Landing on Slippery Runways

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Landing on a Slippery Runway

Agenda

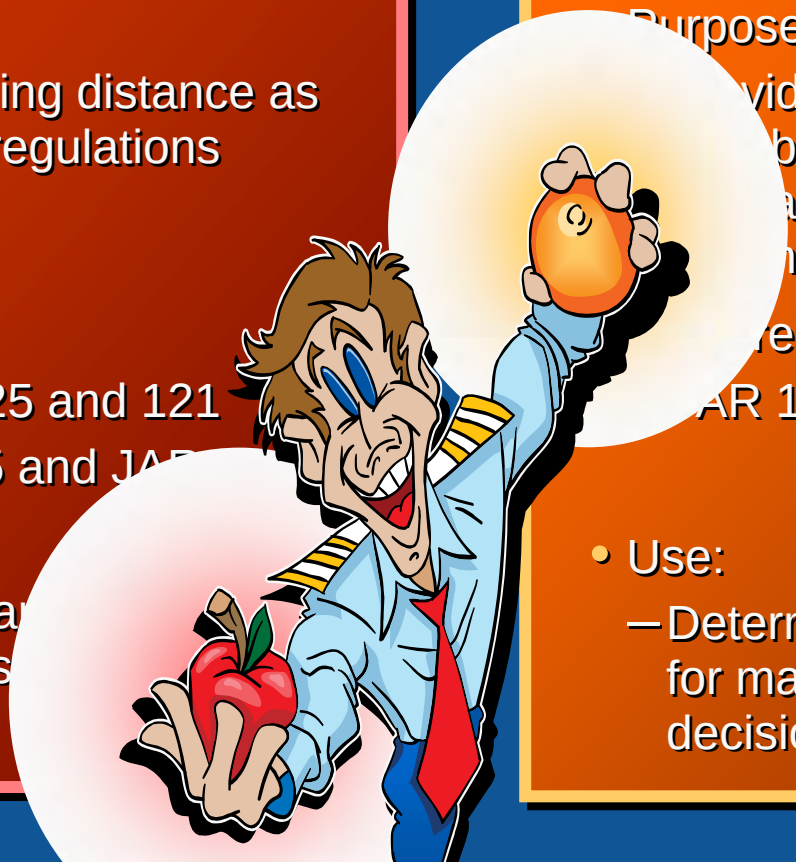
- Review available landing data
  - Certified data
  - QRH advisory data
    - Unfactored status
    - Autobrake performance
- Operational implementation of QRH advisory data
  - Runway condition reporting
  - Margins
- Flying the airplane

Landing Distance Data

Boeing provides two distinct and different data sets:

Certified Data

- Purpose
  - Provide landing distance as required by regulations
- Requirements
  - FAR Parts 25 and 121
  - JAR Part 25 and JA
- Use
  - Determine la requirements dispatch



Advisory Data

- Purpose
  - vide landing distance bility for different ay conditions and ng configurations
- rements
  - AR 121 and JAROPS 1
- Use:
  - Determine landing distance for making operational decisions

