RASG-PA Runway Excursion Prevention Seminar
Proper Use of Deceleration Devices

October 09, 2014

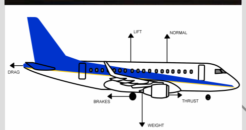
Agenda Items

Statistical Data for Landings

Brakes & Spoilers

Thrust Reversers

Anti-Skid System & Hydroplaning



Landing Performance Analysis

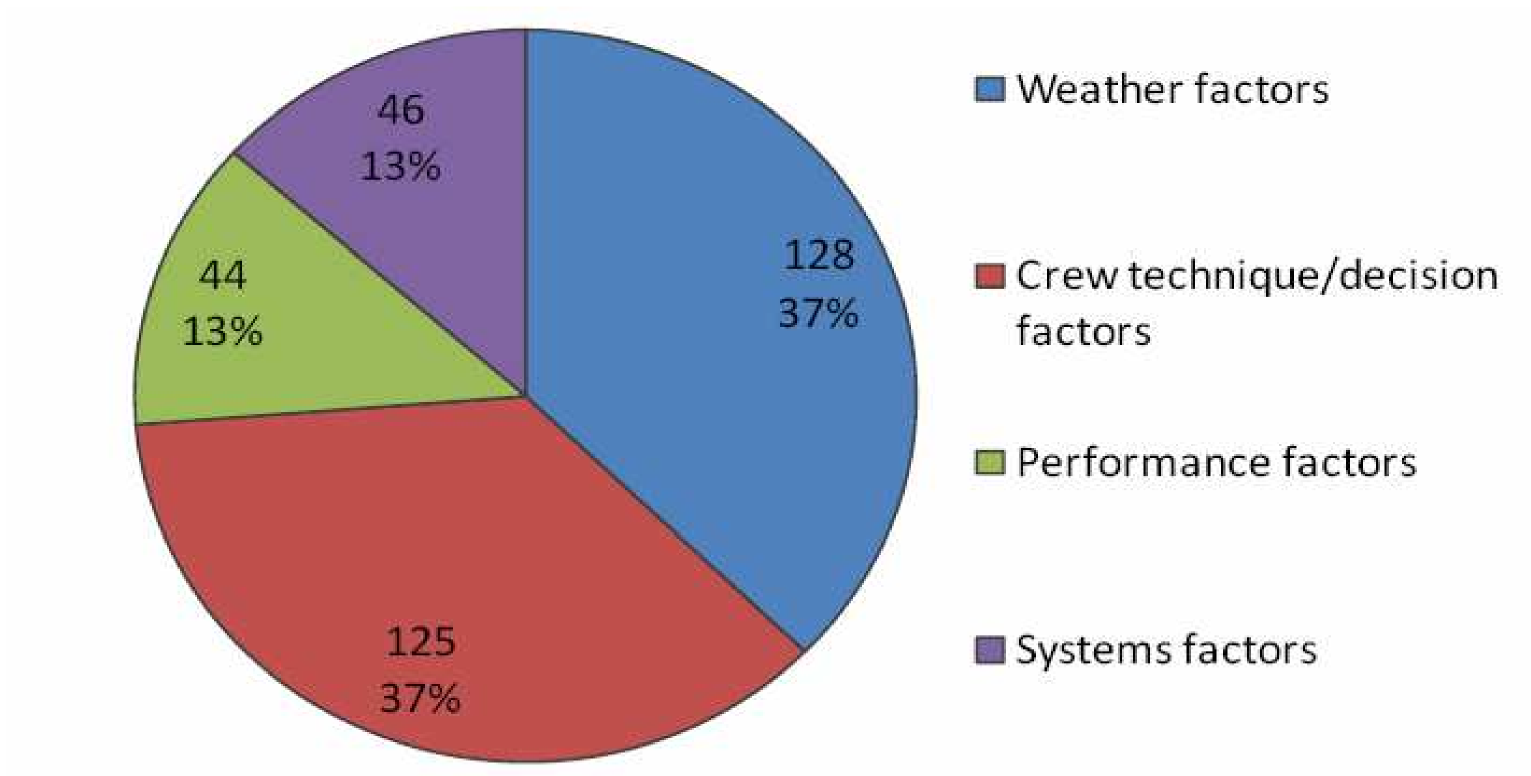
Maximum Performance Landing

Statistical Data for Landings

EMBRAER

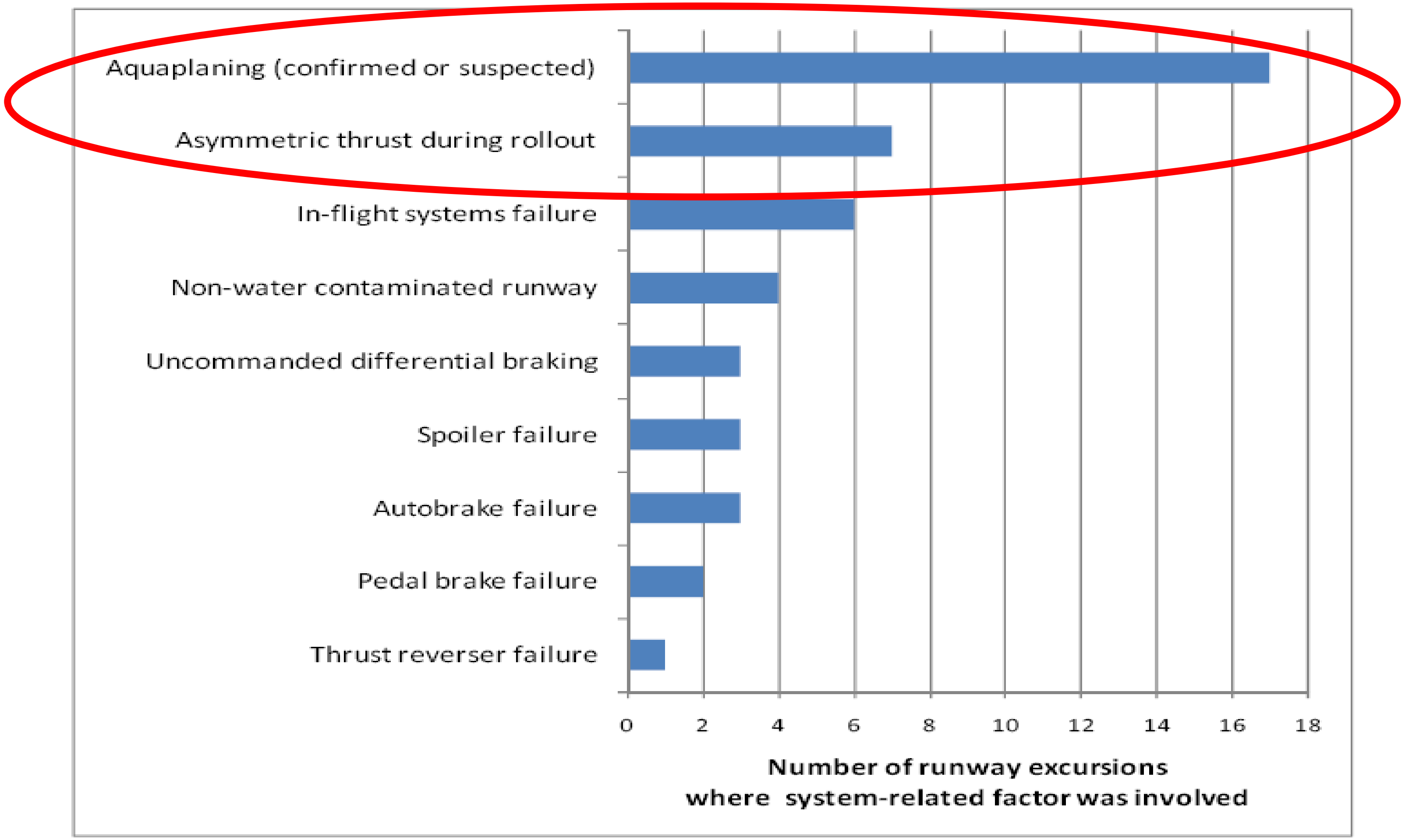
Excursions During Landing

Analysis on 120 runway excursion fatal accidents during landing from 1998 to 2007



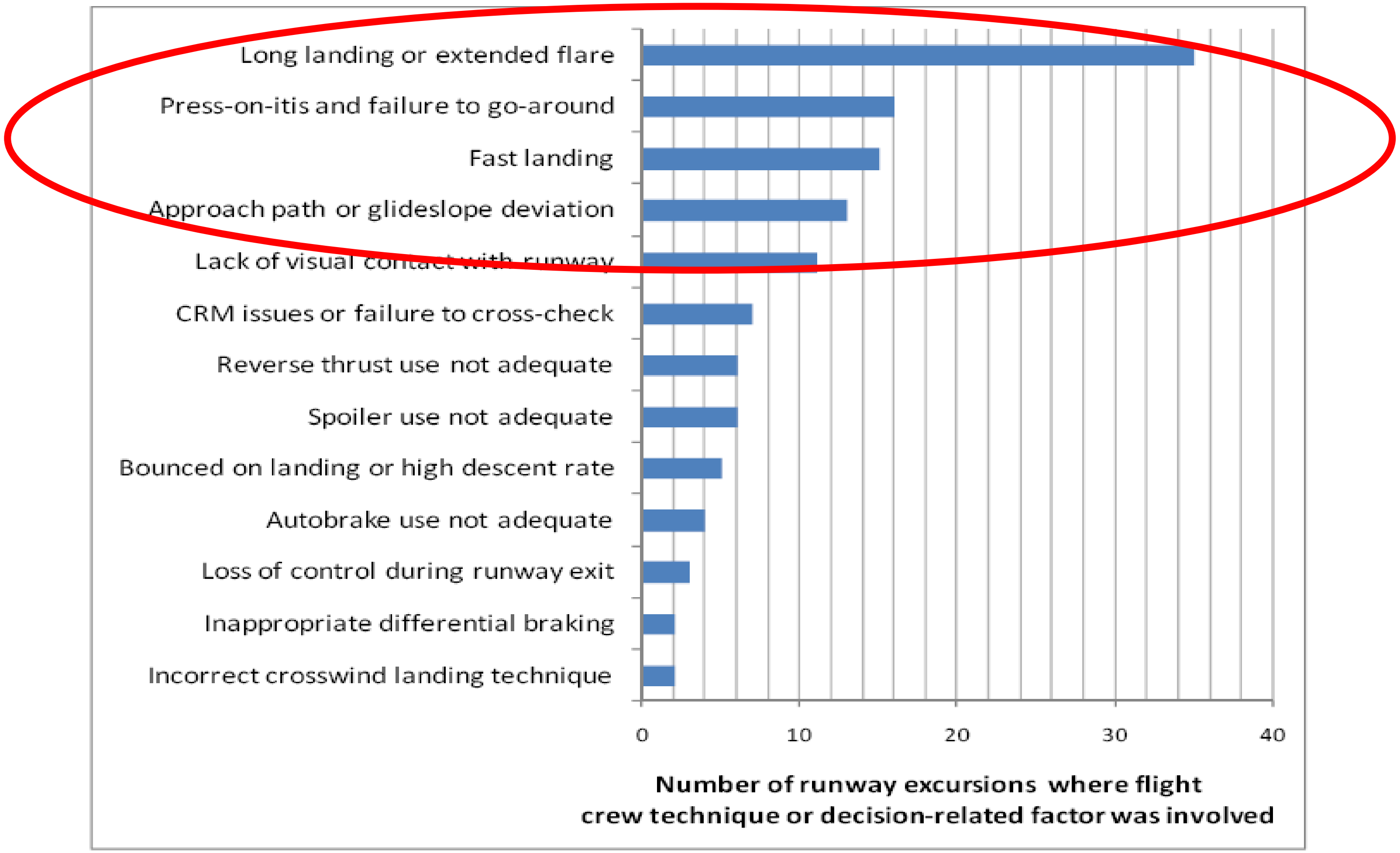
Source: ATSB Transport Safety Report on Runway Excursion

Systems-related Factors (13%)



