BOEING

Flight Services

# Understanding Runway Excursions

Paul Giesman
Flight Operations Engineering
Captain Sam Goodwill
Safety Pilot, Flight Technical and Safety

# Runway Excursion Activity

Runway Excursions

- Off side events
- Overruns

Industry Activity

- Aviation Rulemaking Activity – FAA
- ECAS/Eurocontrol initiatives
- ICAO Friction Task Force
- Flight Safety Foundation
- Others?

# Overruns Are Typically The Result of Multiple Factors

Most often overruns are not the result of a single factor

- Typically 2, 3 or more factors are involved
  - Approach and Flare
  - Speed
  - Stopping Devices
  - Runway conditions
- Often if 1 of the multiple factors were changed a successful stop would occur

Focus on landing

# Study of 29 Excursions Since 2003

- Listing of contributing factors
- Demonstration that multiple factors typically are involved

# Contributing Factors

Runway conditions

- Contaminated/slippery runways
- Wet runways
  - Runway deterioration effects

Performance knowledge

- Misconceptions on the conservatism available in the dispatch data
- Lack of knowledge on the basis of the data or what it covers
- Reverse thrust and autobrakes

# Contributing Factors

Approach to touchdown

- Unstable approaches
- Long landing

High Speed landing

- Tailwind
- Carrying all of the speed additive or excessive speed to the runway
  - Above MCP speed

Reverse thrust technique

- Late application of reverse thrust
- Early shutdown of reverse thrust
- “Quick” shutdown of reverse thrust

# Runway Condition – Wet Runway

Ability of the airplane to stop on a wet runway is a function of:

- Amount of wheel braking used/available
  - Manual or Auto brake
- How wet is wet?
  - Saturation
    - 3mm generally accepted threshold for dynamic hydroplaning
  - Heavy rain
- Runway condition - texture
  - Grooved / PFC or Wet smooth (non-grooved or PFC)
    - Rubber build up
    - Polishing
- Boeing FCOM
  - The performance level used to calculate the "good" data is consistent with wet runway testing done on early Boeing jets



SlipperyRunways_Giesman.8

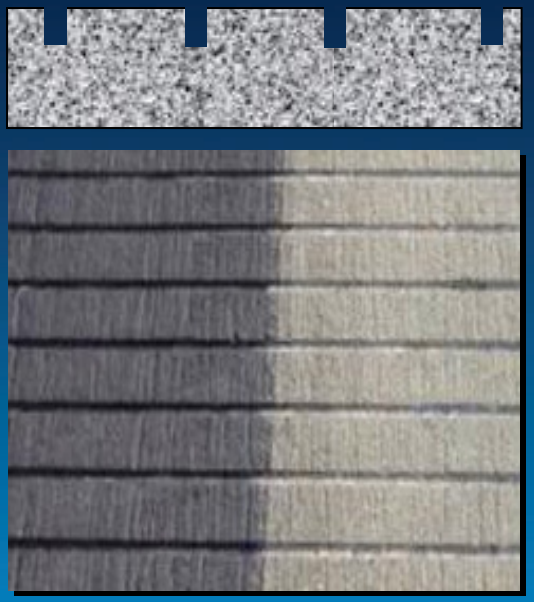
# Wet Runway – Runway Texture

Runway texture (roughness)

