY is unknow, all green values are empty

Active line in green font if TOO SHORT is false

Active line in amber font if TOO SHORT is true



Amber/black rubber for each KO condition. Appears as a continuous symbol, but is actually the association of 1 to 6 individual symbols.
Displayed only if the runway is valid.

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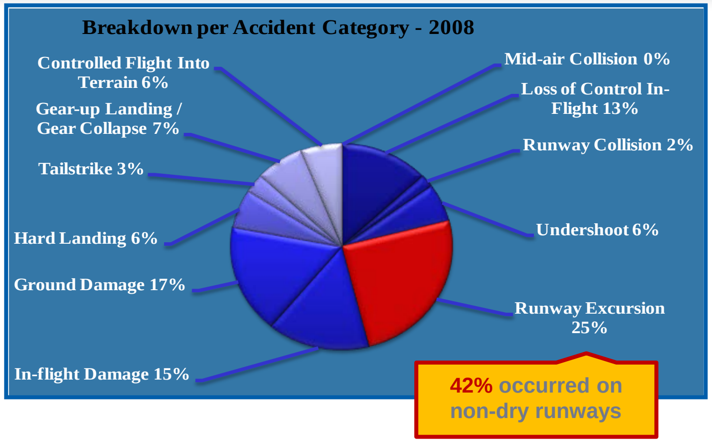
CORSAIR - Generalities
Problematic

- Bad/wrong knowledge of actual **runway condition** at landing is one of the multiple causes of several accidents that occurred in the past years.



- Among main factors of runway overrun at landing (Safety analysis)
  - **Runway friction coefficient lower than expected**
  - Contaminated runway snow, ice ... **more slippery than reported**

⇨ Need for a **reliable**, **real-time**, **seamless** runway condition evaluation

⇨ 3 recommendations were issued by NTSB and AAIB (1982, 2005, 2006) to develop **onboard solutions**

Airbus answer: study launched to assess the technical feasibility of using the aircraft as a runway condition assessment means

COntaminated Runway State Automatic Identification and Reporting

CORSAIR - Generalities

High Level Operational Concept

1. CORSAIR runway Braking Action objective assessment

2. **Pilot validity cross check** from subjective deceleration feeling.