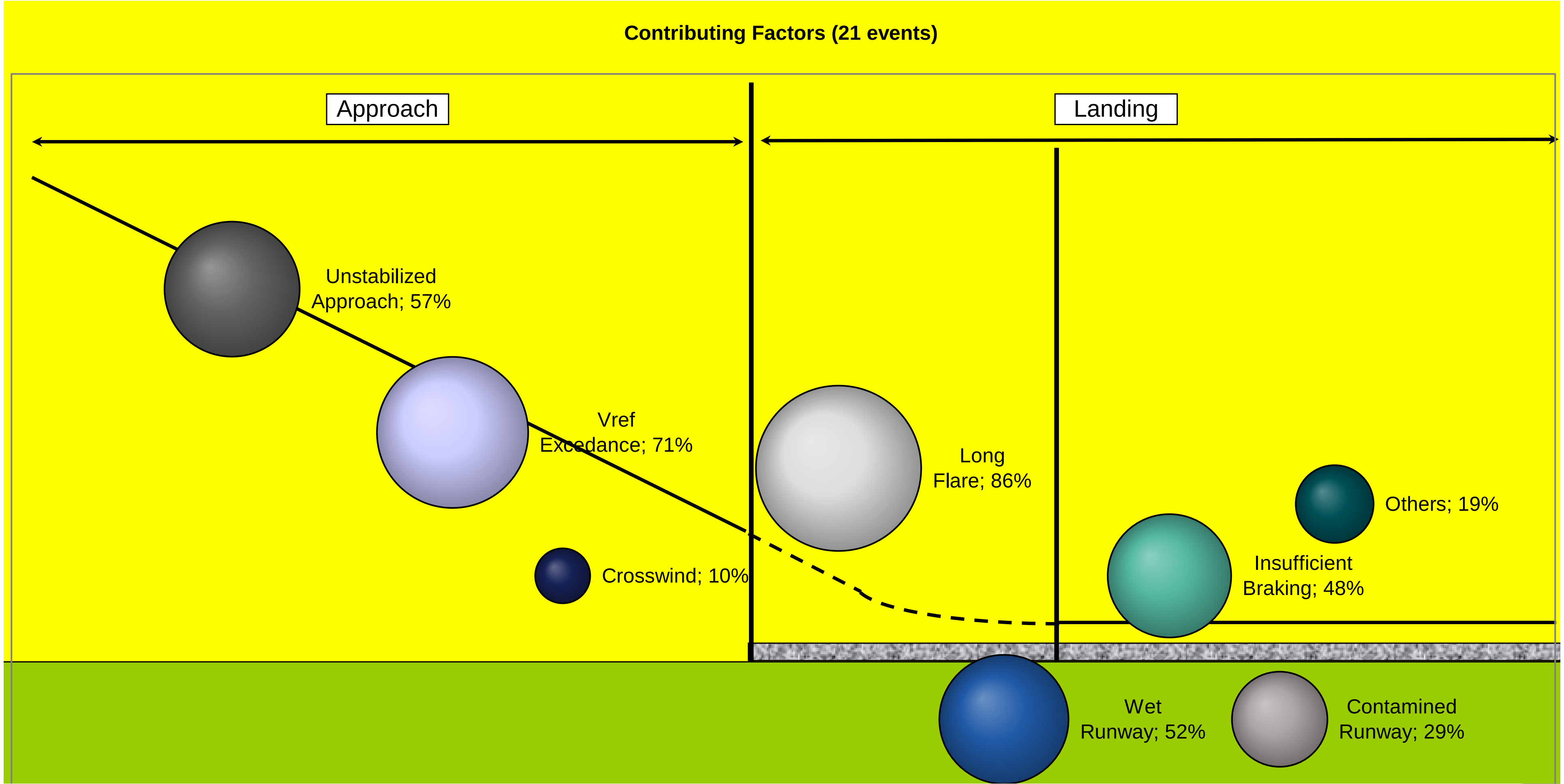
Source: ATSB Transport Safety Report on Runway Excursion

Crew Technique / Decision-related Factors (37%)



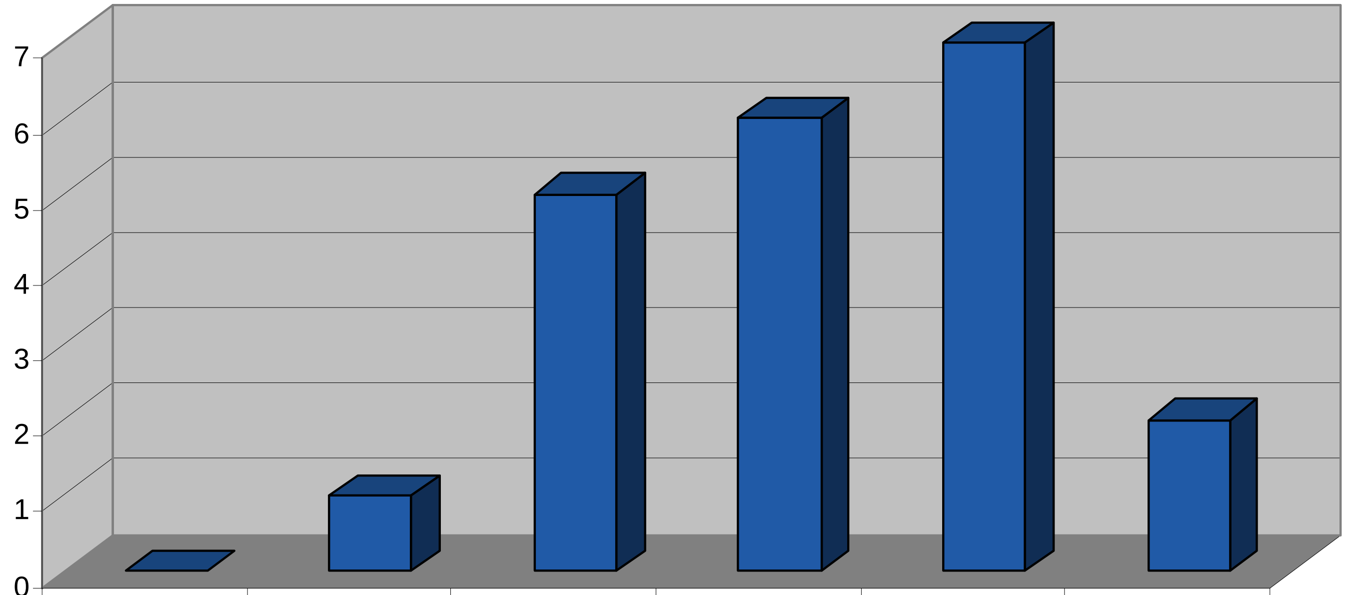
Source: ATSB Transport Safety Report on Runway Excursion

Embraer Jets Overall Statistics



Embraer Jets Overall Statistics

Contributing Factors per event (21 events)



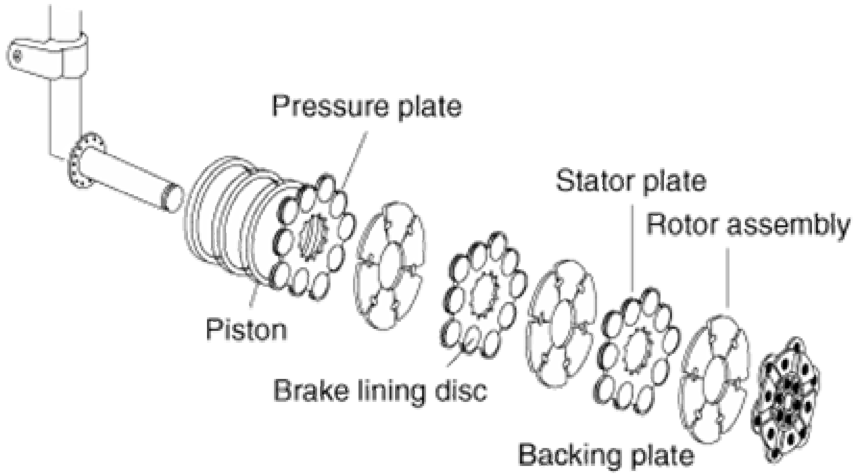
	1	2	3	4	5	6
Frequency	0	1	5	6	7	2

Number of combining Contributing Factors per event

Brakes & Spoilers

Brake System

Typical aircraft brake system



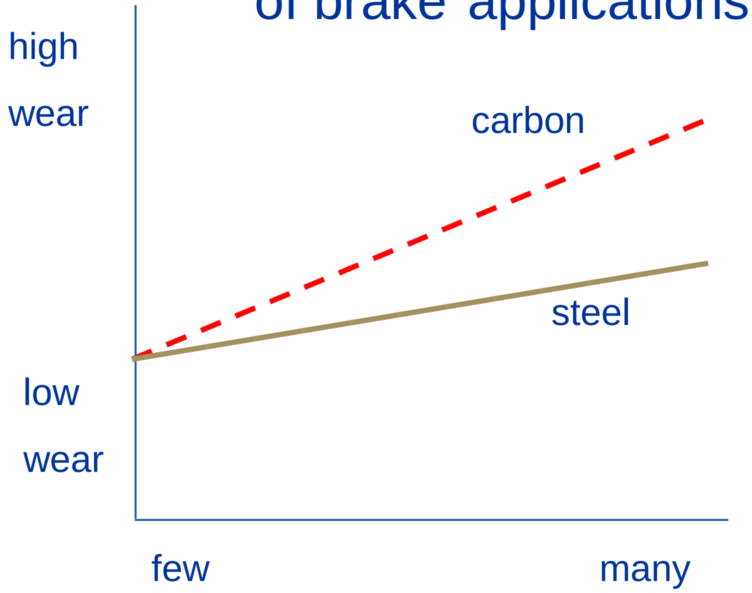
Brakes

Background:

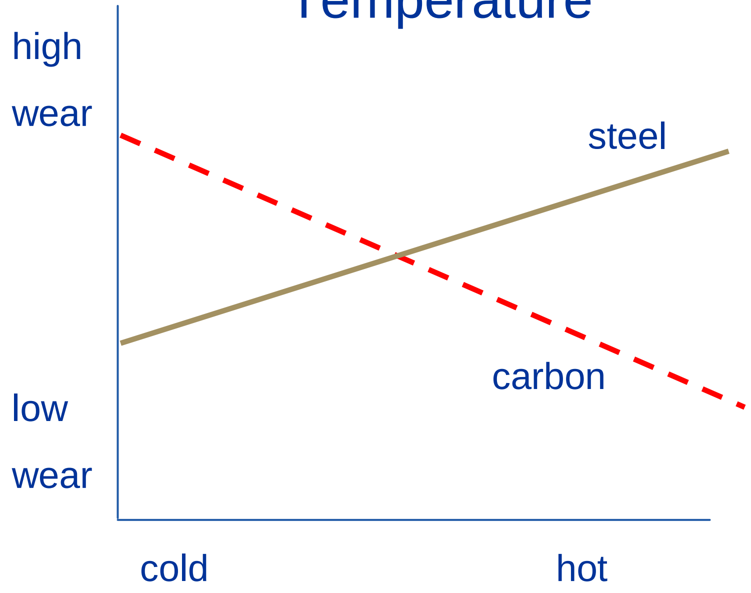
Carbon and Steel brakes have different characteristics, so pilots must know the differences in operation for betters results.

Carbon Brakes are Different From Steel Brakes

Brake wear vs. Number of brake applications



Brake wear vs. Temperature



Braking Technique

REMEMBER:
Brake for Safety!

- It is important that you brake for safety

- SOP on brakes usage:
  - “Apply the brakes with no delay after the main landing gear wheels have touched down.
  - Move directly to a single firm and steady brake application and hold pedal pressure until decelerated to taxi speed.”

- 3 seconds trying to find the centerline can cost you 150 meters (500 feet) of runway distance

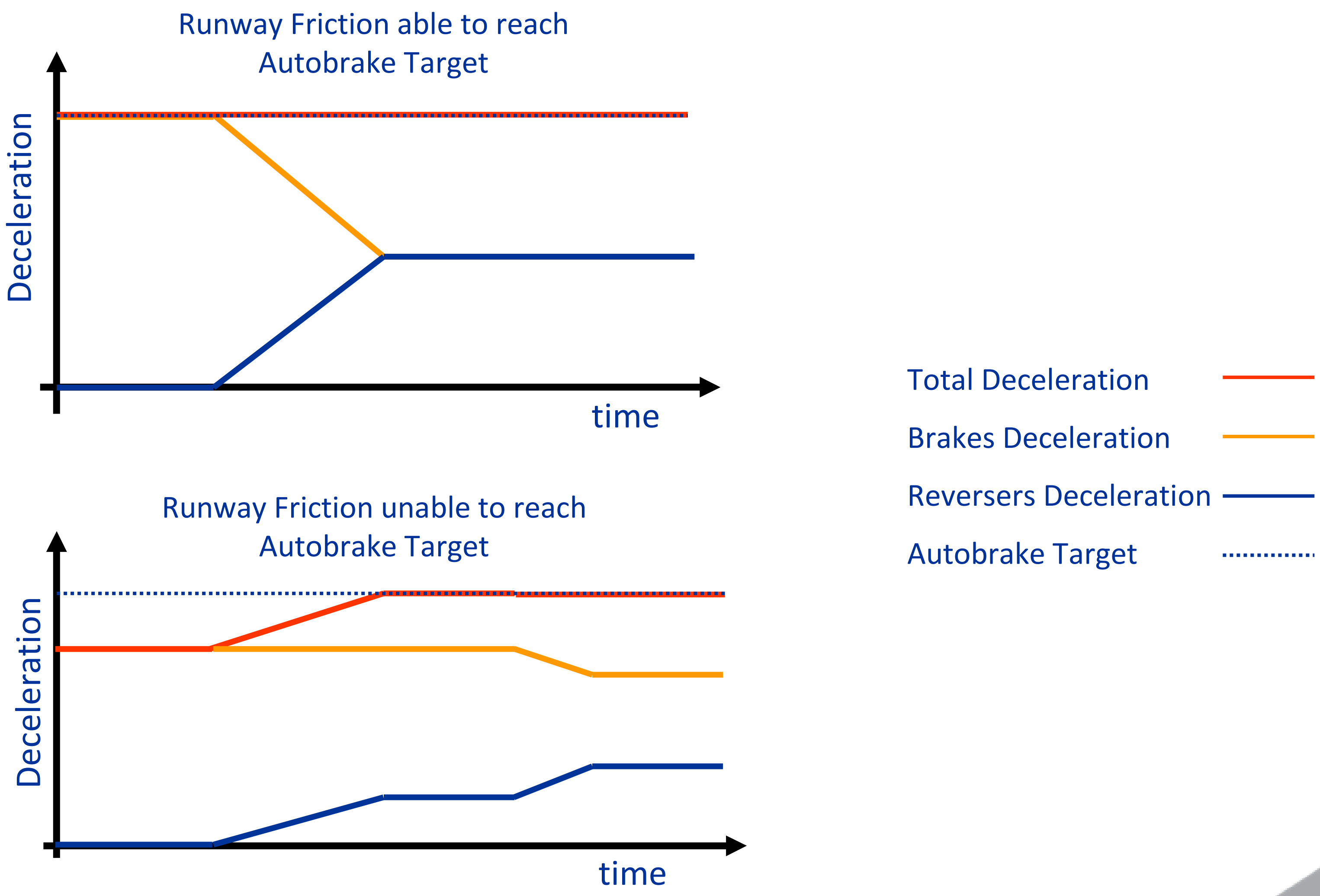
Autobrake Application

- Aims a deceleration target:
  - LO: - 4 ft/s^2 (– 0.12 g)
  - MED: - 8 ft/s^2 (– 0.25 g)
  - HI: -13 ft/s^2 (– 0.40 g)

- System will apply brakes as required to reach target deceleration level

- Deceleration is affected by three factors:
  - Aerodynamic drag
  - Wheel brakes
  - Reverse thrust

Autobrake Application



Autobrake Application

- Keep in mind:
  - Autobrake targets DECELERATION RATE, not brake pressure

  - Landing Actuation Logic:
    - Wheel speed is greater than 60 knots,
    - WOW reports Ground for **2 seconds**,
    - Thrust Lever in Idle

  - Note that these 2 seconds are already considered on performance data!