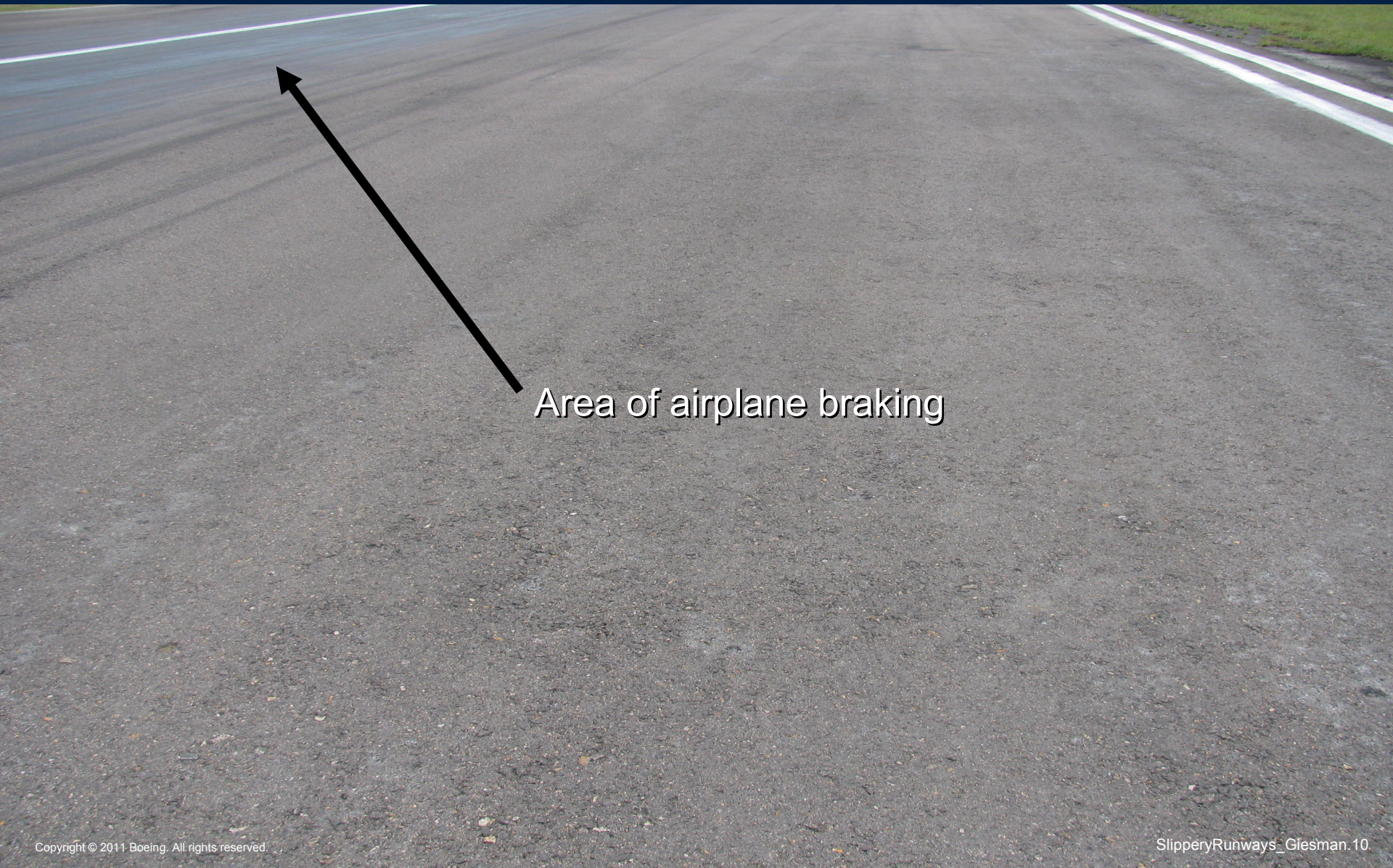
**“OPEN, HIGH”**

**“CLOSED, LOW”**

**Grooved**



# Runway Profile

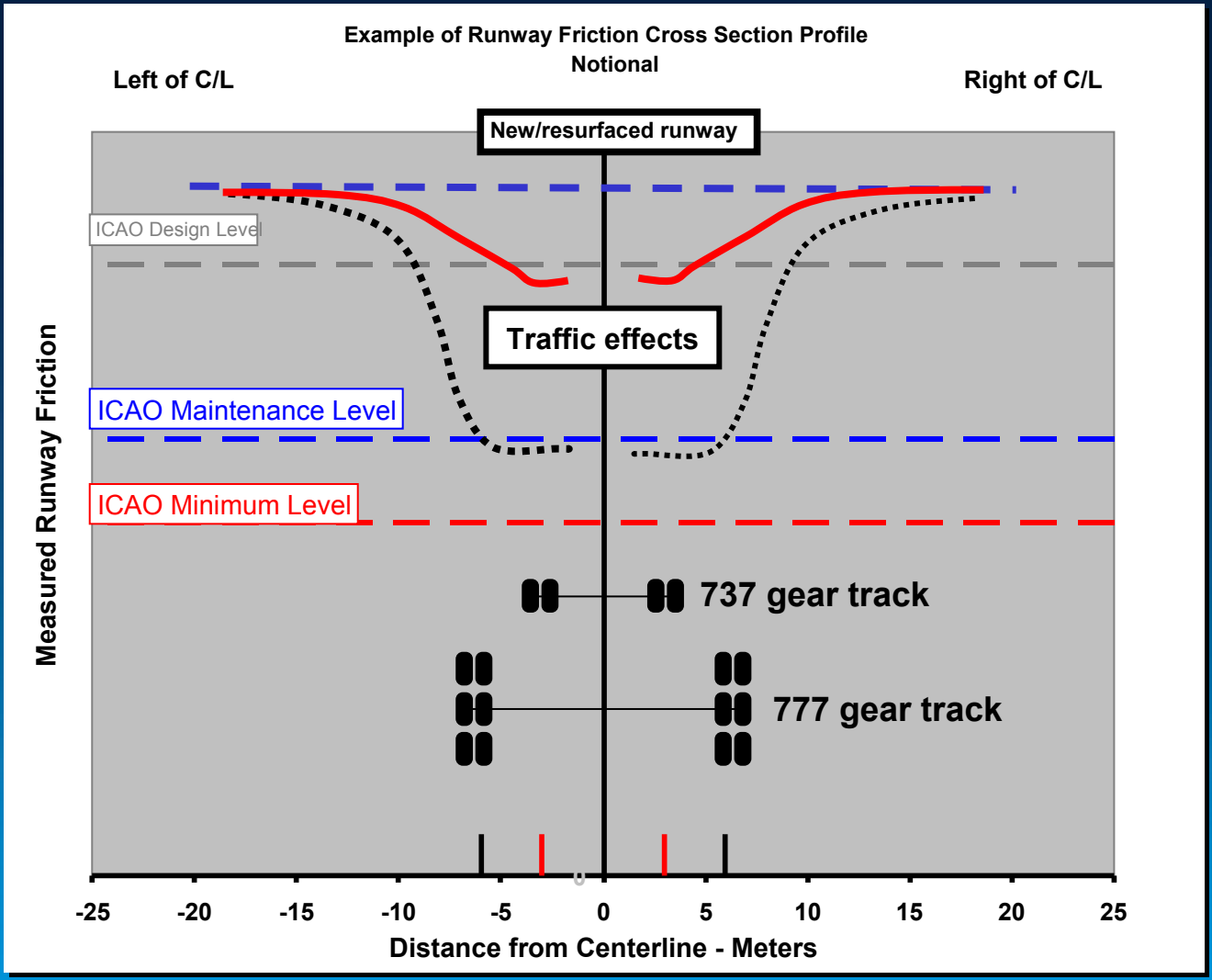


# Wet Runway Condition Measurement

Periodically measure friction using vehicles designed to do this

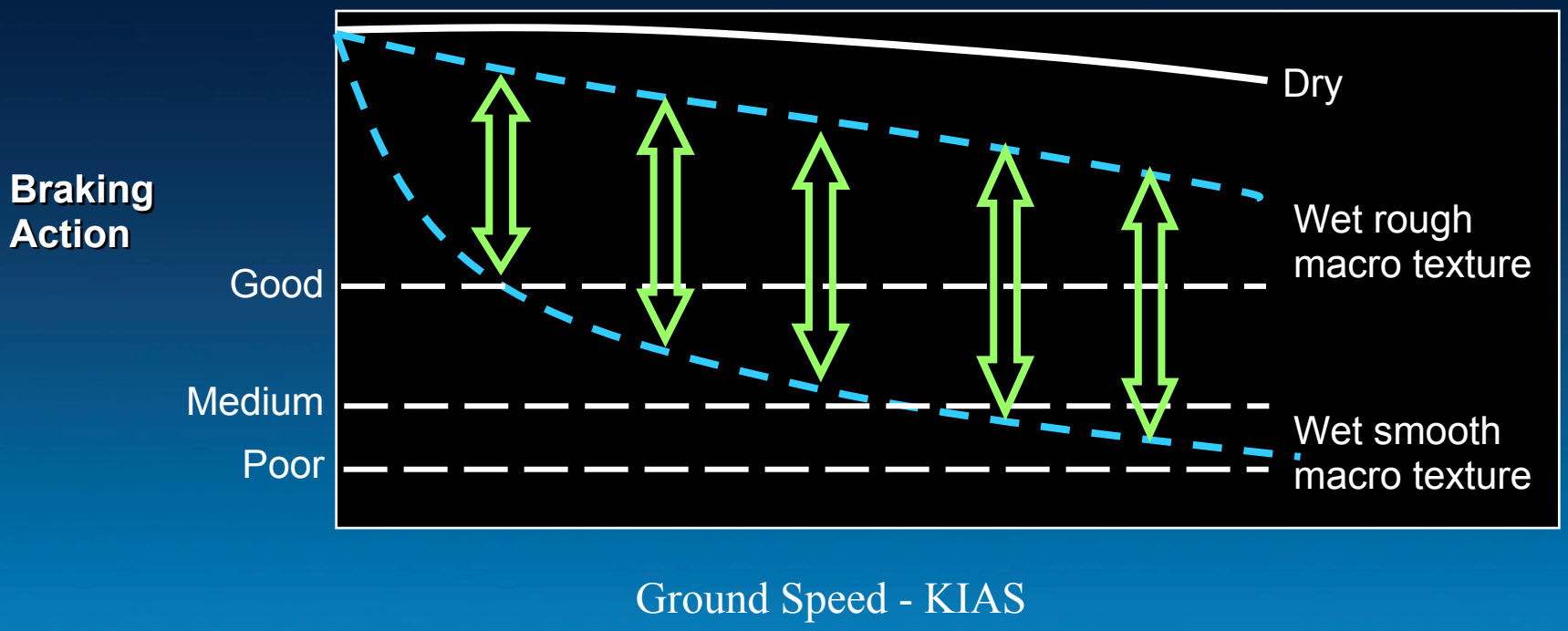
# Runway Deterioration

## Polishing/Rubber Deposits



# Variability In Wet Runway Braking

**All Factors (Rwy Texture, Tire Tread, Saturation, etc.)**



# Runway Condition / Runway Length

For performance comparisons and effects we will use reasonably attainable assumptions and conditions for the baseline