Landing Distance Data
CERTIFIED Data Method

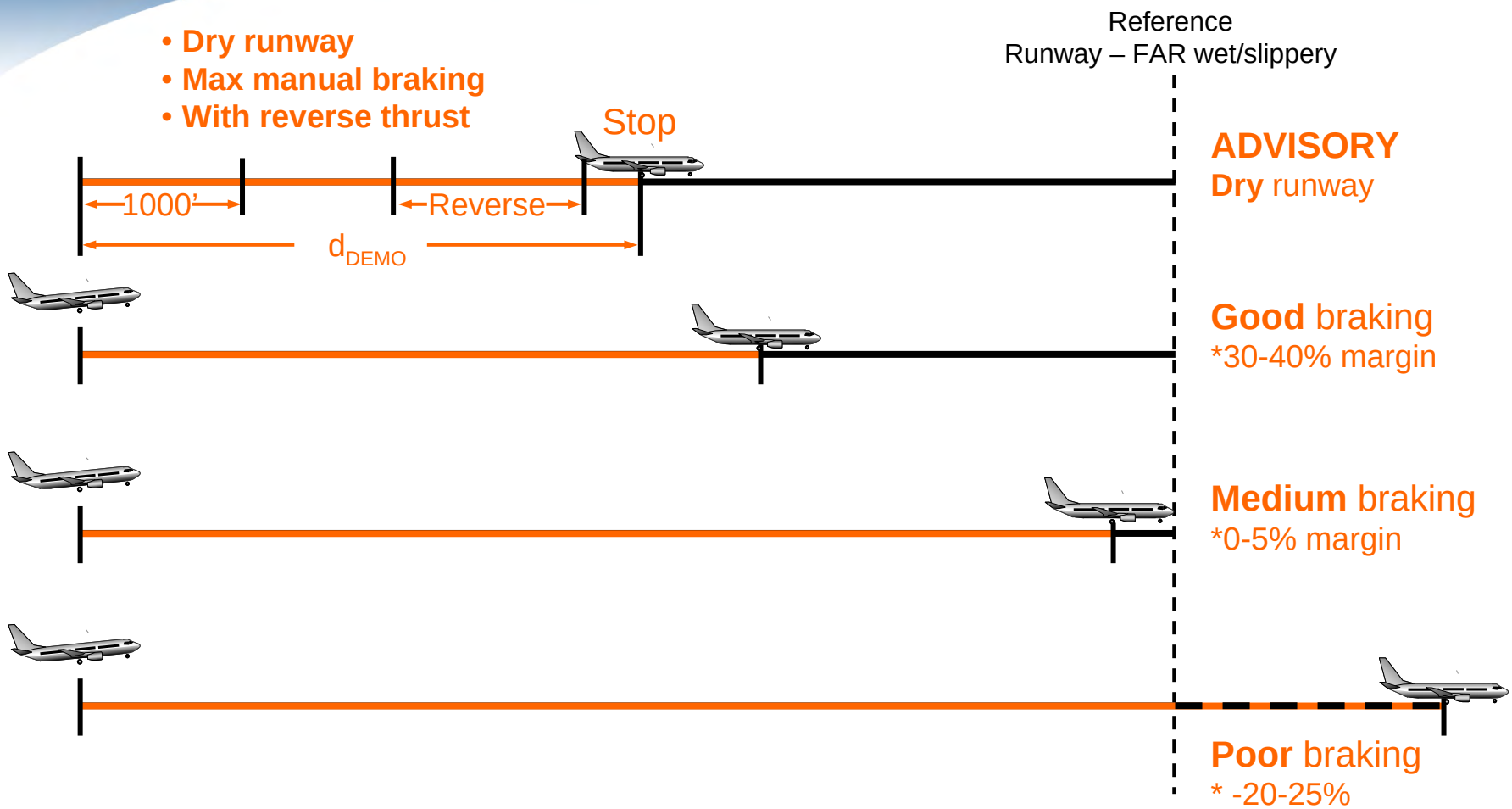
No Reversers

- Dry runway
- Max manual braking
- No reverse thrust

Landing Distance Data
ADVISORY Data Method

Reversers Included

- Dry runway
- Max manual braking
- With reverse thrust



* Values dependant on airplane model

Landing Distance Data

ADVISORY Data

QRH Page

ADVISORY INFORMATION

Normal Configuration Landing Distance

Flaps 40

Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF40	1 REV	NO REV
MAX MANUAL	2510	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-80	460	390	490

Reference distance is for sea level, standard day, VREF 40 approach speed and 2 engine detent reverse thrust

Actual (unfactored) distances are shown

Includes distance from 50 ft. above the threshold (1000 ft of air distance)

								50	-40	280	160	570
								50	-40	280	160	570
								60	-50	400	40	230
								80	-80	470	70	70
								90	-90	440	490	640

Medium Reported Braking Action

MAX MANUAL	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
MAX AUTO	4470	390/-340	130	-240	900	190	-140	70	-60	340	410	1770
AUTOBRAKES 3	4540	400/-340	130	-240	910	160	-110	70	-70	420	340	1700
AUTOBRAKES 2	5250	480/-440	150	-270	1010	140	-140	80	-80	440	200	1100
AUTOBRAKES 1	5580	550/-490	180	-300	1080	210	-170	90	-90	430	540	1300

Poor Reported Braking Action

MAX MANUAL	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
MAX AUTO	5580	530/-470	170	-350	1370	410	-270	80	-80	390	810	4900
AUTOBRAKES 3	5580	530/-460	170	-350	1370	410	-260	80	-80	400	810	4900
AUTOBRAKES 2	5900	560/-500	180	-360	1420	370	-260	90	-90	430	620	4580
AUTOBRAKES 1	6070	600/-540	190	-370	1450	410	-290	90	-90	430	800	4530

Reference distance is for sea level, standard day, no wind or slope, VREF40 approach speed and 2 engine detent reverse thrust.

Actual (unfactored) distances are shown.

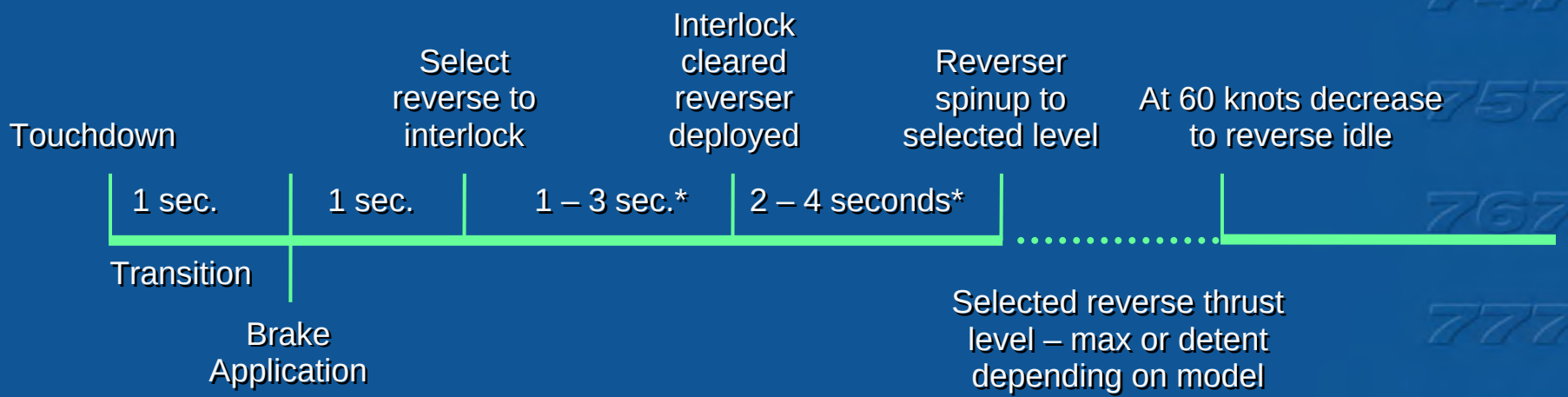
Includes distance from 50 ft above threshold (1000 ft of air distance).