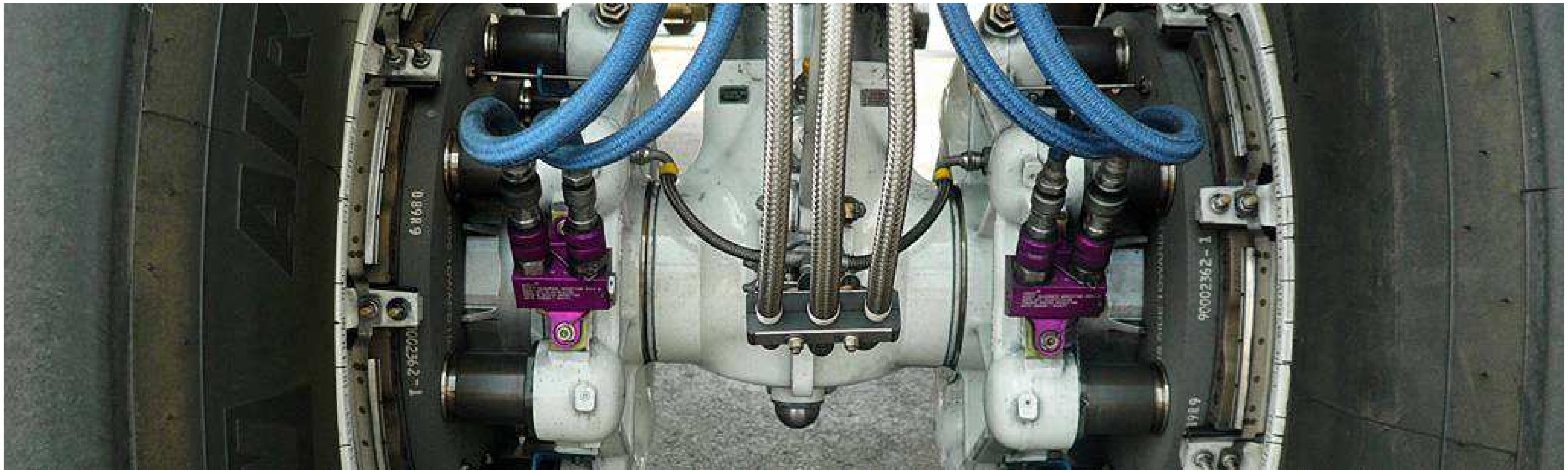
Autobrake Application

Keep in mind:

Autobrake to Manual Braking **transition** behavior

- Autobrake disengages when pedal displacement is greater than 20%
- This can command a pressure lower than the one the system was working at

REMEMBER:
Brake for Safety!



Ground Spoiler Logic

- Automatically opens upon landing
  - Thrust Levers IDLE, AND
  - Airspeed greater than 60 knots, AND
  - 3 WOW (out of 4) indicating GROUND

OR…

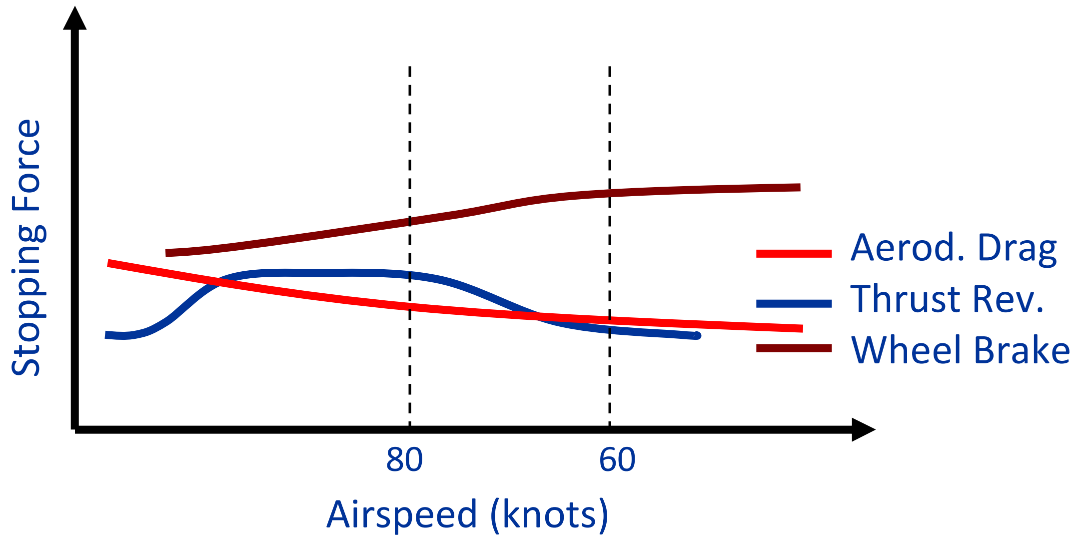
  - 2 WOW on the same side indicating GROUND, AND
  - Wheel speed greater than 45 knots

- "Bounced Landing Prevention": delays the retraction if WOW becomes AIR after landing
  - "Ground" signal is kept for 5 seconds after WOW indicates AIR
  - If Thrust Levers are advanced 2 degrees, "Ground" command is removed.

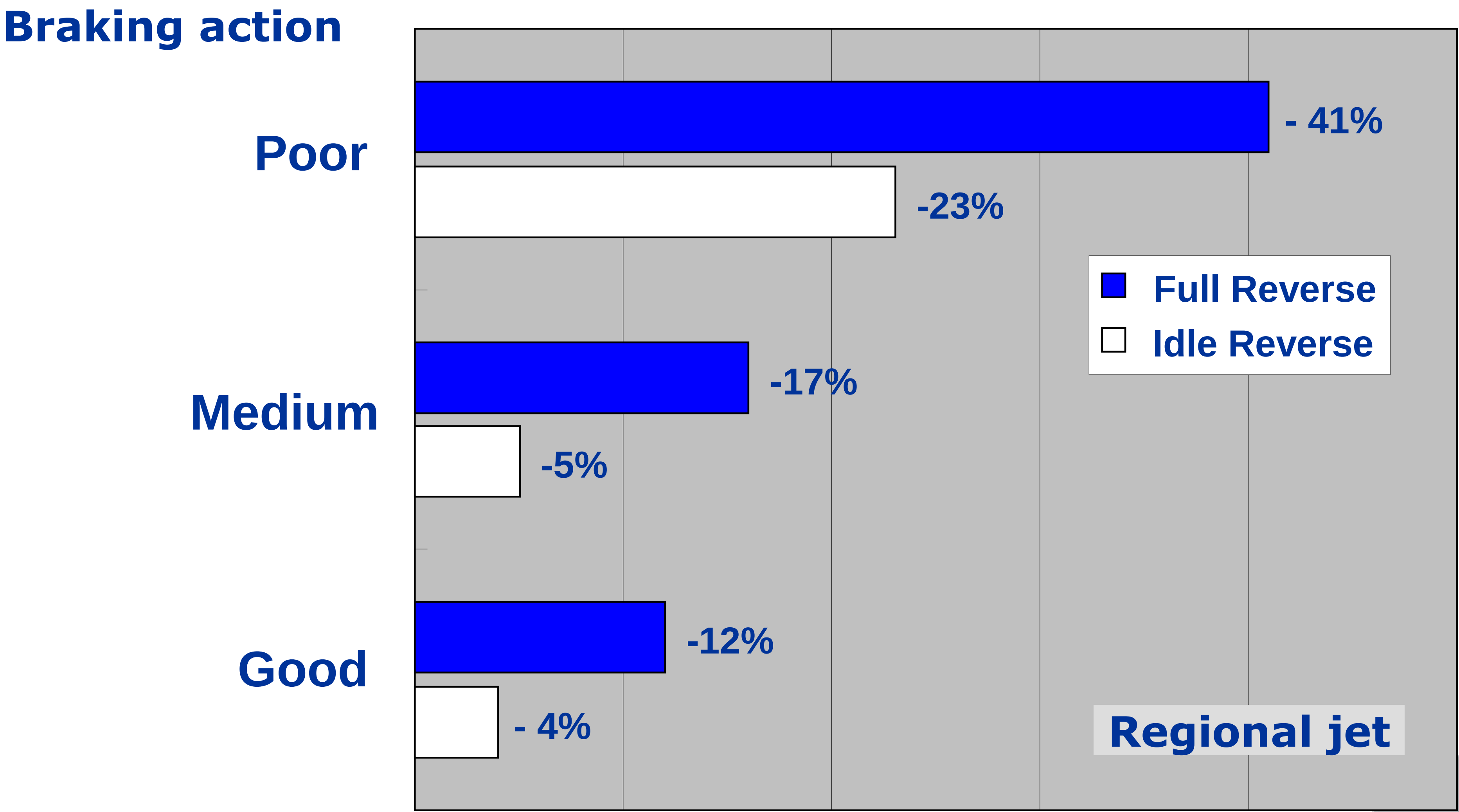
Thrust Reversers

Braking Devices & Stopping Forces

- Thrust Reversers, Ground Spoilers and Wheel Brakes stop the aircraft
- Typical distribution profile:



Influence of Reverse Thrust on Landing Distance



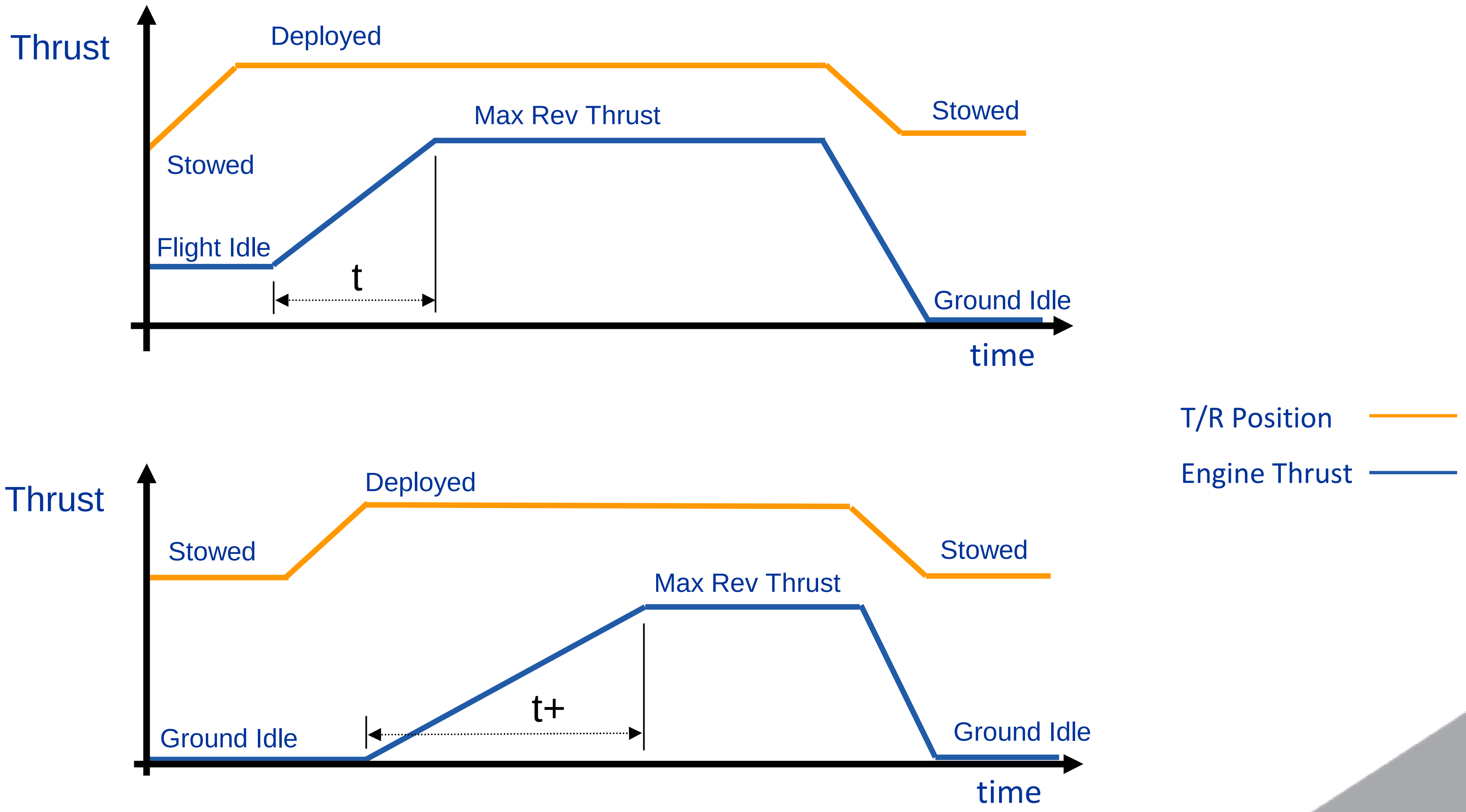
Source: NLR Air Transport Safety Institute