- Maximum Landing Weight
- Assume an air distance of 1500 feet (450 m) (touchdown within the touchdown zone)
- Threshold crossing speed – $V_{REF}$+5
- Touchdown speed – $V_{Ref}$
- 500 ft pressure altitude, 30 C, no wind, no slope
- AB Max, QRH level of reverse thrust
- No factors, wet non-grooved runway assumption

# Performance Knowledge

There have been issues with flight crew knowing and understanding the basis and assumptions for landing performance

- Assumptions used in computing data documented in Boeing documents
  - FCOM and FCTM
  - FOTB (2007)
  - Previous Symposium Presentations
  - Boeing Performance and Flight Operations Conference white papers
- Airline needs to determine if the assumptions are adequate for their operating environment and training
  - Increment or factor the data as appropriate

# Performance Knowledge

- Understanding of interaction of reverse thrust and autobrake
  - Recurring issue

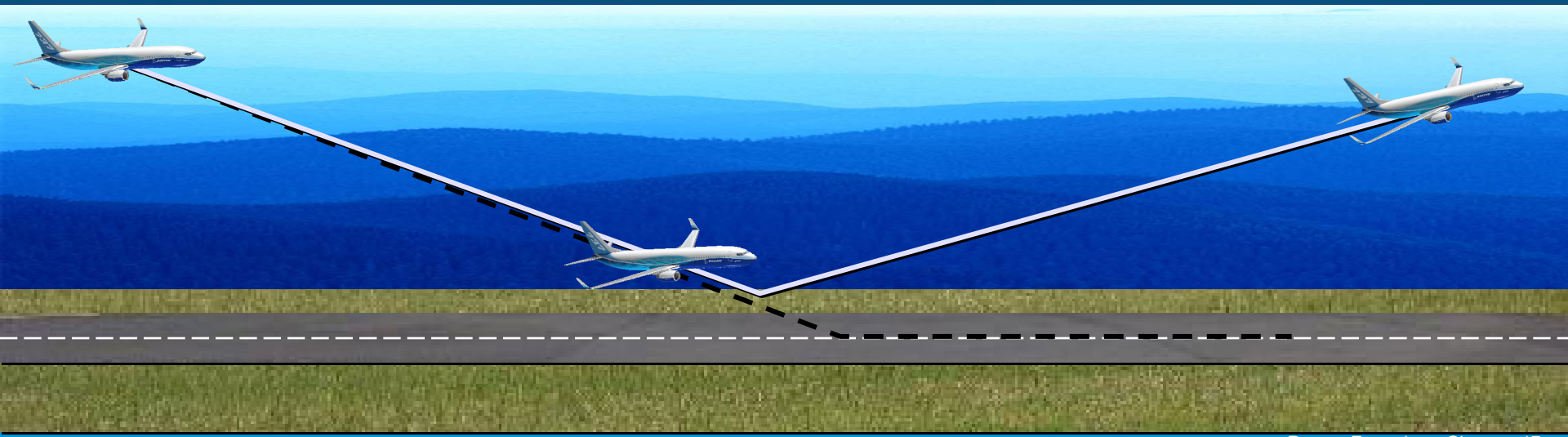
***On a non-dry runway (braking action good, medium, poor)***

- *Reverse thrust is required to obtain the QRH or OPT computed autobrake stopping distances (AB setting greater than 2 or 1)*
- *The published stopping distance will increase if:*
  - *Reverse selection is delayed*
  - *Less than assumed level of reverse thrust is used*
    - *Detent 2 (737) or Max (other 7 series models)*
    - *Reducing reverse at higher speeds than recommended*

# Approach to Touchdown

Unstable approach

- Know the criteria
  - FCTM
  - ALAR tool kit (Flight Safety Foundation)
- Flight crew mindset
- It is okay to go-around



# Proper Speed Additives / Flair and Speed Bleed Off

**Airspeed Control**

If the autothrottle is disengaged, or is planned to be disengaged prior to landing, maintain VREF plus the wind additive until beginning the flare. The steady headwind correction is bled off during the flare, however the gust correction is maintained to touchdown. Plan to touchdown at VREF plus the gust correction. With proper airspeed control and thrust management, touchdown should occur at no less than VREF - 5 knots.