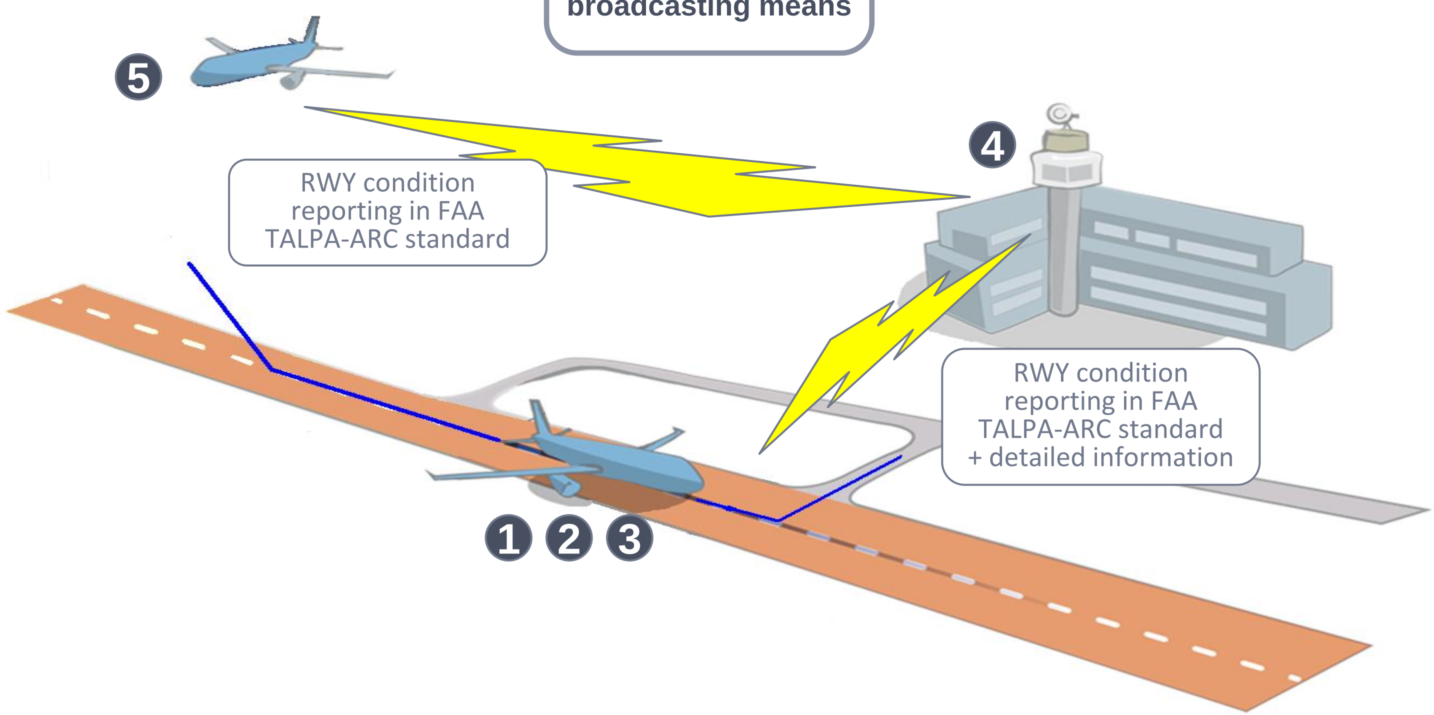
3. Pilot reporting to tower *via* radio

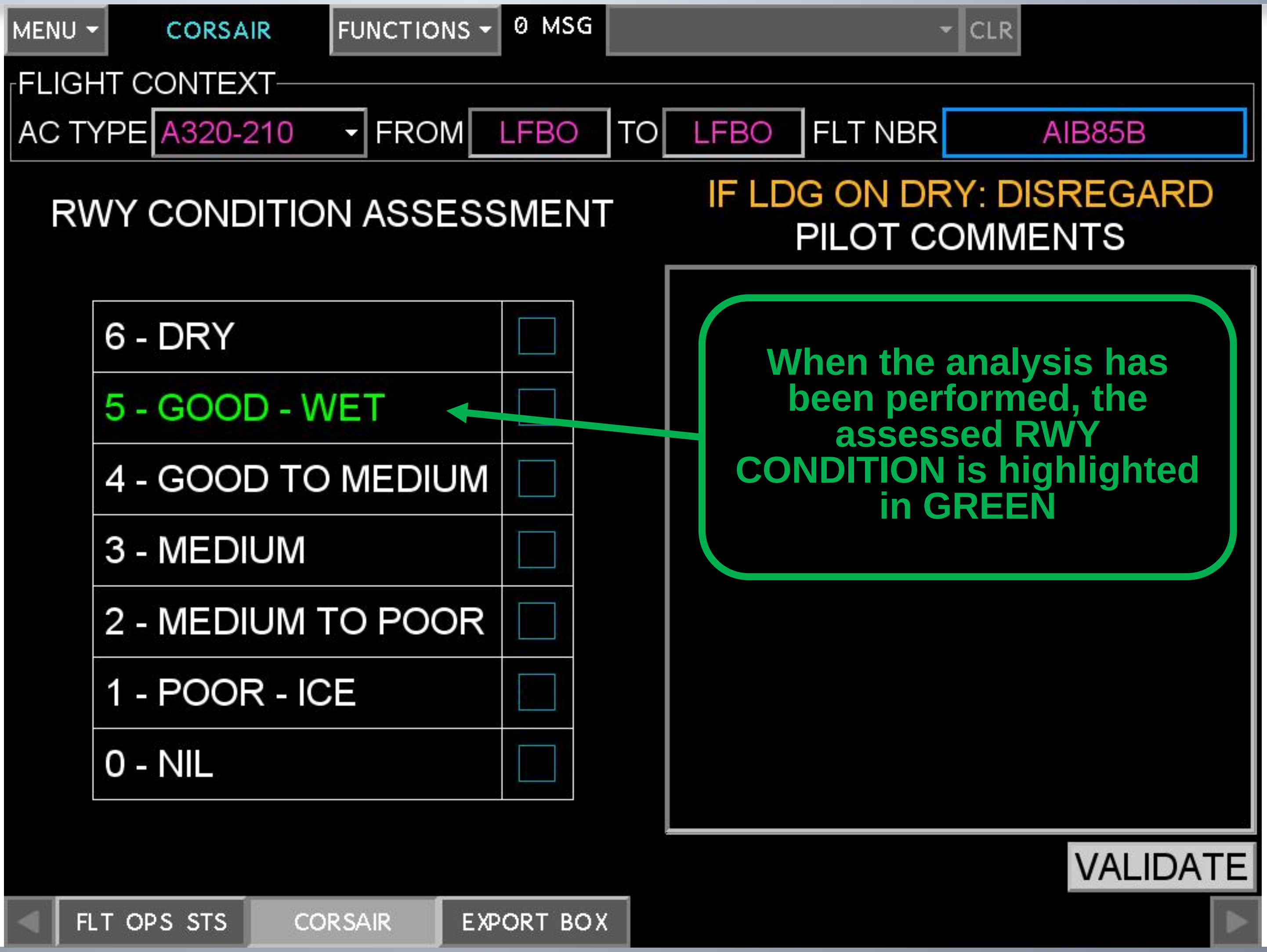
3bis. Automatic reporting to tower *via* TBD broadcasting means

4. **Tower report** to incoming aircraft

Only if lower than Airport RWY condition

5. Incoming aircraft to use report of Braking Action for Landing Performance evaluation




MENU
CORSAIR
FUNCTIONS
0 MSG
CLR
FLIGHT CONTEXT
AC TYPE A320-210
FROM LFBO
TO LFBO
FLT NBR AIB85B
RWY CONDITION ASSESSMENT
IF LDG ON DRY: DISREGARD
PILOT COMMENTS
6 - DRY
5 - GOOD - WET
4 - GOOD TO MEDIUM
3 - MEDIUM
2 - MEDIUM TO POOR
1 - POOR - ICE
0 - NIL
When the analysis has been performed, the assessed RWY CONDITION is highlighted in GREEN
VALIDATE
FLT OPS STS
CORSAIR
EXPORT BOX

MUCHAS GRACIAS