Thrust Reverser Application

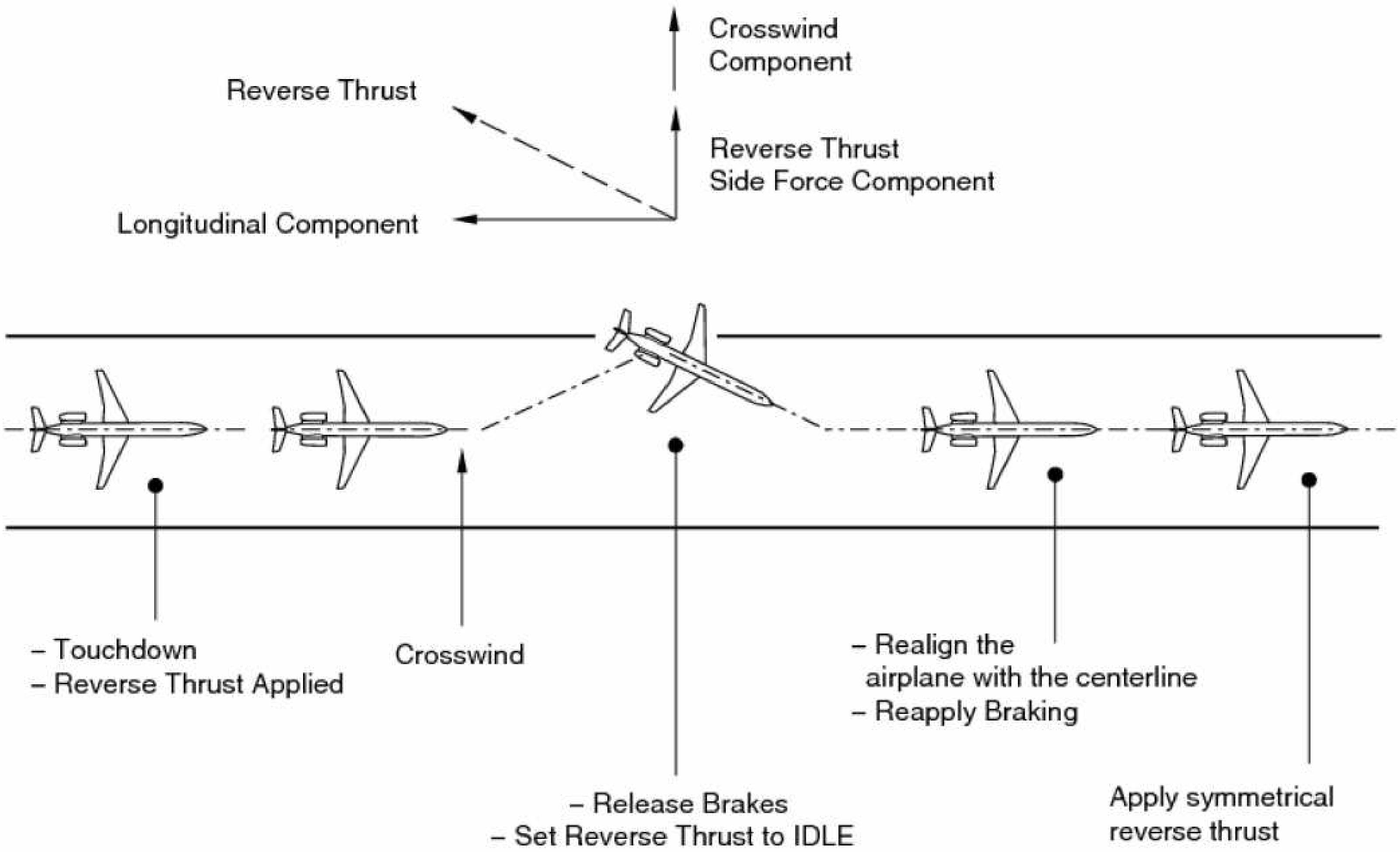
- Promptly use Thrust Reverser, while engine is still at flight idle
- When operating in wet / contaminated runway, apply maximum reverse thrust
- Avoid early Thrust Reverser stowage: only reduce thrust levers to minimum reverse thrust at 60 knots

Delayed Thrust Reverser Application

Flight Idle vs. Ground Idle engine spin up time



Thrust Reverser & Crosswind Landings on Slippery Runways



Anti-Skid System & Hydroplaning

EMBRAER

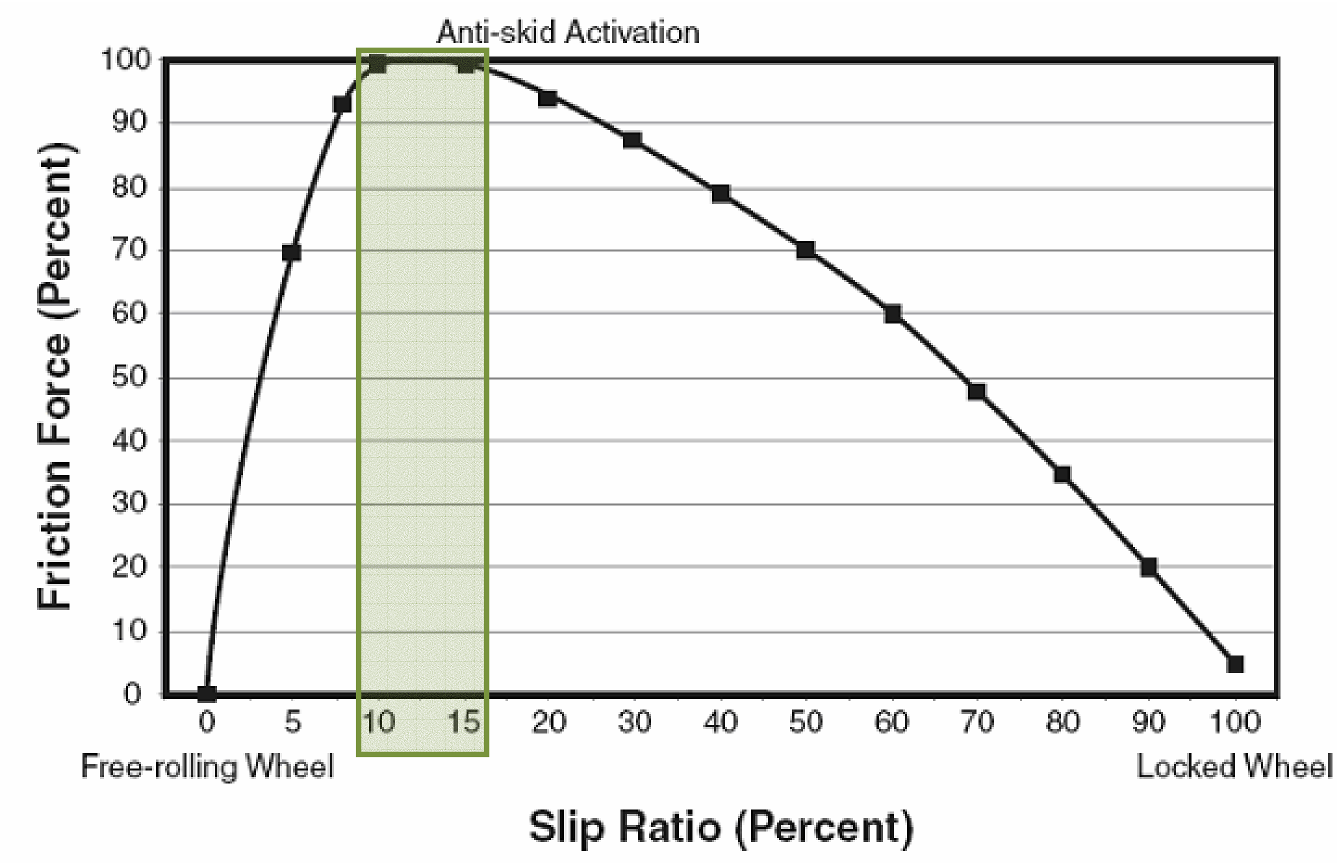
Anti-Skid System

System Review:

- Anti-skid protection
  - On an individual wheel basis, anti-skid will detect a non-spinning wheel and release brake pressure to avoid locking
  - Anti-skid operates only above 10 kts wheel speed

- Locked Wheel Crossover Protection
  - Compares each Inboard/Outboard wheel pair
  - If the wheel speed of one wheel of the pair is 1/3 of the other, system commands zero pressure to the locked one

Anti-Skid System



Anti-Skid System

- Anti-skid systems are designed to achieve optimum braking action
- Several complex comparison of speeds (wheels speed, aircraft speed), hundreds of times per second
- Alleviates brake force application
- Deactivated by the parking brake actuation ("emergency" brakes)

Anti-Skid and Hydroplaning

- Will not avoid or get the tire out of a hydroplaning condition
- Helps braking in viscous hydroplaning, where there is some wheel speed
- Reducing brake pedal application will not help, let the system work!

Hydroplaning

- Hydroplaning is a phenomenon in which a film of standing liquid contaminant causes a tire to lose its contact with the surface, preventing the aircraft from responding to control inputs such as steering and braking.

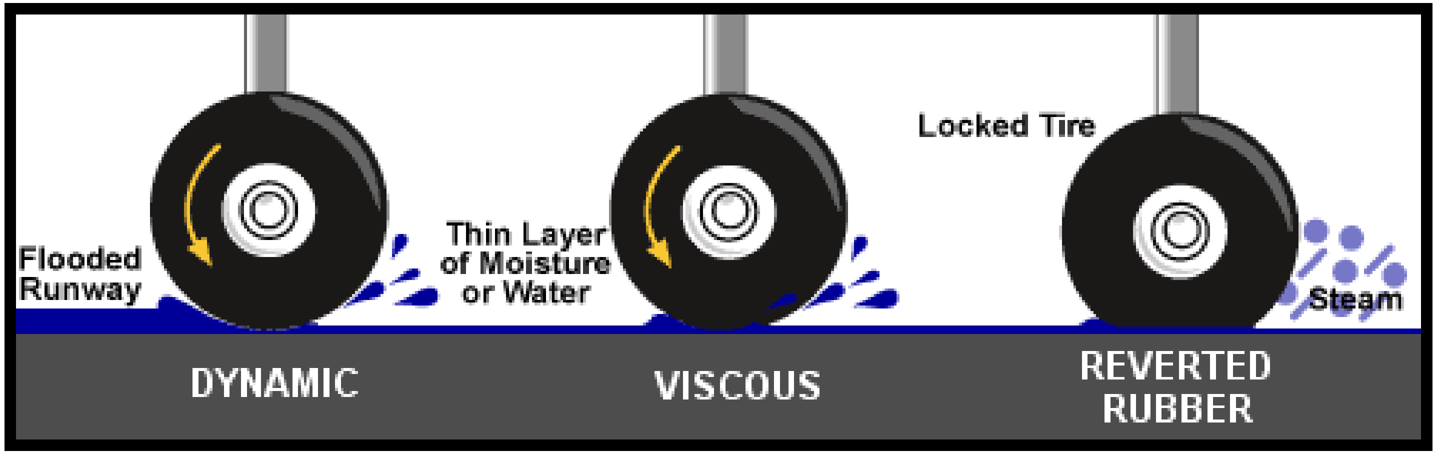
- Also known as aquaplaning.

- Sometimes people associate it with tire marks after the event…


Hydroplaning

- The build up of fluid pressure beneath a tire depends on:
  - Thickness of water film
  - Aircraft speed
  - Tire pressure/threat quality/footprint
  - Runway micro and macro texture
  - Runway construction

- Three types:



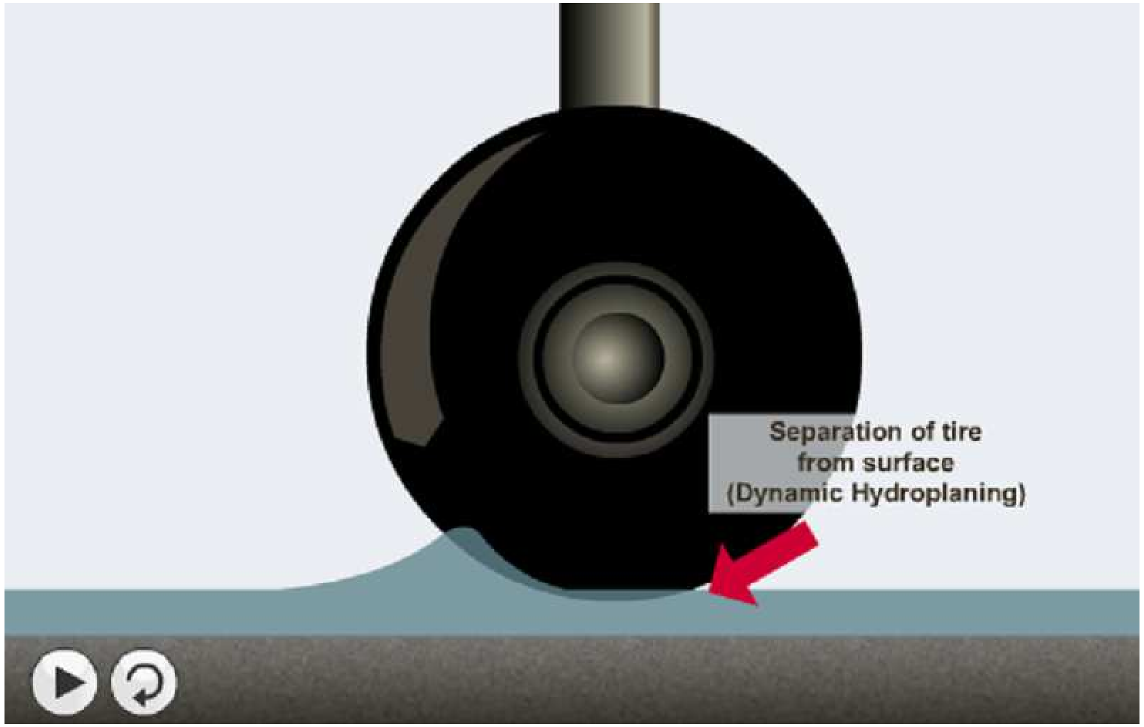
Source: FAA Safety at https://www.faasafety.gov

Hydroplaning: Viscous

- A thin film of fluid no more than 2.5 mm (0.1 in)
- The tire cannot penetrate the fluid and rolls on top of the film
- This can occur at a much lower speed than dynamic hydroplane, but requires a smooth or smooth acting surface such as asphalt or a touchdown area coated with the accumulated rubber of past landings