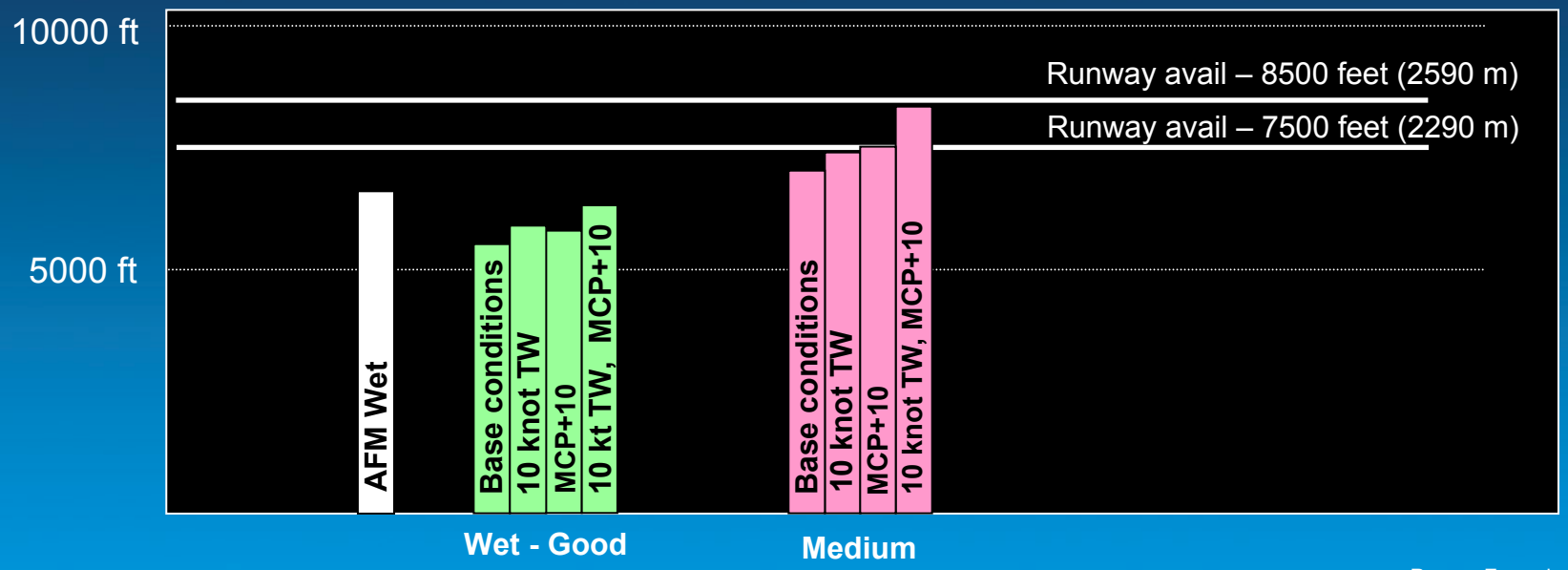
With calm winds and tailwind

- $V_{Ref}$ + 5 at threshold
- $V_{Ref}$ at touchdown

# High Speed Landings

Stopping distance will be directly related to ground speed

- Approach speed above MCP speed
- Speed increase during the flare
- Tailwind
  - Runway choice
  - Unreported tailwind