JAR operators advisory data in QRH include 1.15 factor

Based on these notes

Reverse Thrust Application Sequence

As Applied in QRH Advisory Data



* Actual time dependant on engine/airframe

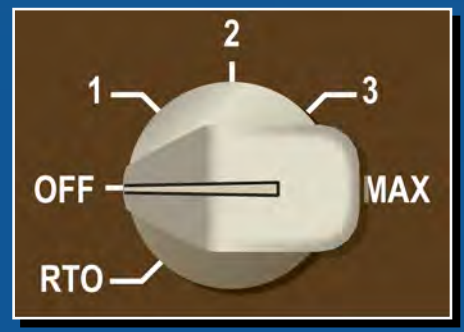
Landing Distance Data
ADVISORY Data—QRH Page

- Provides adjustments for several variables

Variables

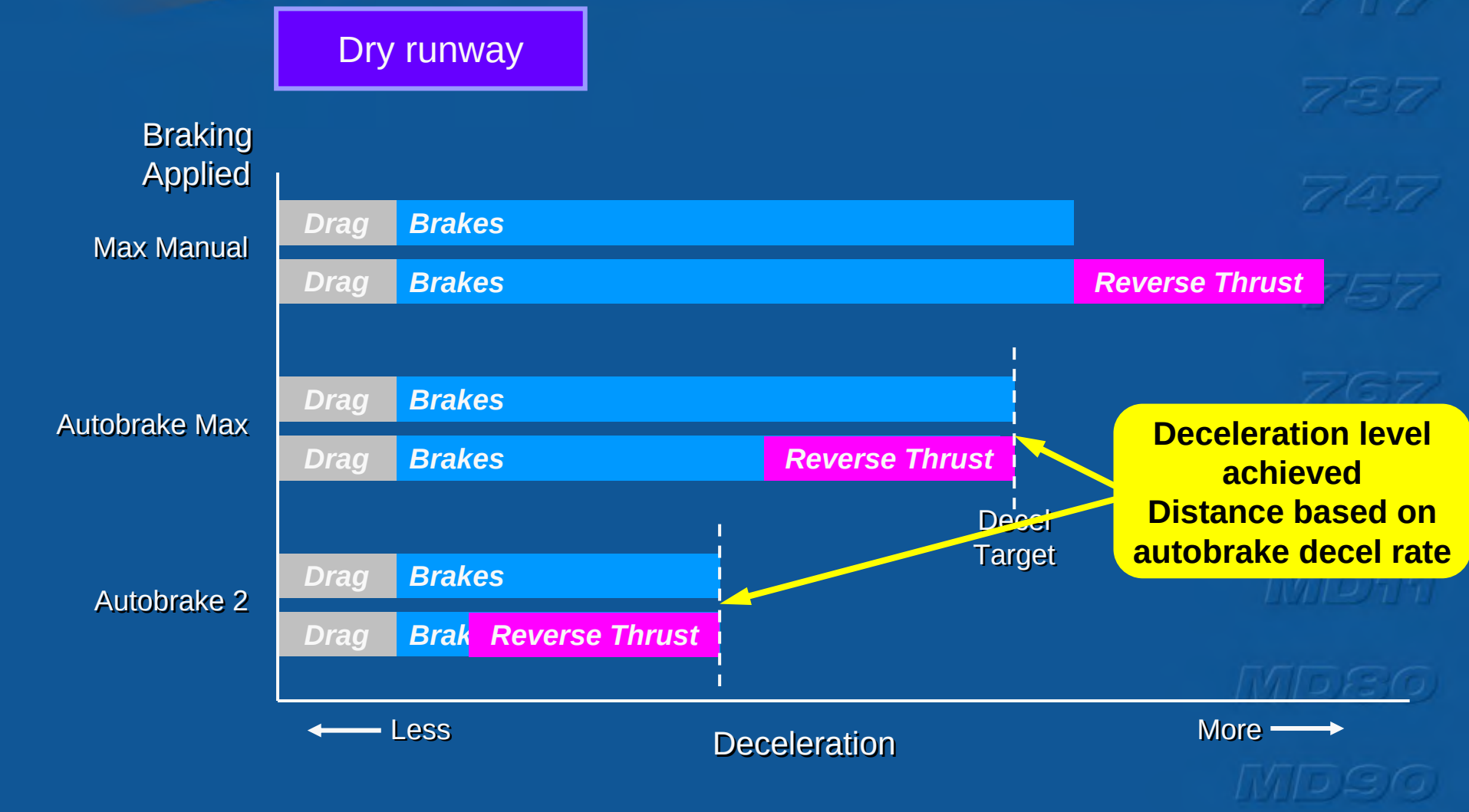
	LANDING DISTANCE AND ADJUSTMENTS (FT)											
	REF DIST	WT ADJ	ALT ADJ	WIND ADJ PER 10 KTS		SLOPE ADJ PER 1%		TEMP ADJ PER 10°F		VREF ADJ	REVERSE THRUST ADJ	
BRAKING CONFIGURATION	105000 LB LANDING WEIGHT	PER 10000 LB ABOVE/ BELOW 105000 LB	PER 1000 FT ABOVE SEA LEVEL	HEAD WIND	TAIL WIND	DOWN HILL	UP HILL	ABV ISA	BLW ISA	PER 10 KTS ABOVE VREF40	1 REV	NO REV
MAX MANUAL	2510	270/-140	50	-90	320	30	-20	30	-30	200	40	120
MAX AUTO	2610	250/-160	60	-90	350	20	-10	40	-30	240	20	40
AUTOBRAKES 3	3140	370/-230	90	-140	540	30	-30	50	-50	360	30	60
AUTOBRAKES 2	4460	560/-450	130	-230	820	40	-40	80	-80	520	10	60
AUTOBRAKES 1	5100	560/-450	170	-280	1000	150	-140	90	-80	460	390	490

