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

Presented by
Wolfgang Absmeier / Experimental Test Pilot
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
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

• 1\textsuperscript{st} Mod: Braking algorithms and aircraft performance calculations installed in a modified autopilot computer

• 2\textsuperscript{nd} 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

- MAX BRAKING WITH PREDICTION OF RUNWAY OVERRUN
  Equivalent to MAX PEDAL BRAKING or MAX AUTOBRAKING

\[ 0.35G = \text{MAX AUTHORITY IF TAXIWAY OVERRUN} \]
Equivalent to HI Autobraking

\[ 0.2G = \text{Min target deceleration} \]
Set when system is armed

\[ 0.15G \]
- End of Runway

\[ 0.3G = \text{Max target deceleration} \]

A/C release with Jx=0 at 10 kts, 65m from Exit
How to use BTV?
How does BTV manage the braking applications? (cont’d)

• BTV deceleration profile

Deceleration

Time

MLG Impact

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
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
Comparison with basic autobrake mode

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

<table>
<thead>
<tr>
<th>Deceleration</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic autobrake</td>
<td>10 kt at 65 m from the exit</td>
</tr>
<tr>
<td>BTV</td>
<td>taxi</td>
</tr>
</tbody>
</table>

**How to use BTV?**

**How does BTV manage the braking applications? (cont’d)**
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
How to use BTV?
How to manage a high speed turn-off (cont’d)

Reference point
10 kt target
65m
90° exit
How to use BTV?
How to manage a high speed turn-off (cont’d)
How to use BTV?
How to manage a high speed turn-off (cont’d)
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

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

12/2008: Maximum overweight landing with EASA test pilot

05/2008: 1st flight on A380

9/2009 Certification

07/05/2013 XI ICAO/ASPA REGIONAL SEMINAR
Reducing runway excursion: a safety priority

IATA Safety Report 2010
Breakdown per Accident Category

- 23% Runway Excursion
- 14% Gear-up Landing / Gear Collapse
- 10% In-flight Damage
- 11% Ground Damage
- 9% Undershoot
- 5% Hard Landing
- 0% Runway Collision
- 0% Mid-air Collision
- 5% windshear/ Crosswind
- 8% Controlled Flight into Terrain
- 2% Other

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

HELPS CREW DECISION MAKING

WARNS THE CREW IF RUNWAY TOO SHORT
ROPS Principle

- TAWS
  - Runway data and Aircraft position
- ROPS
  - 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
ROPS Principle

ROPS = ROW + ROP

Transition Point: Autobrake activation or Ground Spoilers extension

Row end Overrun Warning
GO-AROUND

Runway end Overrun Protection
STOP
**How does ROW work?**

**Before the Transition point:** **ROW Alerts**

<table>
<thead>
<tr>
<th><strong>PFD</strong> (Below 500 ft)</th>
<th><strong>Audio</strong> (Below 200 ft)</th>
<th><strong>Pilot Action</strong> (Below 500 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="PFD Image" /></td>
<td>None</td>
<td>Go-Around Decision If Runway Condition is not DRY</td>
</tr>
</tbody>
</table>

**Transition Point**

- **Runway end Overrun Warning**
  - **Go around**

- Below 500 ft
- Below 200 ft

**Runway Condition**

- If not DRY, take a Go-Around Decision.
How does ROW work?

Before the Transition point: **ROW Alerts**

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</thead>
<tbody>
<tr>
<td><img src="image1" alt="PFD Image" /></td>
<td>&quot;RWY TOO SHORT!&quot;</td>
<td>Go-Around Decision Whatever Runway Condition</td>
</tr>
</tbody>
</table>

**Runway end Overrun Warning**

Go around

Transition Point

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

<table>
<thead>
<tr>
<th>PFD</th>
<th>Audio</th>
<th>Pilot Action</th>
</tr>
</thead>
</table>
| ![PFD Image] | "BRAKE…MAX BRAKING…MAX BRAKING" 
- If Max Braking applied and Max Reverse not selected, "MAX REVERSE" "KEEP MAX REVERSE" | Max Braking Max Reverse |
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
Selecting the Brake Release Point

Including when the runway END was selected

GEO distances tested: 50m, 65m, and 75m
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 Hl braking triggered at touchdown
Possible Trap: Runway Errors

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

Snapshot taken at 50 feet RA
Auto brake Hi applied at TD

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3. Runway Overrun Protection
4. Problems encountered during Tests
5. Way forward
WAY FORWARD

Braking System for all different Runway states

Requirements:
Reliable Runway state forecast’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

Short Feedback on ND

RWY condition Matrix on WHEEL page

RWY condition Selector

ABRK Push-button
### 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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<table>
<thead>
<tr>
<th>RWY COND CODE</th>
<th>RWY CONDITION (TYPICAL DESCRIPTION)</th>
<th>BRAKING ACTION</th>
<th>MAX X-WIND (KTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>DRY</td>
<td>DRY</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>WET</td>
<td>GOOD</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>COMPACTED SNOW</td>
<td>GOOD TO MEDIUM</td>
<td>27</td>
</tr>
<tr>
<td>3</td>
<td>SNOW OR SLIPPERY WHEN WET</td>
<td>MEDIUM</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>STANDING WATER OR SLUSH</td>
<td>MEDIUM TO POOR</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>ICE</td>
<td>POOR</td>
<td>15</td>
</tr>
</tbody>
</table>
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
5. Incoming aircraft to use report of Braking Action for Landing Performance evaluation

Only if lower than Airport RWY condition

RWY condition reporting in FAA TALPA-ARC standard

RWY condition reporting in FAA TALPA-ARC standard + detailed information
When the analysis has been performed, the assessed RWY CONDITION is highlighted in GREEN.
MUCHAS GRACIAS