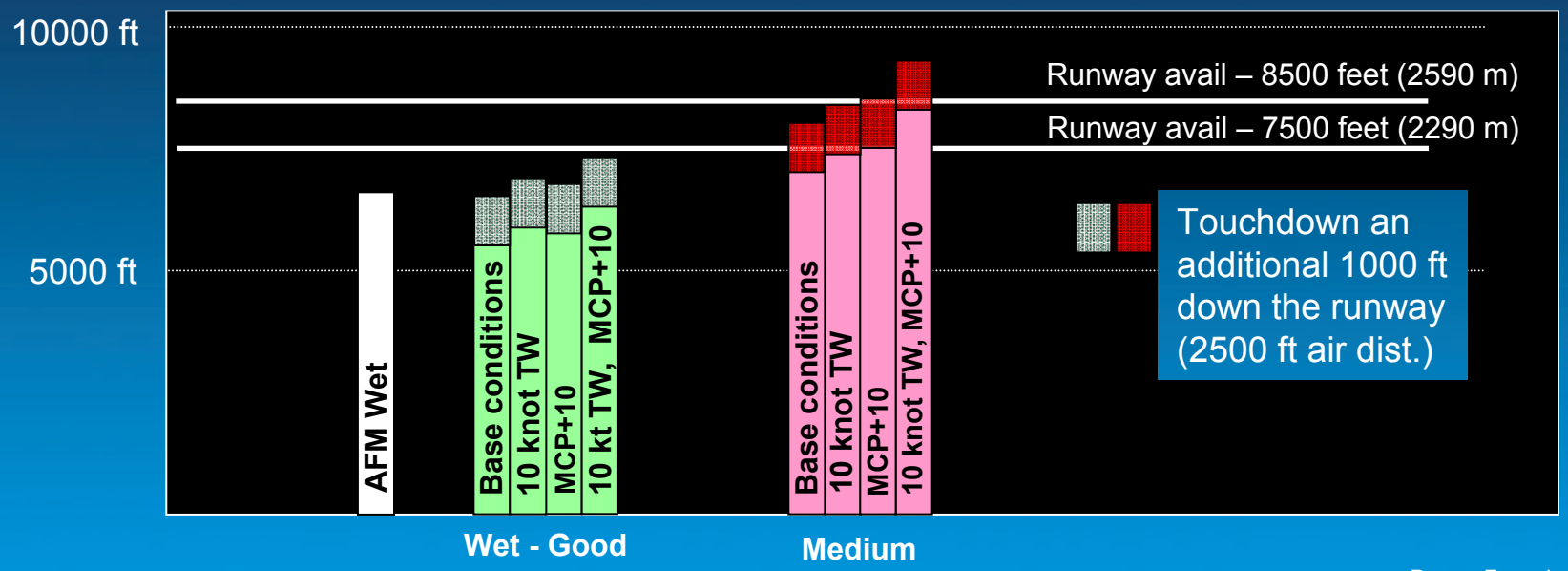
# Air Distance

Touchdown zone often described as 1st third of runway up to 3000 ft

- Boeing FCTM 1000-2000 ft

Touchdown point becomes more important with

- Higher speeds
- Worse runway conditions
- Shorter runways



# Reverse Thrust usage

QRH performance assumes reverse thrust usage

- Prompt use of reverse thrust required to achieve normal performance numbers
  - Delayed Reverse
  - Early reduction of reverse to forward idle

# Example of good use of reverse thrust

# Example of early reduction in reverse thrust

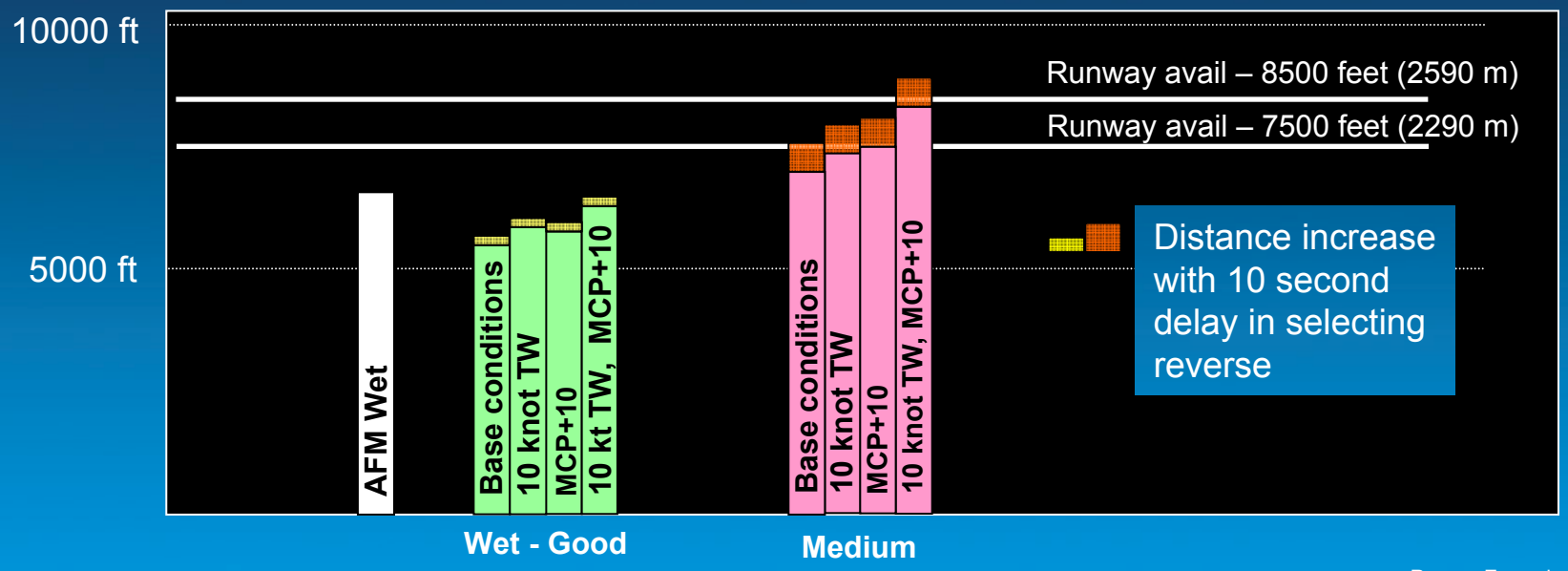
# Reverse Spinup Time

- Reverse idle to maximum reverse immediately after landing – 3.5s
- Reverse idle to maximum reverse after spindown to ground idle – $10^{+}$s
- On the ground selecting forward idle allows thrust to spin down to ground idle
  - Result - in a long spinup time to achieve effective reverse