Hydroplaning: Dynamic

- High-speed phenomenon when there is a film of water on the runway that is at least 2.5 mm (0.1 in) deep
- This results in the formation of a wedge of water beneath the tire



FAA animation at https://www.faasafety.gov/gslac/ALC/course_content.aspx?cID=34&sID=171&preview=true

Hydroplaning: Dynamic

- At some speed (V_P), the water pressure equals the weight of the airplane and the tire is lifted off the runway surface.
  - $V_P = 9\sqrt{TirePressure(psi)}$ when the aircraft is rolling on the runway and encounters water contamination
  - $V_P = 7.7\sqrt{TirePressure(psi)}$ when contamination is encountered on touchdown, before the wheels are spinning
- Above this speed, hydroplaning is likely to occur
  - Critical hydroplaning speeds for E-Jets: 95 to 115 knots

Hydroplaning: Reverted Rubber (Steam or Vapor)

- Results of a prolonged locked-wheel skid
  - The tire skidding generates heat that causes the rubber to revert to its original uncured state
  - Reverted rubber acts as a seal between the tire and the runway, and delays water exit from the tire footprint area
  - The water heats and is converted to steam which supports the tire off the runway
- Eventually the airplane slows enough to where the tires make contact with the runway surface and the airplane begins to skid

Evidences of Steam Hydroplaning on Tires

Reverted rubber on tires

Evidences of Steam Hydroplaning on the Runway

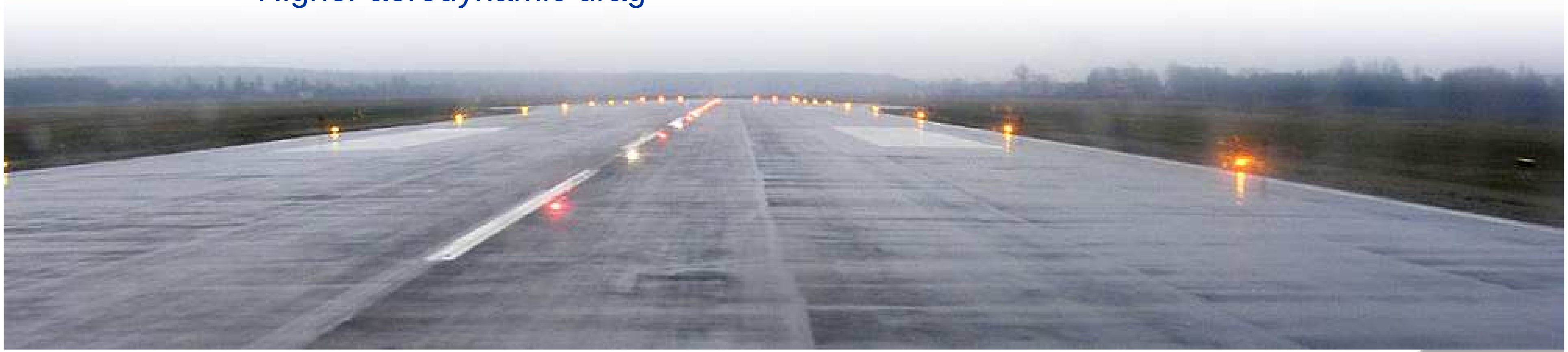
White marks on runway

Hydroplaning: How to Deal With?

- Remember: Thrust Reverser and Ground Spoiler stopping forces are independent of runway condition

- Conduct a positive landing to ensure initial wheel spin-up and initiate firm ground contact upon touchdown

- Consider landing with FLAPS FULL:
  - Slower approach speed,
  - Higher aerodynamic drag



In-Flight Landing Distance Assessment

- Performance numbers are good and necessary, but INFORMATION is to be considered
- How is your pilot fed with information about the destination?
    - METARs? PIREPs?

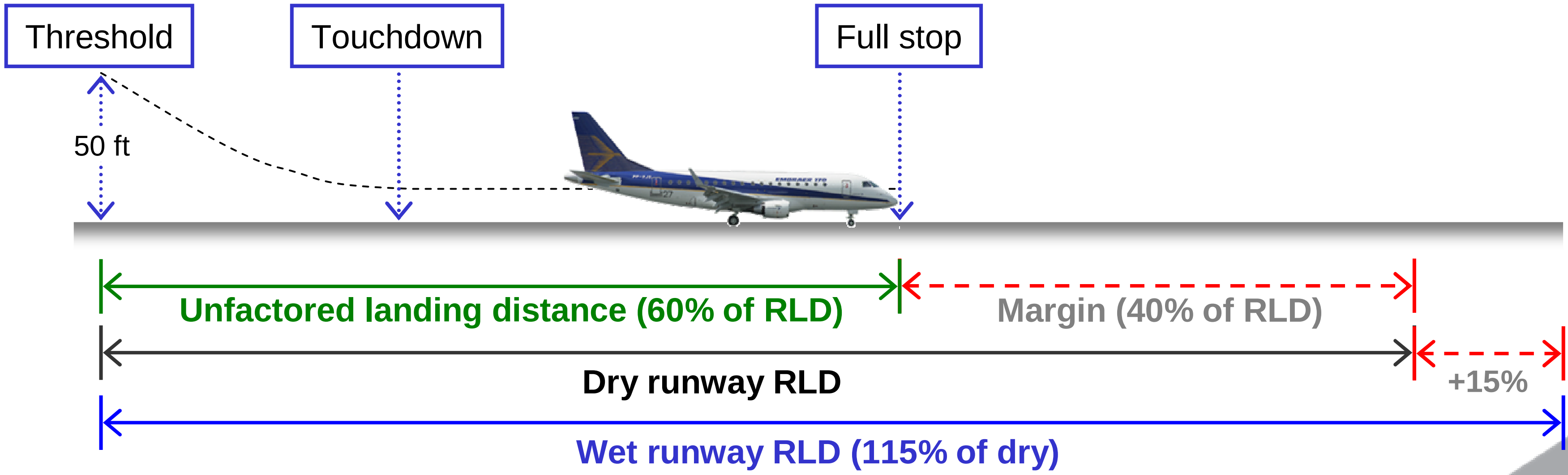
Landing Performance Analysis

The Safety Margins Provided by Requirements

Operational requirements: define minimum margins to apply over the certified landing performance of the airplane

- **Dry runway Required Landing Distance (RLD):** The airplane **shall be able to stop within 60%** of the landing distance available (FAR 121.195(b) and EU-OPS 1.515)

- **Wet runway RLD:** An **additional 15%** over the dry RLD shall be required (FAR 121.195(d) and EU-OPS 1.520)

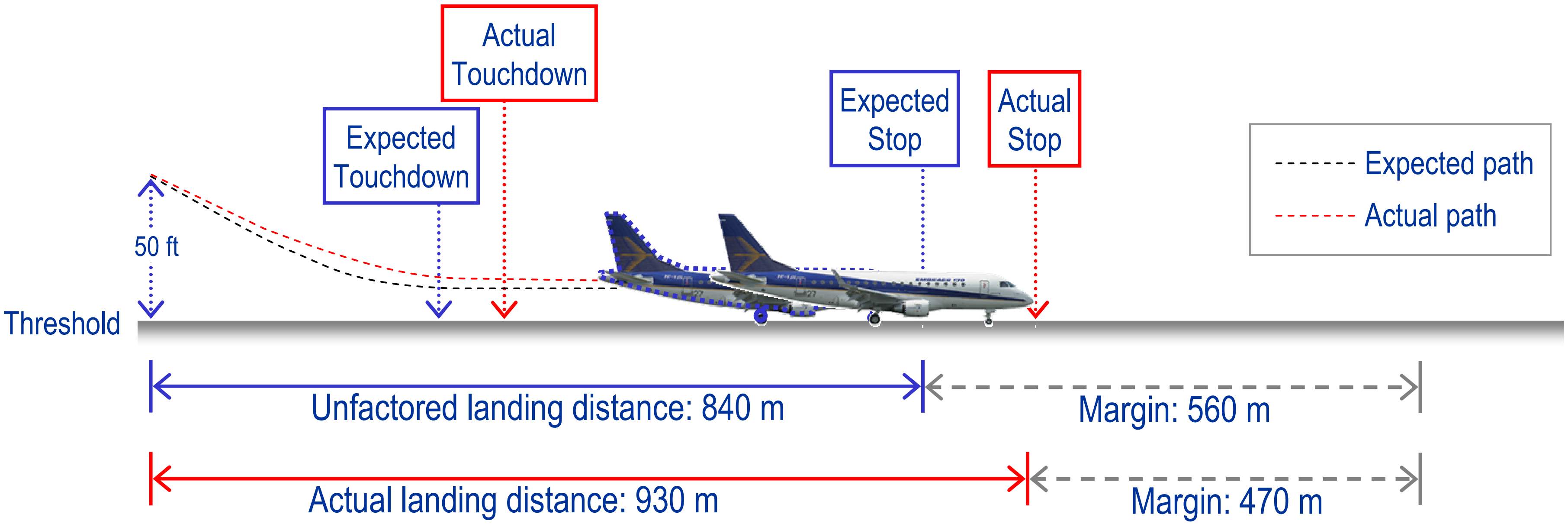


Case Study

- **Baseline performance:**
  - Model: EMBRAER 190
  - Landing configuration: Flaps 5 (Dry/Wet), Flaps FULL (Contaminated)
  - Weight: 44,000 kg (97,003 lb)
  - Sea level
  - No wind
  - Threshold crossing at V_{REF}
  - Maximum manual braking, applied immediately after main landing gears touch down
- **Remarks:**
  1. Contaminated runway calculation: AMJ 25X1591 (for Slush, depth = 10 mm)
  2. Wet runway calculation: it was assumed that μ_{WET} is 50% of μ_{DRY}. (Obs: this is not a tested value, but an assumption for didactic purposes only)
  3. Reverse thrust credit considered for contaminated runways

Case Study: V_{REF} Overspeed

- Runway Condition: **Dry**
- ULD: **840 m**
- Deviation from procedures: **10 kt overspeed at threshold**