Landing With Autobrakes Selected

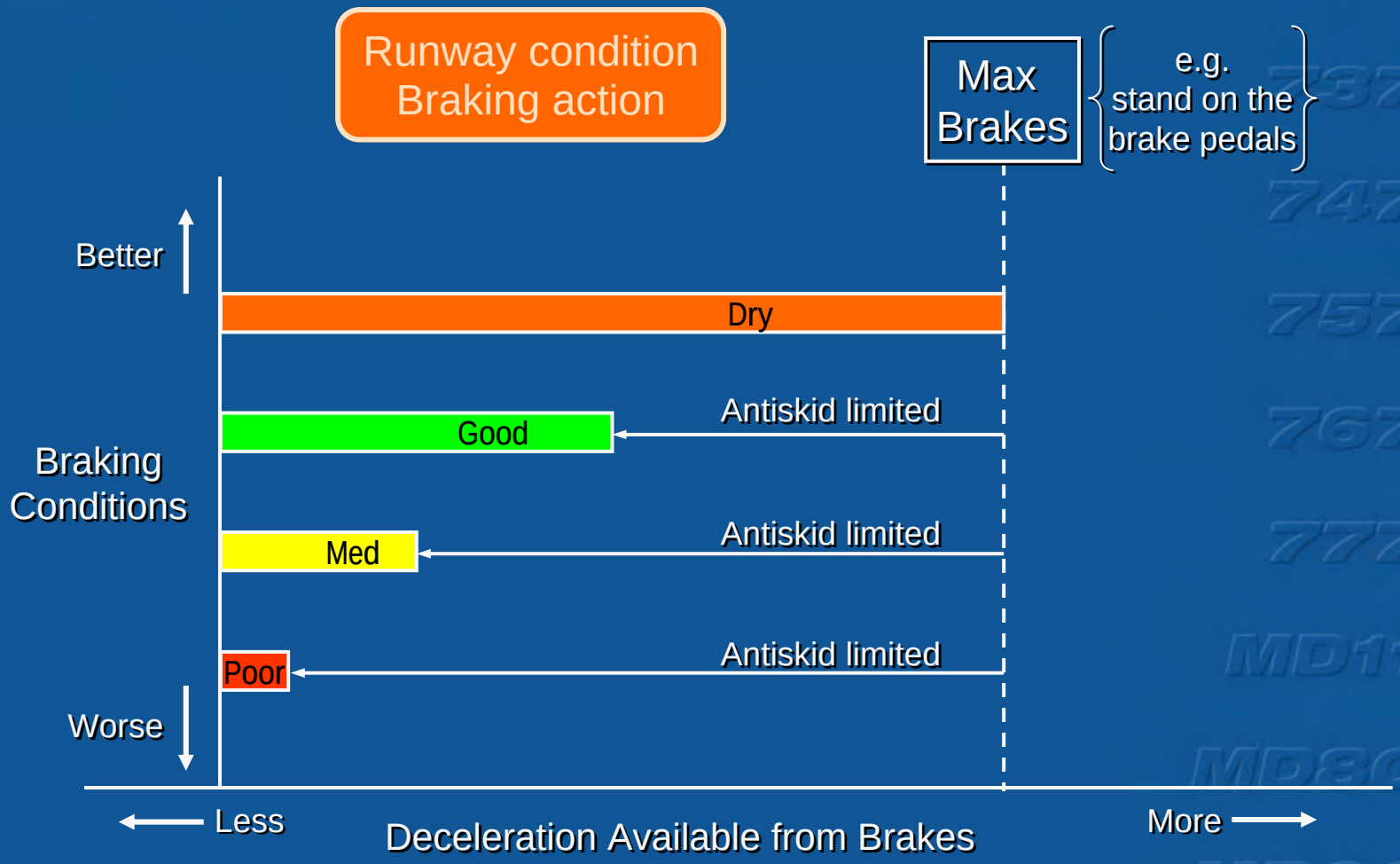


- Autobrake system
  - Targets a deceleration level
  - Brakes applied as required to reach target deceleration level
- Deceleration is affected by three factors:
  - Aerodynamic drag
  - Wheel brakes – dependant on runway friction available
  - Reverse thrust

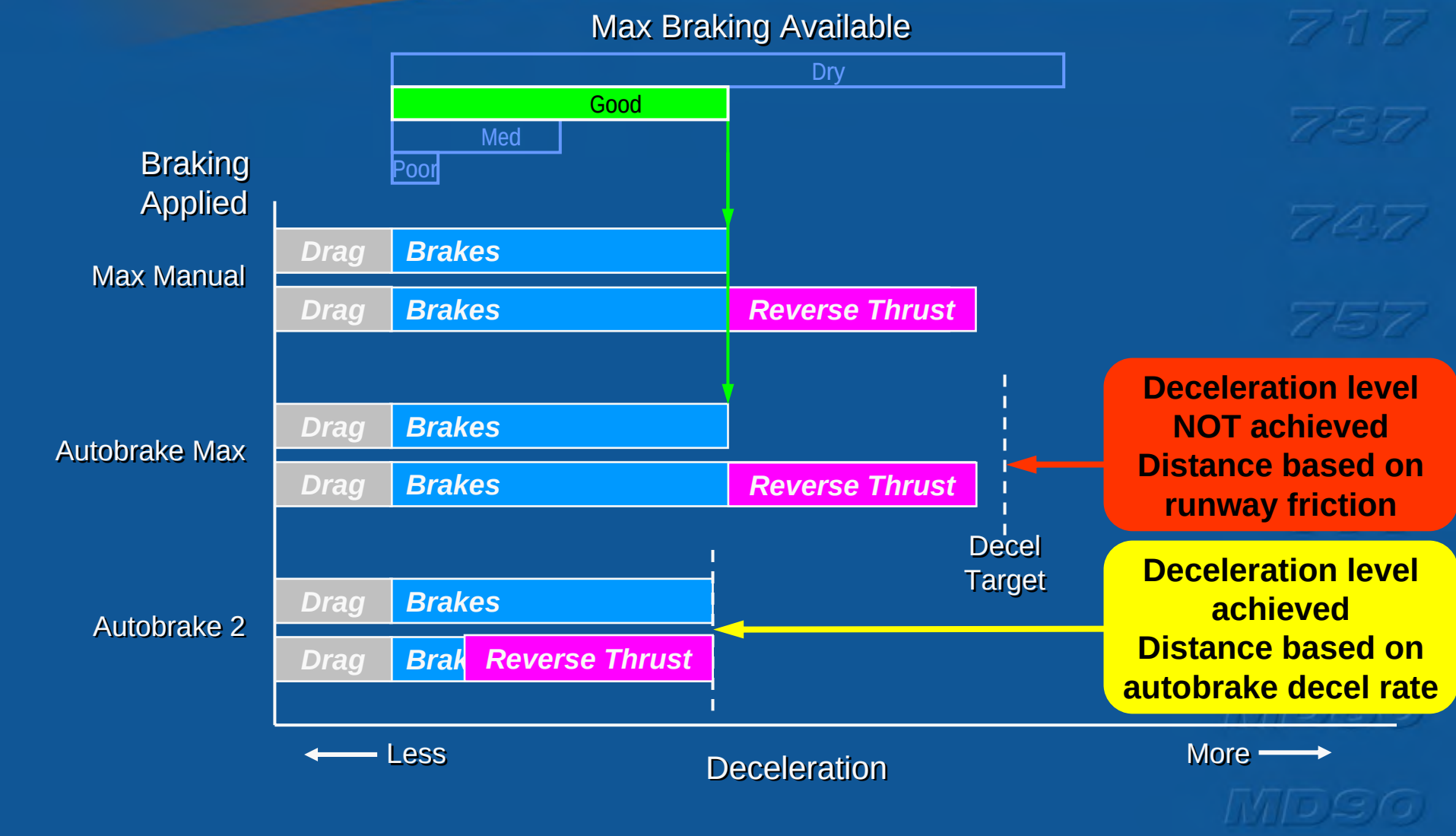
Maximum Deceleration
Manual Versus Autobrakes