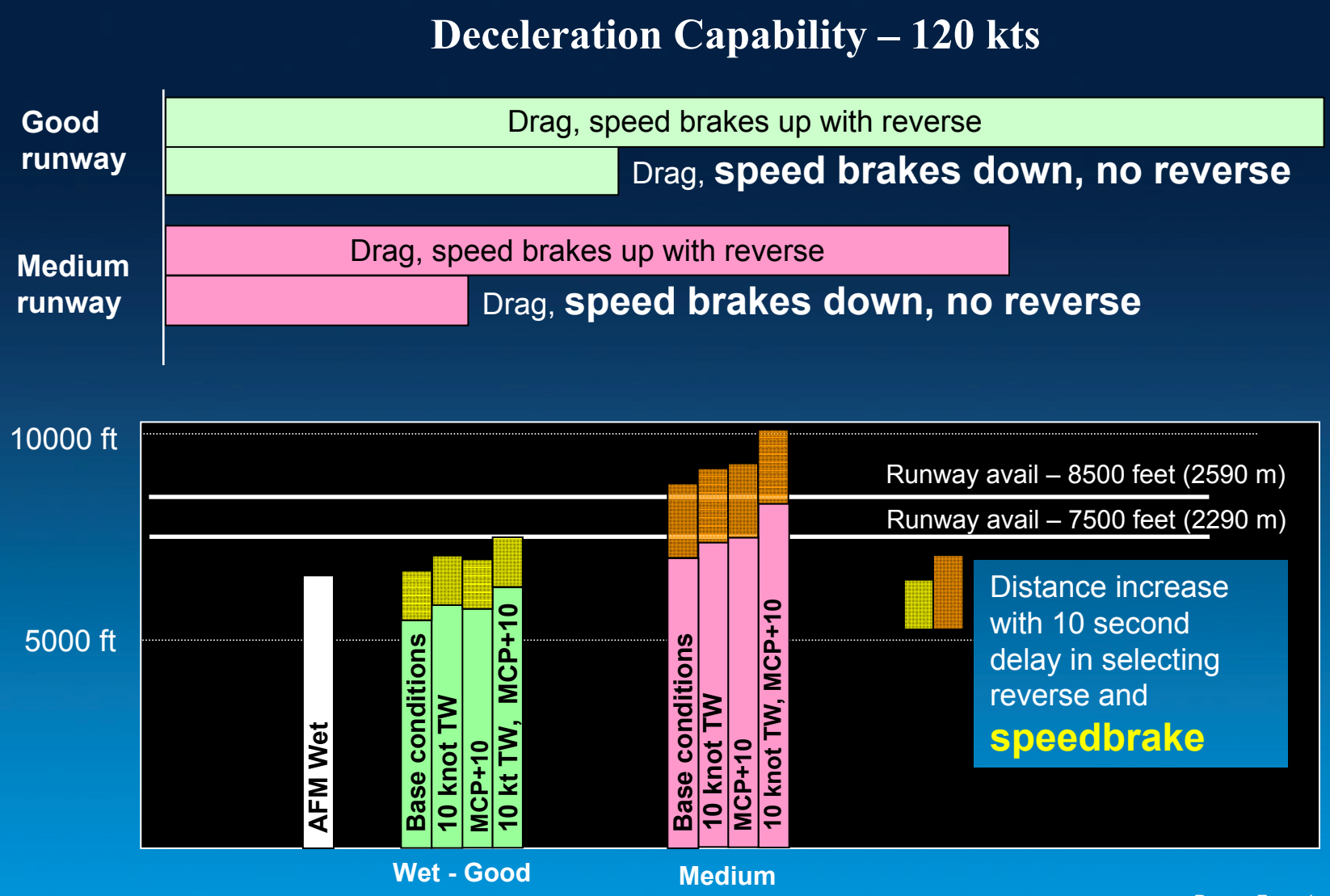
# Reverse thrust issues

Many excursion incidents have a contribution of reduced reverse thrust either by:

- Early stowage of reverser and unsuccessful re-application
- Delayed selection and therefore spin-up of reverse thrust
- The more slippery the runway the greater the contribution of reverse thrust to stop



# Delayed Reverse Thrust Application and Unarmed Speed Brakes



# Boeing Performance Data in QRH is Consistent With Recommended Flying Techniques in the FCTM

Assumed time for device activation:

- Brake application
- Spoiler deployment
- Reverse thrust usage


**Normal Configuration Landing Distance**
**Flaps 30**

| REPORTED BRAKING ACTION | RUNWAY DESCRIPTION |
|---|---|
| Dry | Dry |
| Good | Wet (smooth, grooved or PFC)<br>1/8" or less of: Water, slush, dry and wet snow |
| Good to Medium | Frost at or below - 15°C OAT: Compact snow |
| Medium | Wet (slippery), dry or wet snow, (any depth) over compacted snow<br>Greater than 1/8" of : Dry and Wet Snow<br>Warmer than - 15°C : Compacted Snow |
| Medium to Poor | Greater than 1/8" of: Water, Slush |
| Poor | Ice |
| Nil | Wet Ice, Water on top of compacted snow dry or wet snow over ice |

| | LANDING DISTANCE AND ADJUSTMENTS (FT) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | REF DIST | WT ADJ | ALT ADJ | WIND ADJ | SLOPE ADJ | TEMP ADJ | VREF ADJ | REVERSE THRUST ADJ | |
| BRAKING CONFIGURATION | 380000 LB LANDING WEIGHT | PER 10000 LB ABV/BLW 380000 LB | PER 1000 FT ABOVE SEA LEVEL | PER 10 KTS HEAD/ TAIL WIND | PER 1% DOWN/ UP HILL | PER 10°C ABV/ BLW ISA | PER 5 KTS ABOVE VREF30 | ONE REV | NO REV |
| **Dry Runway** | | | | | | | | | |
| MAX MANUAL | 4430 | 110/-70 | 130 | -220/730 | 0/-40 | 110/-110 | 190 | 90 | 190 |
| MAX AUTO | 5370 | 110/-90 | 160 | -260/870 | 20/-10 | 140/-140 | 310 | 0 | 0 |
| AUTOBRAKE 4 | 6510 | 150/-120 | 210 | -340/1130 | 0/0 | 190/-190 | 380 | 0 | 0 |
| AUTOBRAKE 3 | 7400 | 170/-150 | 250 | -400/1330 | 10/-50 | 210/-220 | 400 | 10 | 10 |
| AUTOBRAKE 2 | 8030 | 200/-180 | 300 | -440/1490 | 100/-140 | 230/-240 | 380 | 310 | 310 |
| AUTOBRAKE 1 | 8500 | 230/-190 | 340 | -480/1650 | 190/-200 | 240/-250 | 370 | 870 | 980 |
| **Good Reported Braking Action** | | | | | | | | | |
| MAX MANUAL | 5320 | 140/-100 | 210 | -310/1110 | 90/-80 | 160/-160 | 270 | 250 | 610 |
| MAX AUTO | 5510 | 130/-90 | 200 | -270/1020 | 30/-20 | 150/-150 | 300 | 170 | 520 |
| AUTOBRAKE 4 | 6620 | 150/-120 | 220 | -350/1160 | 20/-20 | 190/-190 | 390 | 0 | 0 |
| AUTOBRAKE 3 | 7460 | 170/-150 | 260 | -400/1340 | 30/-70 | 220/-220 | 400 | 20 | 20 |
| AUTOBRAKE 2 | 8080 | 200/-180 | 310 | -450/1510 | 120/-160 | 230/-240 | 380 | 330 | 330 |
| AUTOBRAKE 1 | 8500 | 230/-190 | 350 | -480/1660 | 210/-200 | 250/-250 | 380 | 880 | 980 |
| **Good to Medium Reported Braking Action** | | | | | | | | | |
| MAX MANUAL | 5770 | 120/-100 | 190 | -320/1100 | 130/-110 | 150/-150 | 240 | 350 | 850 |
| MAX AUTO | 5930 | 130/-100 | 200 | -320/1120 | 110/-90 | 160/-160 | 290 | 350 | 860 |
| AUTOBRAKE 4 | 6700 | 150/-120 | 220 | -360/1230 | 60/-50 | 190/-190 | 390 | 50 | 290 |
| AUTOBRAKE 3 | 7460 | 170/-150 | 260 | -400/1340 | 30/-70 | 220/-220 | 400 | 20 | 20 |
| AUTOBRAKE 2 | 8080 | 200/-180 | 310 | -450/1510 | 120/-160 | 230/-240 | 380 | 330 | 330 |
| AUTOBRAKE 1 | 8500 | 230/-190 | 350 | -480/1660 | 210/-200 | 250/-250 | 380 | 880 | 980 |

# Summary

- Overruns are typically the result of multiple issues
  - Some not under flight crew control
  - Some under flight crew control
- Pilot flying
  - Fly the airplane following standard procedures
- Pilot monitoring
  - Has shared responsibility
- It is okay to go-around