Landing distance margin is reduced by **90 m (16%)**

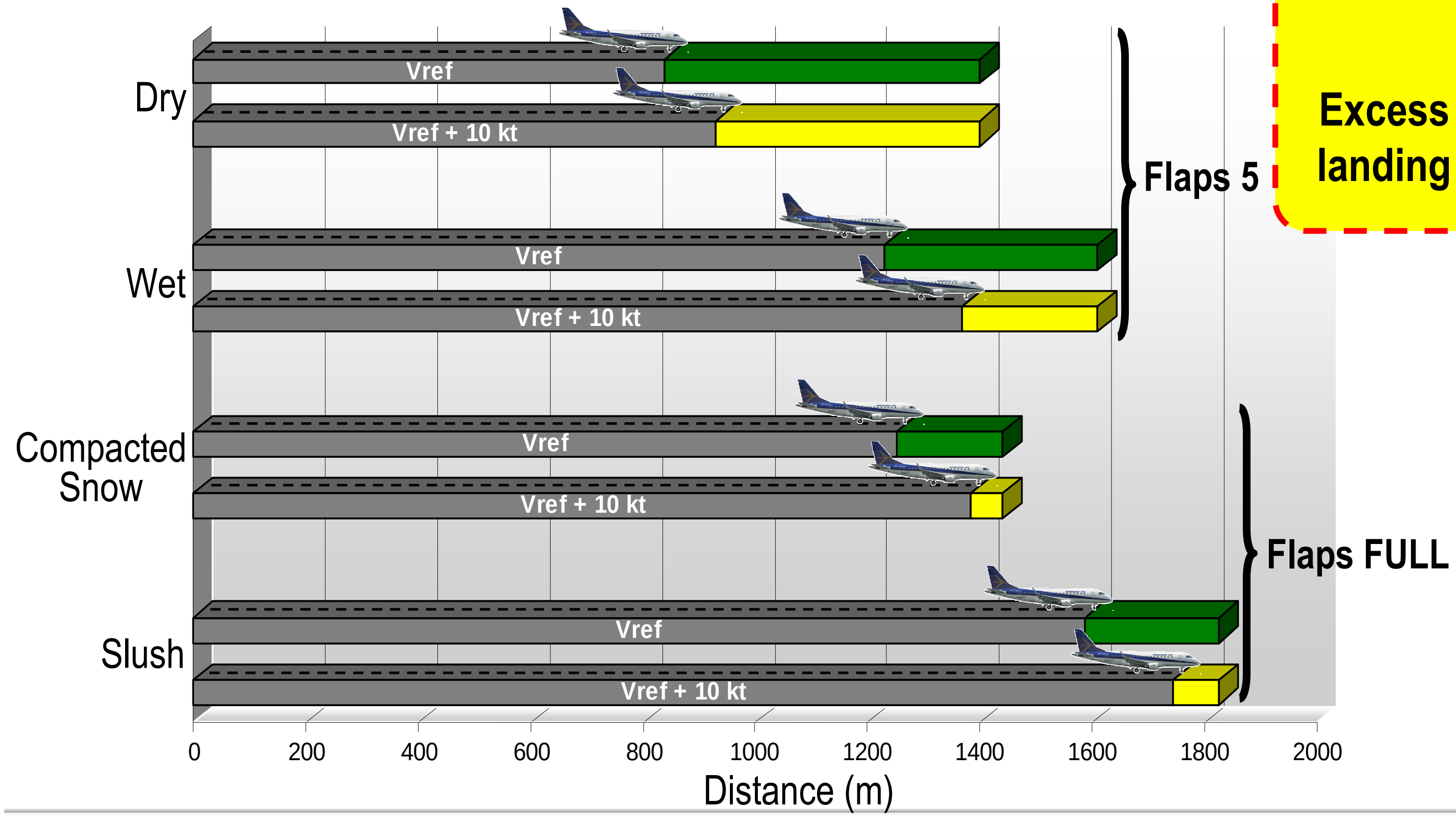
Case Study: V_{REF} Overspeed

Description: Threshold crossing with excess of speed

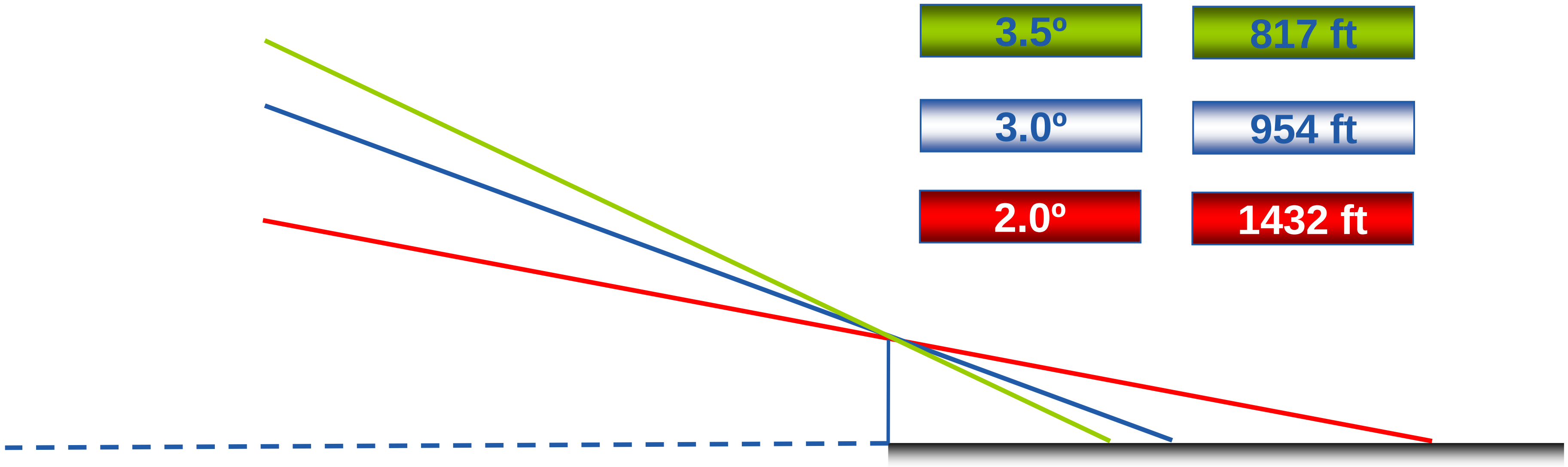
- **Standard speed at threshold:** V_{REF}
- **Considered speed at threshold:** V_{REF}+10 kt

Whenever possible, <u>cross threshold at the standard speed</u>

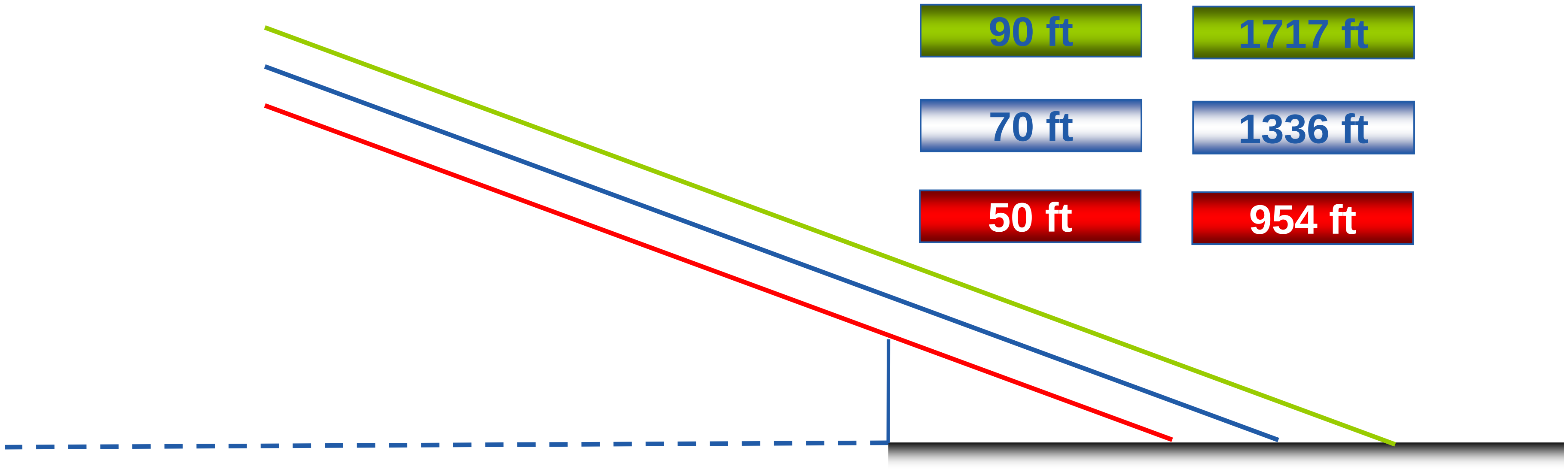
Excess of speed reduces landing distance margins



Approach Angle (Flight Path)

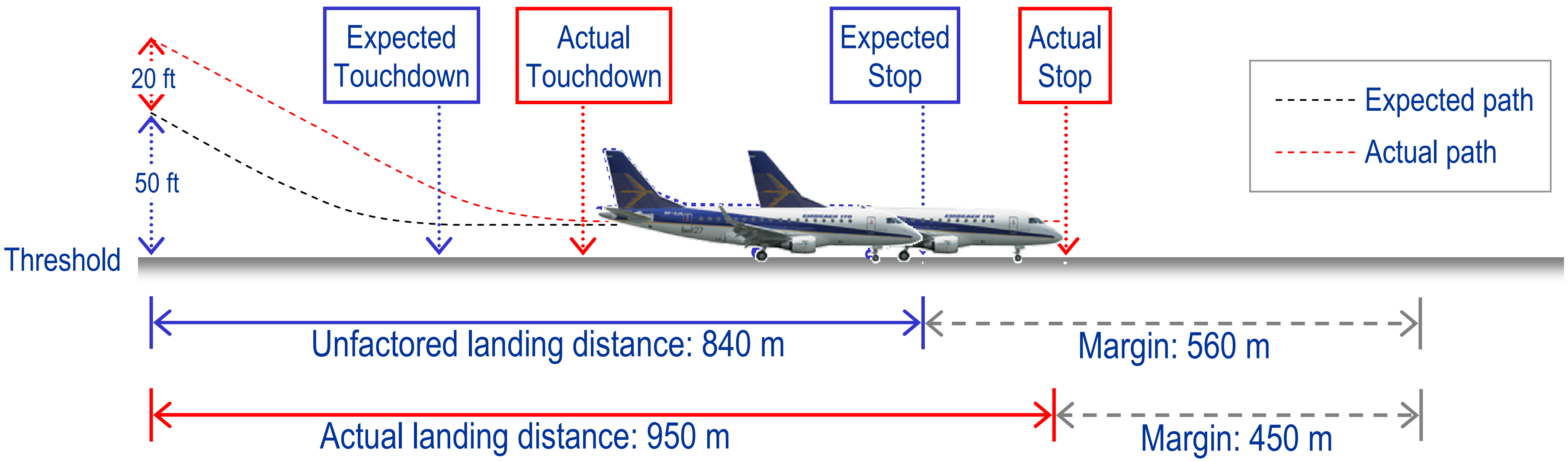


High Threshold Crossing



Case Study: High Threshold Crossing

- Runway Condition: **Dry**
- ULD: **840 m**
- Deviation from procedures: **70 ft height at threshold**



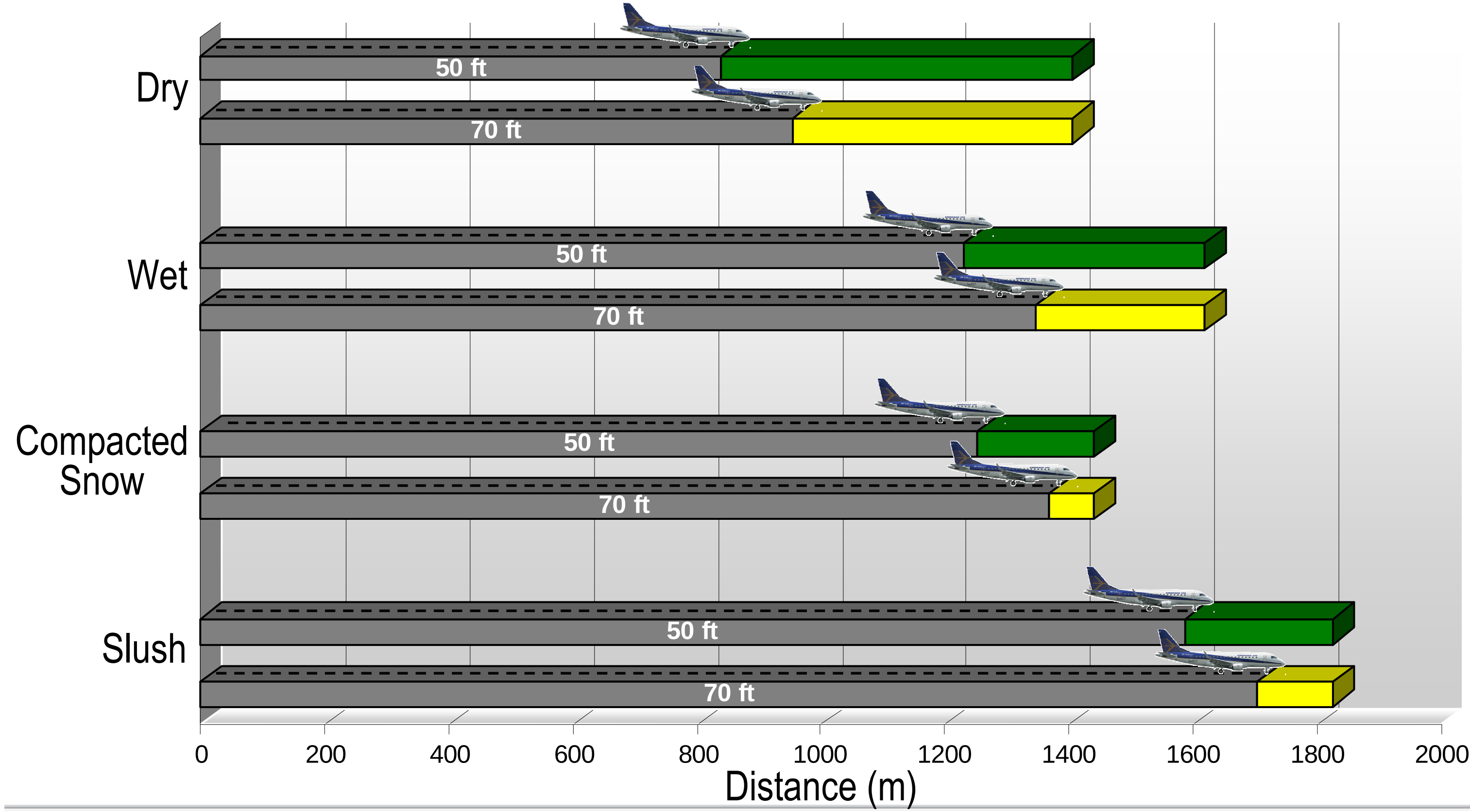
Landing distance margin is reduced by **110 m (20%)**

Case Study: High Threshold Crossing

Description: Threshold crossing higher than 50 ft

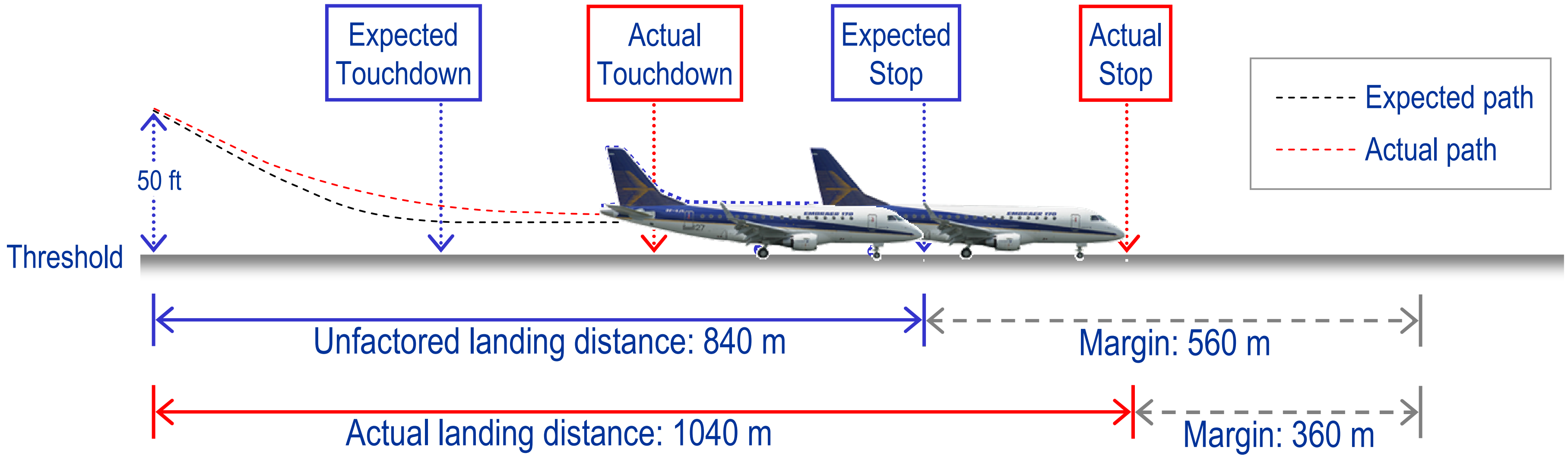
- **Standard height at threshold:** 50 ft
- **Considered height at threshold:** 70 ft