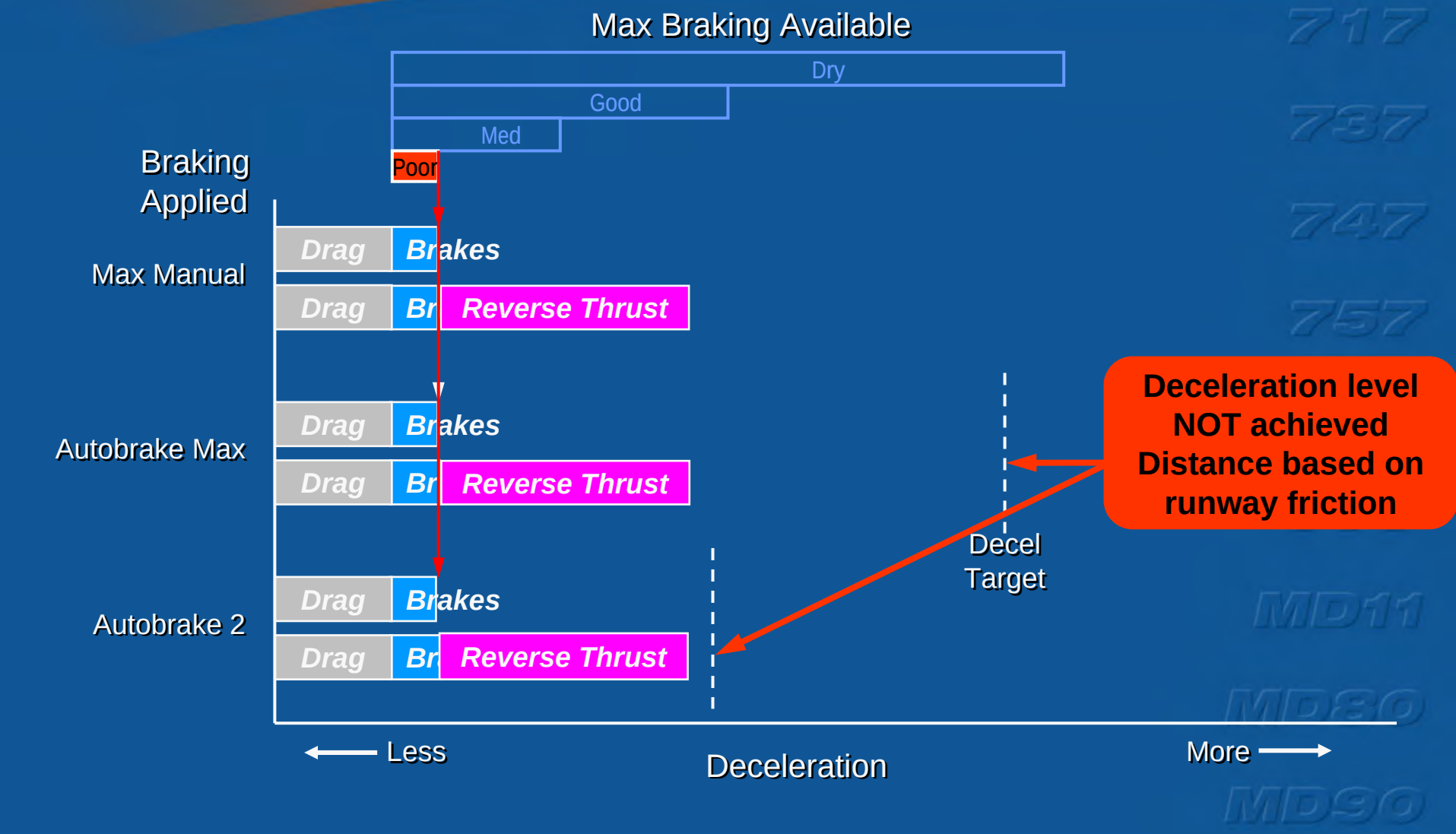
Maximum Deceleration Available from Brakes



Maximum Deceleration
Good Braking



Maximum Deceleration
Poor Braking



Autobrakes Versus Manual Brakes

- Manual Brakes
  - Dry runway: Reversers are additive
  - Slippery runway: Reversers are additive
- Autobrakes
  - Dry runway: Reversers NOT additive
  - Slippery runway: Reversers may be additive
- Landing Distance Advisory Data includes reversers for Manual and Autobrakes

Landing Distance Data Summary

- Certified Data Set
  - NO reversers
  - Factored data
  - Required for dispatch
- Advisory Data Set
  - Reversers included
  - Unfactored data
  - Operators add margin appropriate to their operation
  - Used for making operational decisions
- The data sets are different with a different purpose

Landing on a Slippery Runway

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- Review available landing data
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  - QRH advisory data
    - Unfactored status
    - Autobrake performance
- Operational implementation of QRH advisory data
  - Runway condition reporting
  - Margins
- Flying the airplane

Runway Condition Reporting

Runway condition is typically provided three ways

- PIREP's (pilot reports) – braking action – good, fair, medium, poor, nil
- Description of runway condition
  - Snow, wet, slush, standing water, sand treated compact snow etc.
- Reported friction based on Ground Friction Vehicle Report
  - 30 or 0.30 etc.

Evaluate the Information

- Flight crew needs to evaluate all the information available to them
  - Time of report
  - Changing conditions
  - Wind conditions
- Information may be conflicting
  - For example:
    - Braking action is good, runway description is slush covered
    - Measured friction is 40, braking action poor

Slush/Standing Water/Snow Report

- FAA AC 150.5200-30A addresses the conditions that the friction surveys should be conducted.
  - **”13b. Conditions Not Acceptable for Conduct of Friction Surveys on Frozen Contaminated Surfaces.** The data obtained from friction surveys are not considered reliable if conducted under the following conditions:
    - (1) when there is more than .04 inch (1 mm) of water on the surface, or
    - (2) when the depths of dry snow and/or wet snow/slush exceed the limits in the note above.” (presented below)
  - “13a…….It is generally accepted that friction surveys will be reliable as long as the depth of dry snow does not exceed 1 inch (2.5 cm), and/or the depth of wet snow/slush does not exceed 1/8 inch (3 mm).”

Slush/Standing Water/Snow Report

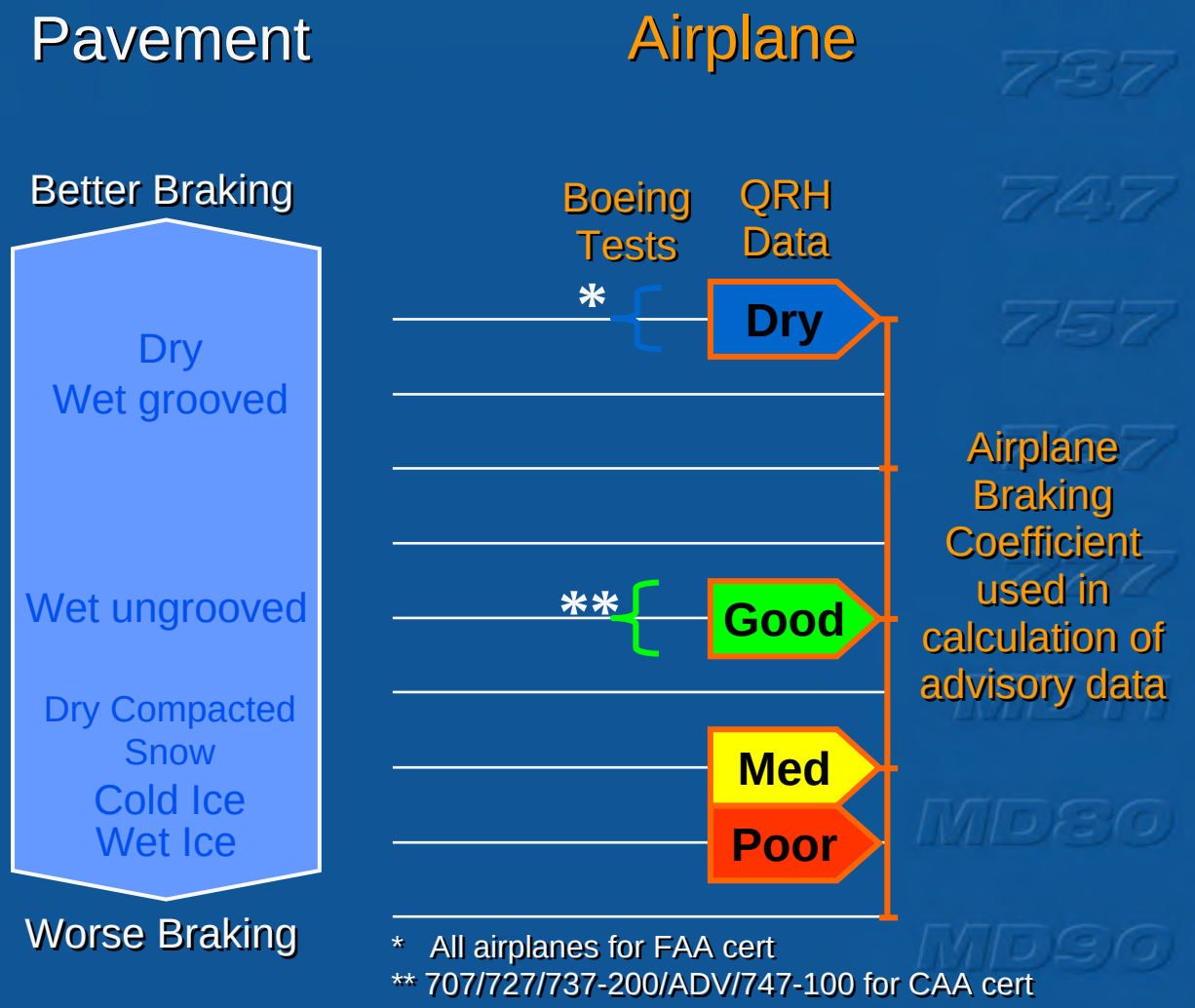
- ” … A decelerometer should not be used in loose snow or slush, as it can give misleading friction values. Other friction measuring devices can also give misleading friction values under certain combinations of contaminants and air/pavement temperature.” (ICAO Annex 14, Att. A-6, 6.8)