Whenever possible, <u>cross threshold at 50 ft</u>



Case Study: Early Flare (floating)

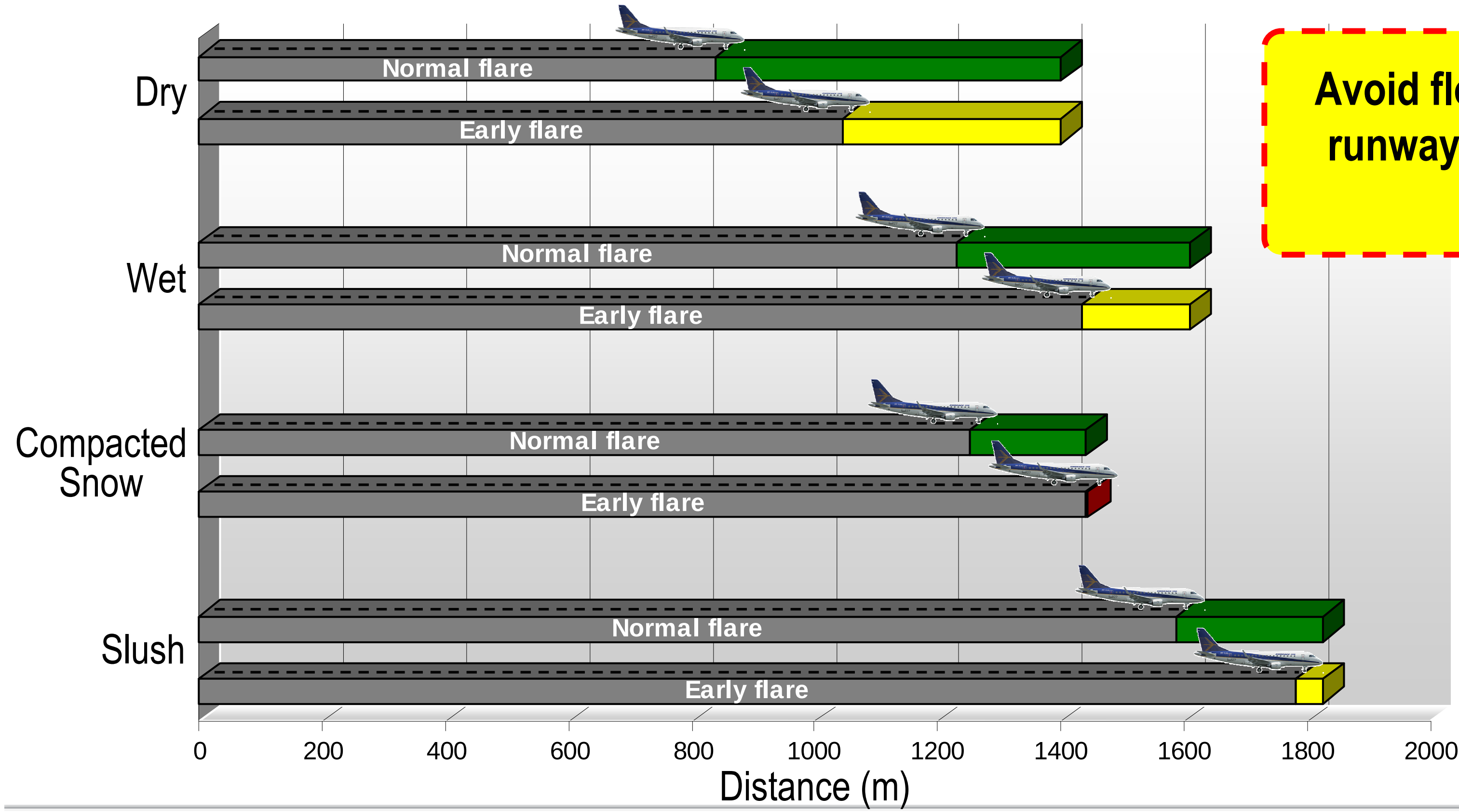
- Runway Condition: **Dry**
- ULD: **840 m**
- Deviation from procedures: **touchdown delayed by 3 seconds**



Landing distance margin is reduced by **200 m (35%)**

Case Study: Early Flare (floating)

- **Description:** Early flare resulting in extended air distance
- **Standard procedure:** no flare delay
- **Considered procedure:** early flare, delaying touchdown by 3 seconds

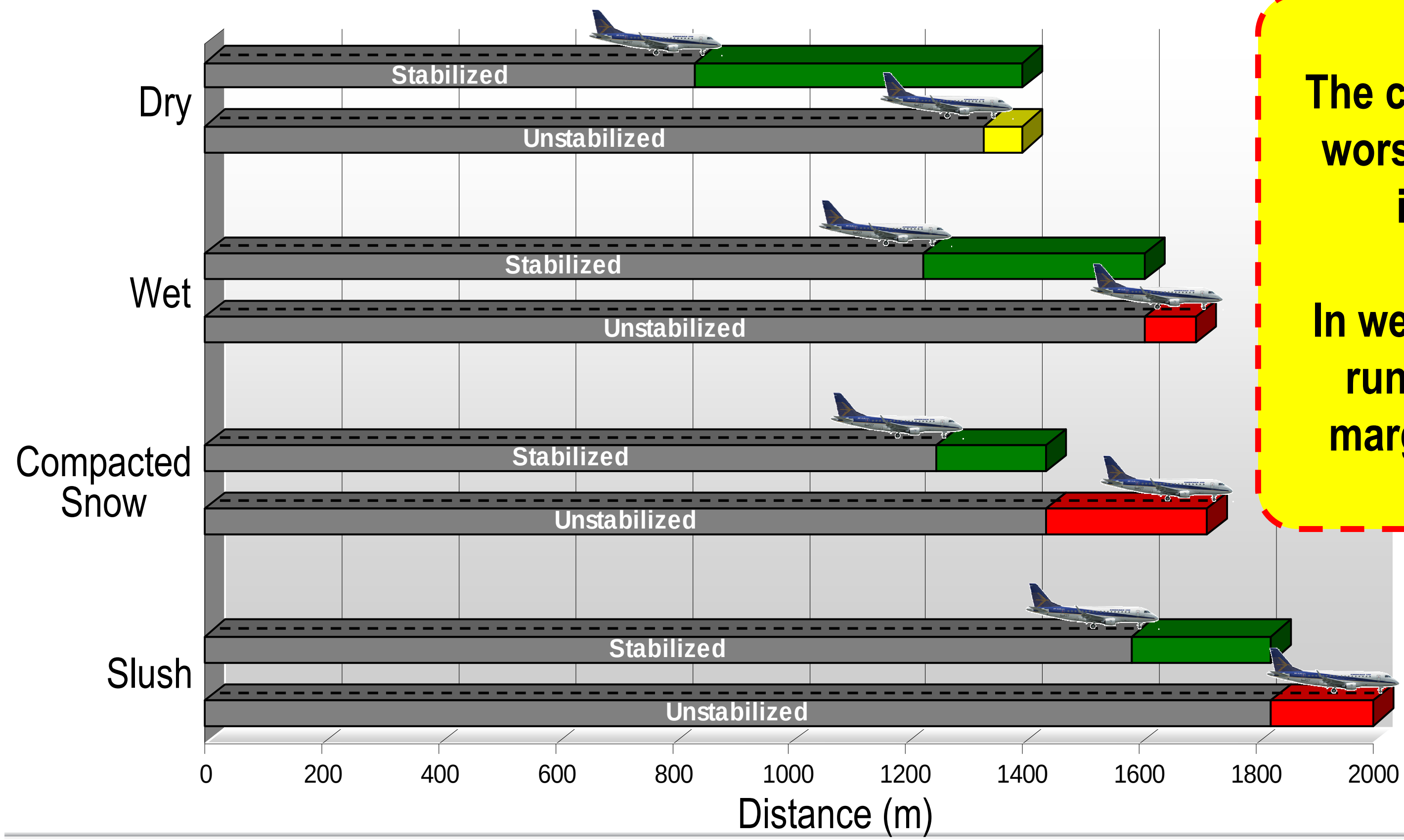


Avoid floating above the runway, conduct a firm landing

Case Study: Unstabilized Approach

Description: Simulated unstabilized approach. Procedure deviations considered **simultaneously**:

- **Threshold crossing with V_{REF} + 10 kt at 70 ft height**
- **Touchdown delayed for 3 seconds**

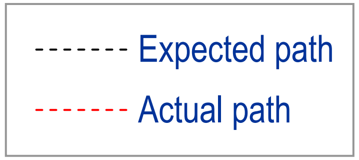


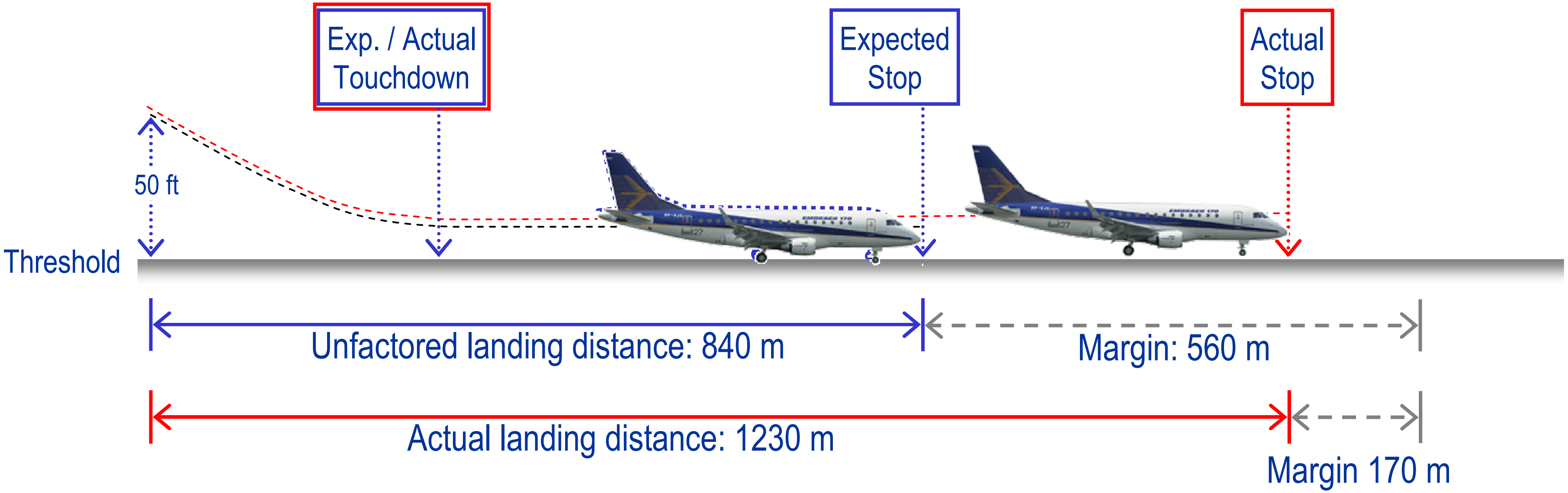
The combined effects are worse than those of the isolated factors

In wet and contaminated runways, operational margins are exceeded!

Case Study: Partial Brakes Application

- Runway Condition: **Dry**
- ULD: **840 m**
- Deviation from procedures: **partial brakes application**



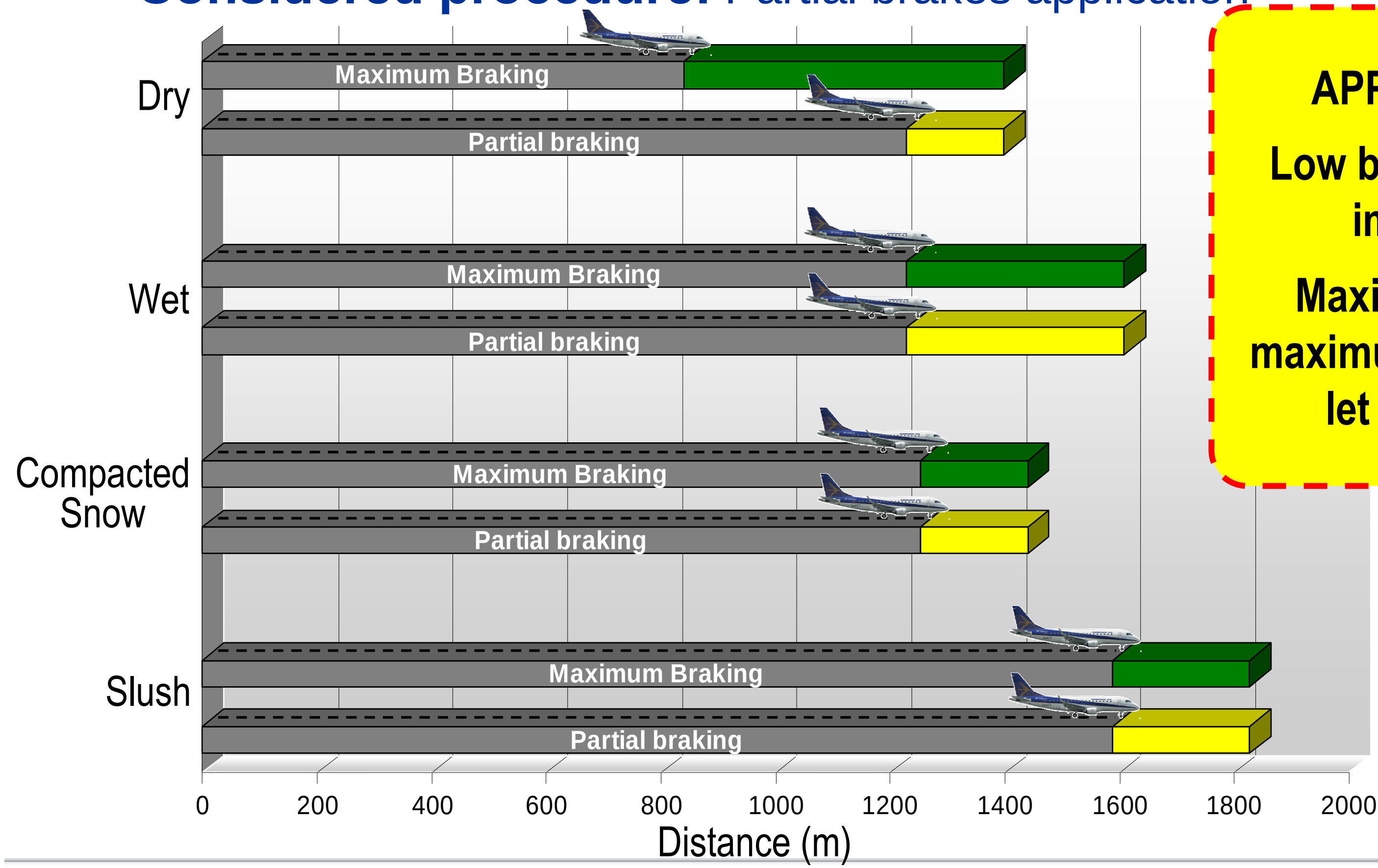


Landing distance margin is reduced by **390 m (70%)**

Case Study: Partial Brakes Application

Description: Dispatch calculation always considers that maximum brakes will be applied

- **Certified braking procedure:** Maximum braking capacity applied
- **Considered procedure:** Partial brakes application



APPLY FULL BRAKES!