Landing Performance Data Available to Crews (Boeing OM—Section PI)

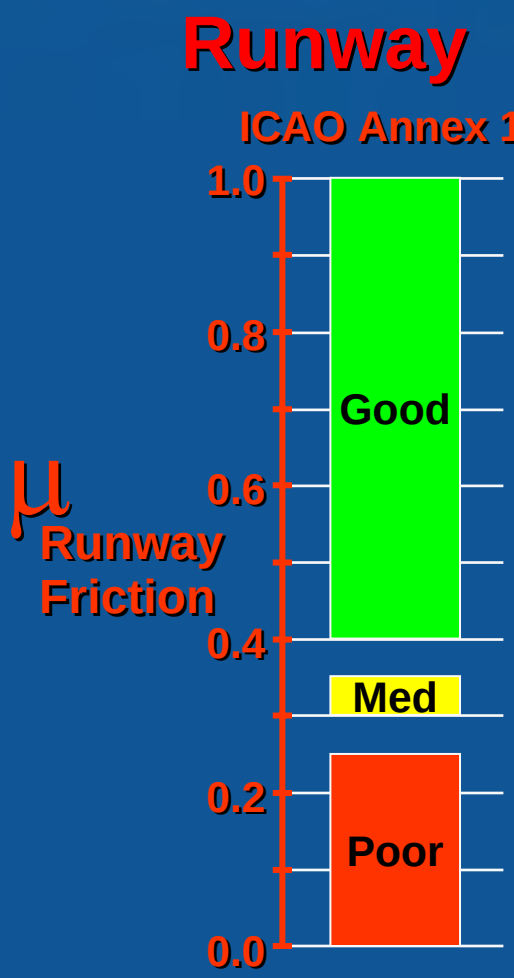
Boeing performance data is provided for pilot decision making

- Information published as a function of Reported Braking Action
  - Good – Wet runway, JAR defined compact snow
  - Medium – Ice, not melting
  - Poor – Wet melting ice
  - For landing, Boeing recommends the use of the data labeled poor for slush/standing water due to the possibility of hydroplaning

Airplane Performance Terminology



Runway Terminology



FAA terminology - Not related directly to Runway friction by any FAA publication

Margin

- Advisory data for FAA operators is unfactored
- Operators add margin specific to their operations
  - Advisory data supplied to JAROPS 1 customer includes 1.15 factor
- Boeing does not provide specific margins
- Margins vary by operator

Slippery Runway Landing Performance

When landing on slippery runways contaminated with ice, snow, slush or standing water, the reported braking action must be considered. Advisory information for reported braking actions of good, medium and poor is contained in the PI section of the QRH. The performance level associated with good is representative of a wet runway. The performance level associated with poor is representative of a wet ice covered runway. Also provided in the QRH are stopping distances for the various autobrake settings and for non-normal configurations. Pilots should use extreme caution to ensure adequate runway length is available when poor braking action is reported.

Pilots should keep in mind slippery/contaminated runway advisory information is based on an assumption of uniform conditions over the entire runway. This means a uniform depth for slush/standing water for a contaminated runway or a fixed braking coefficient for a slippery runway. The data cannot cover all possible slippery/contaminated runway combinations and does not consider factors such as rubber deposits or heavily painted surfaces near the end of most runways. With these caveats in mind, it is up to the airline to determine operating policies based on the training and operating experience of their flight crews.

Landing Distance Data
Examples of Margin Versus Braking Conditions

Conditions: 737-800 145,000 lb (65800 kg), V_{REF}+ 5
Flaps 40, sea level, std.day, no wind, max man. brakes

	Margin to baseline (feet)			
	Dry	Good	Medium	Poor
AFM FAR Wet - baseline	6130	6130	6130	6130
QRH Advisory - unfactored	2990	1780	200	X
QRH Advisory - + 500 feet	2490	1280	X	X
QRH Advisory * 1.15	2510	1130	X	X
QRH Advisory * 1.15 + 200m	1860	470	X	X
NTSB rec. – no rev. in calc.	2980	1450	X	X

Landing Distance Data
Examples of Margin Versus Braking Conditions

Conditions: 737-800 145,000 lb (65800 kg), V_{REF}+ 5
Flaps 30, sea level, std.day, no wind, max man. brakes

	Margin to baseline (feet)			
	Dry	Good	Medium	Poor
9000 ft (2745m) of runway	8000	8000	8000	8000
QRH Advisory - unfactored	4700	3460	1780	X*
QRH Advisory - + 500 feet	4200	2960	1280	X
QRH Advisory * 1.15	4210	2770	840	X
QRH Advisory * 1.15 + 200m	4050	2120	190	X
NTSB rec. – no rev. in calc.	4690	3120	570	X
Note Flaps 40 would increase margin by approximately:	~ 170	~ 210	~ 330	~ 430