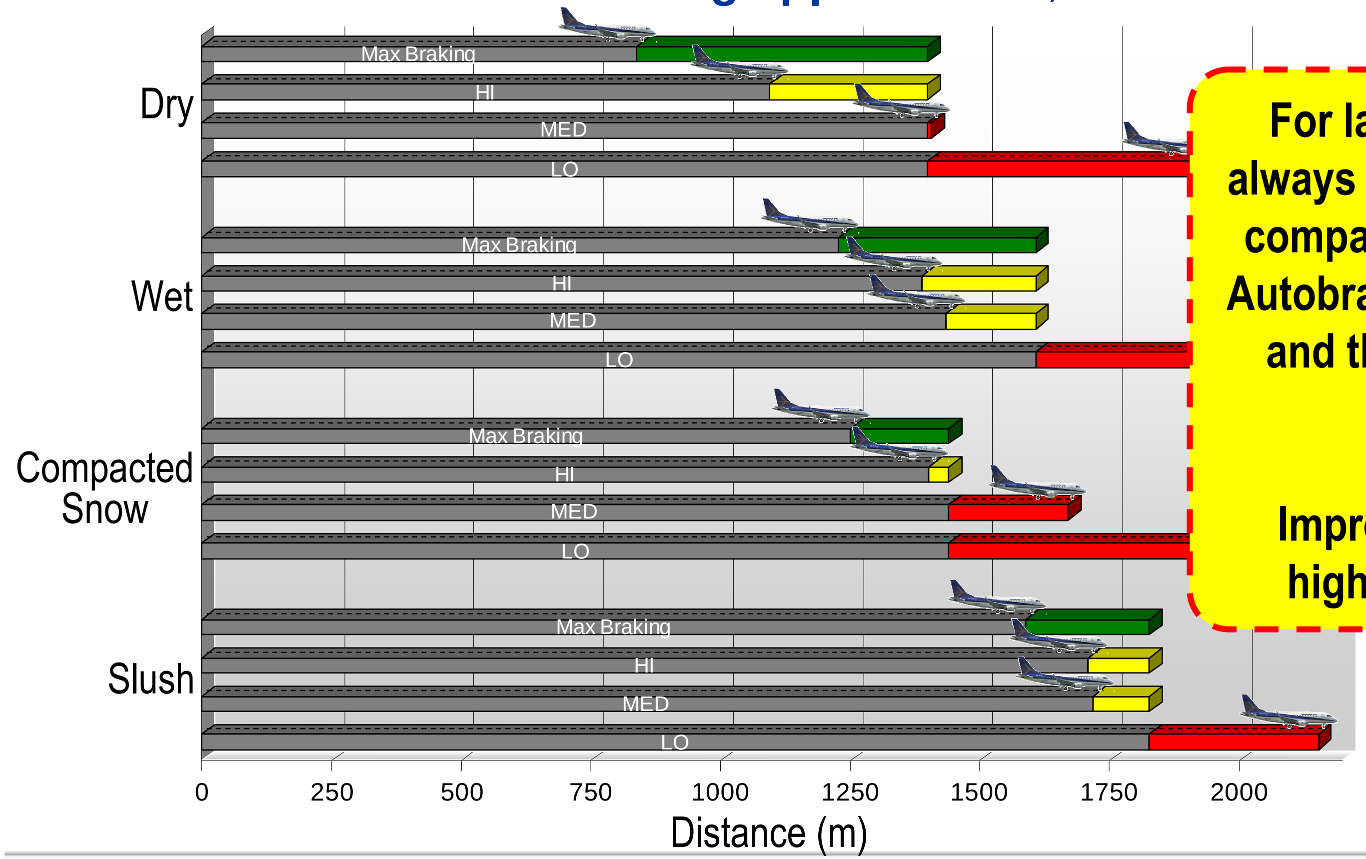
Low braking has significant impact on margins

Maximum braking grants maximum possible efficiency, let the anti-skid work!

Case Study: Improper Autobrakes Application

Description: Autobrake use not adequate. The dispatch was calculated considering manual brake application. Landing is performed with autobrake on

- **Autobrake status considered for dispatch:** Maximum manual braking
- **Autobrake selected during approach:** HI, MED or LO



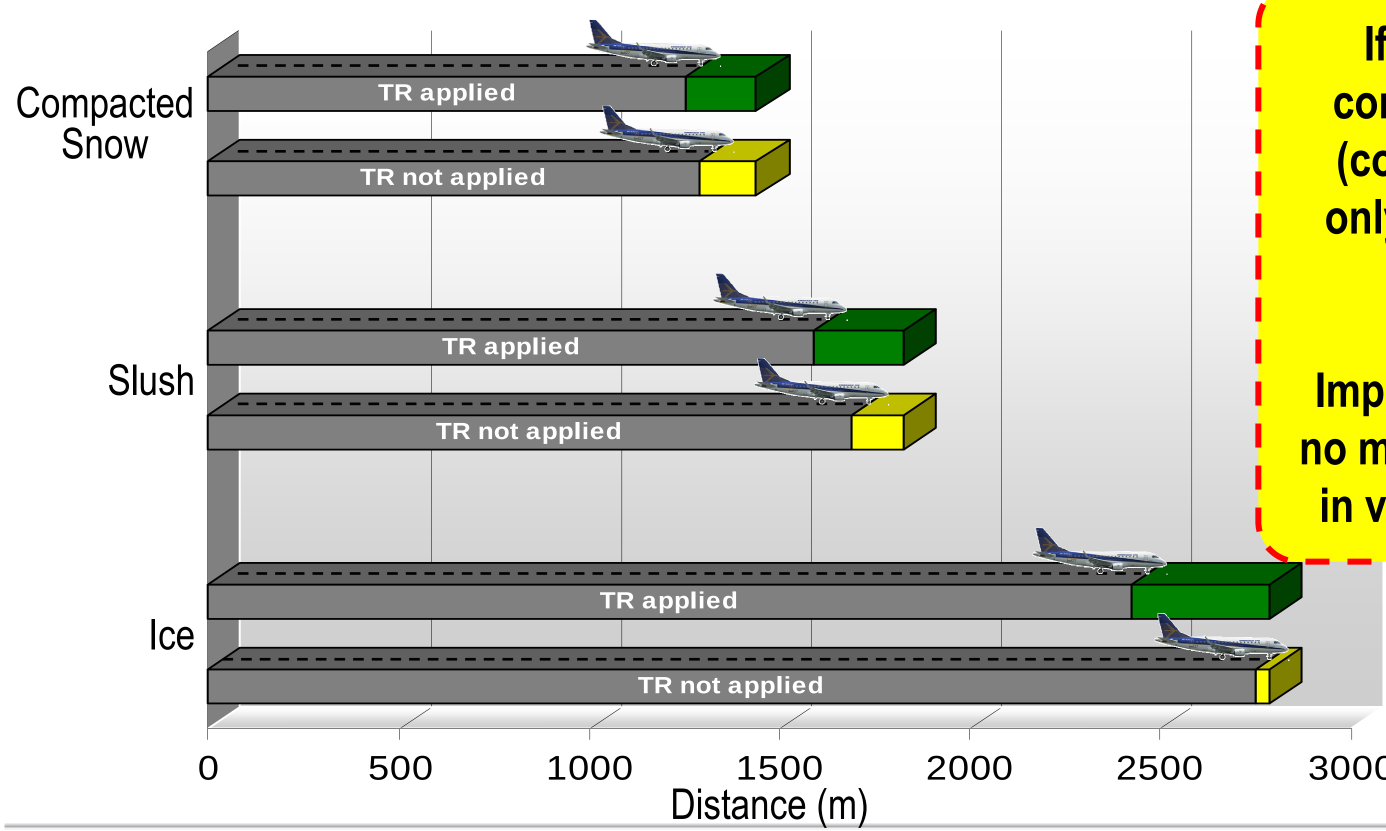
For landing, autobrake will always give lower performance compared to manual braking. Autobrake HI is not full braking and the transition is longer than in manual

Improper use can result in highly negative margins!

Case Study: Improper Reverse Thrust Use

Description: Dispatch is calculated **considering that Thrust Reverser (TR) will be applied**. Landing is performed without it

- **Reverse thrust considered for dispatch:** All reversers applied
- **Reverse thrust applied at landing:** reversers not deployed

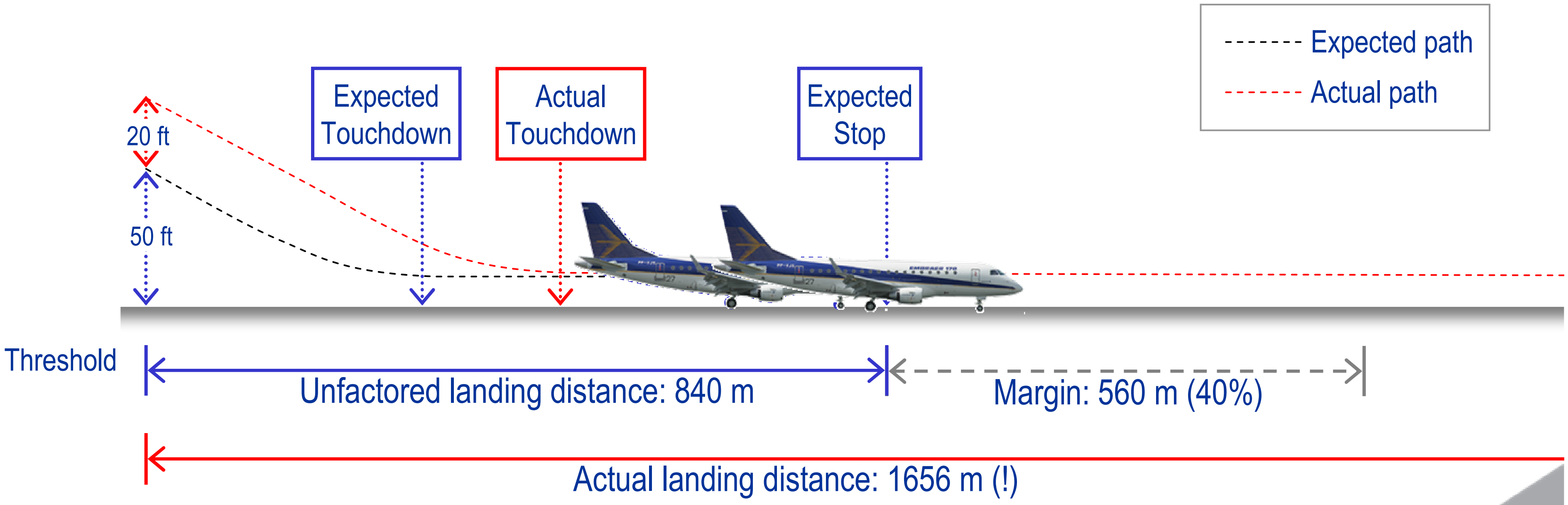


If reverse thrust was considered for dispatch (contaminated runways only), apply reversers as soon as possible

Improper use can result in no margins when operating in very slippery runways!

Case Study: If everything happens together…

- Runway condition: **Dry**
- ULD: **840 m**
- Deviation: 10 kt overspeed + 70 ft at threshold + 3 seconds floating + partial brakes application…



Maximum Performance Landing

Maximum Performance Landing

A set of techniques that leads to stopping the airplane with the least landing run. The following recommendations apply:

- Review the approach procedures and speeds earlier: keep your situation awareness over the stabilized approach and stabilized landing is mandatory for a well-planned and executed approach.
- Use Full Flaps.
- Cross the Threshold at Screen Height of 50 ft and V_{REF}.
- Avoid extended flare.
- Conduct a positive landing.
- Apply maximum Thrust Reverser.
- Immediately after the main landing gear wheels have touched down apply firm and steady maximum manual brakes and hold pedal pressure until the airplane decelerates to a safe taxi speed within the runway.
- Lower nose wheel immediately to the runway. It will decrease lift and increase main landing gear loading.

Conclusions

Conclusions

- Maintain situation awareness after touch down
- Use Thrust Reversers promptly on touch down and until stop is assured
- Autobrake targets deceleration rate, not brake pressure
- Anti-skid functionality is overridden after application of Emergency Brakes
- Dry runways: braking time and intensity play a major role
- Contaminated runways: braking is less effective. Use of reverse thrust must be performed accordingly
- Use Maximum Performance Landing whenever necessary
- Brake for safety!

To grant a safe landing:
– **Follow the standard procedures**. Leave margins for the unknown!


QUESTIONS


Gracias!
FOR THE JOURNEY
EMBRAER