*Flaps 40 410 ft margin

Landing Distance Data
Examples of Margin Versus Braking Conditions

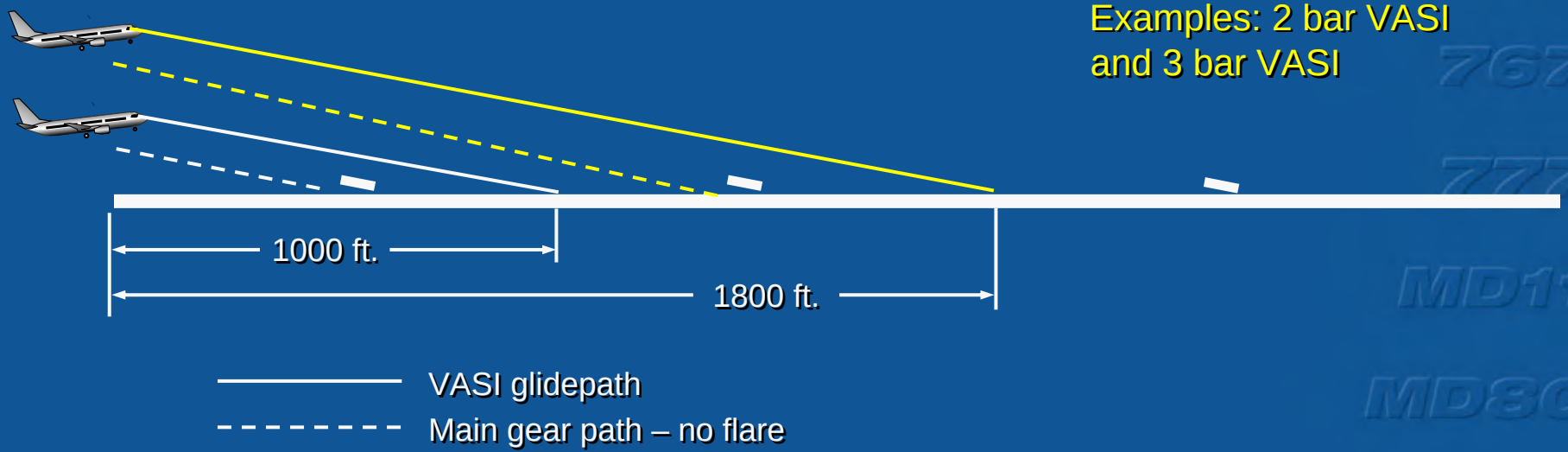
Conditions: 737-800 145,000 lb (65800 kg), V_{REF}+ 5
Flaps 30, sea level, std.day, no wind, max man. brakes

	Margin to baseline (feet)			
	Dry	Good	Medium	Poor
10000 ft (3050m) of runway	10000	10000	10000	10000
QRH Advisory - unfactored	6700	5460	3780	1020
QRH Advisory - + 500 feet	6200	4960	3280	520
QRH Advisory * 1.15	6210	4770	2840	700
QRH Advisory * 1.15 + 200m	6050	4120	2190	50
NTSB rec. – no rev. in calc.	6690	5120	2570	X*
Note Flaps 40 would increase margin by approximately:	~ 170	~ 210	~ 330	~ 430

*NTSB rec. would require 11,000+ runway at this condition

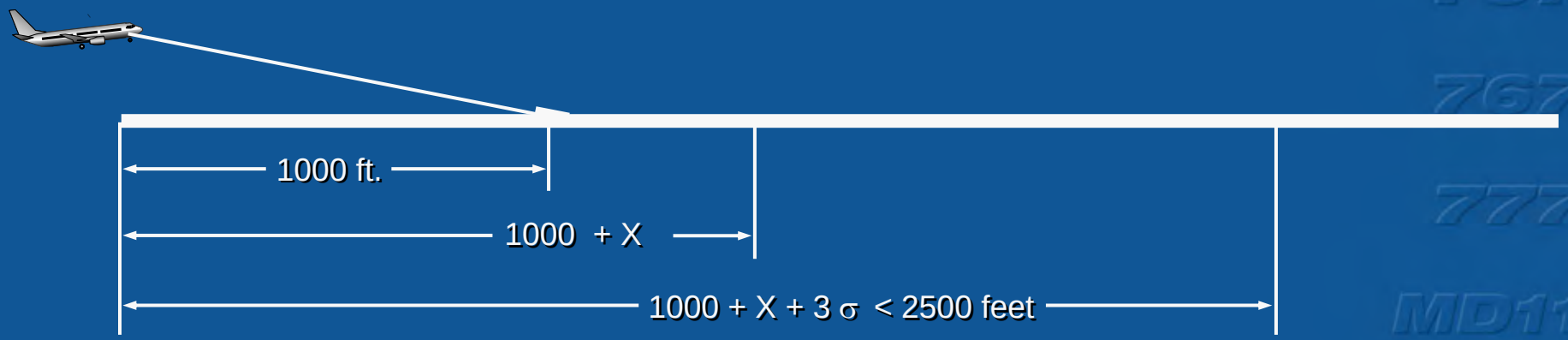
Variability in Touchdown Point

- QRH data based on 1000 ft. touchdown point (747 1200 ft.)
- Approach type is a consideration when considering touchdown point at a specific airport



Autoland Touchdown Data

- Autoland air distance from 50 ft to touchdown is less than 2500 feet
  - Based on flight test
  - Assuming 3º glideslope



X – average touchdown point from autoland testing.

3σ – 99.7% probability of touchdown prior to this distance

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Flying the Airplane

- Reference – Boeing Flight Crew Training Manual
  - Chapter 6 – Landing
    - Landing techniques
    - Factors affecting landing distance
    - Slippery runway landing

Flying the Airplane

Factors Affecting Landing Distance

- Approach, Flare and Touchdown
  - Fly the airplane onto the runway
    - On Glideslope, On Speed
  - Do not allow the airplane to float
  - Do not extend flare by increasing pitch attitude
  - Do not attempt to hold the nose wheel off the runway
    - Deceleration on the runway is approximately 3 times greater than in the air (dry runway)

Autoland Touchdown Data

7 series airplanes autoland touchdown point has been demonstrated to be less than approximately 2100 feet +/- 200 with a high degree of probability (greater than 99%)

Note: based on 3^{o} glideslope and 1000 foot from the threshold glideslope intersection.

Flying the Airplane

- Transition
  - After main gear touchdown - initiate landing roll procedure
    - Speedbrakes
      - Manually raise speedbrake if they do not extend automatically
        - Increase load on the gear for brake effectiveness
        - Drag
    - Fly the nose wheel on to the runway smoothly
    - Use appropriate autobrake or manually apply wheel brakes smoothly

Flying the Airplane

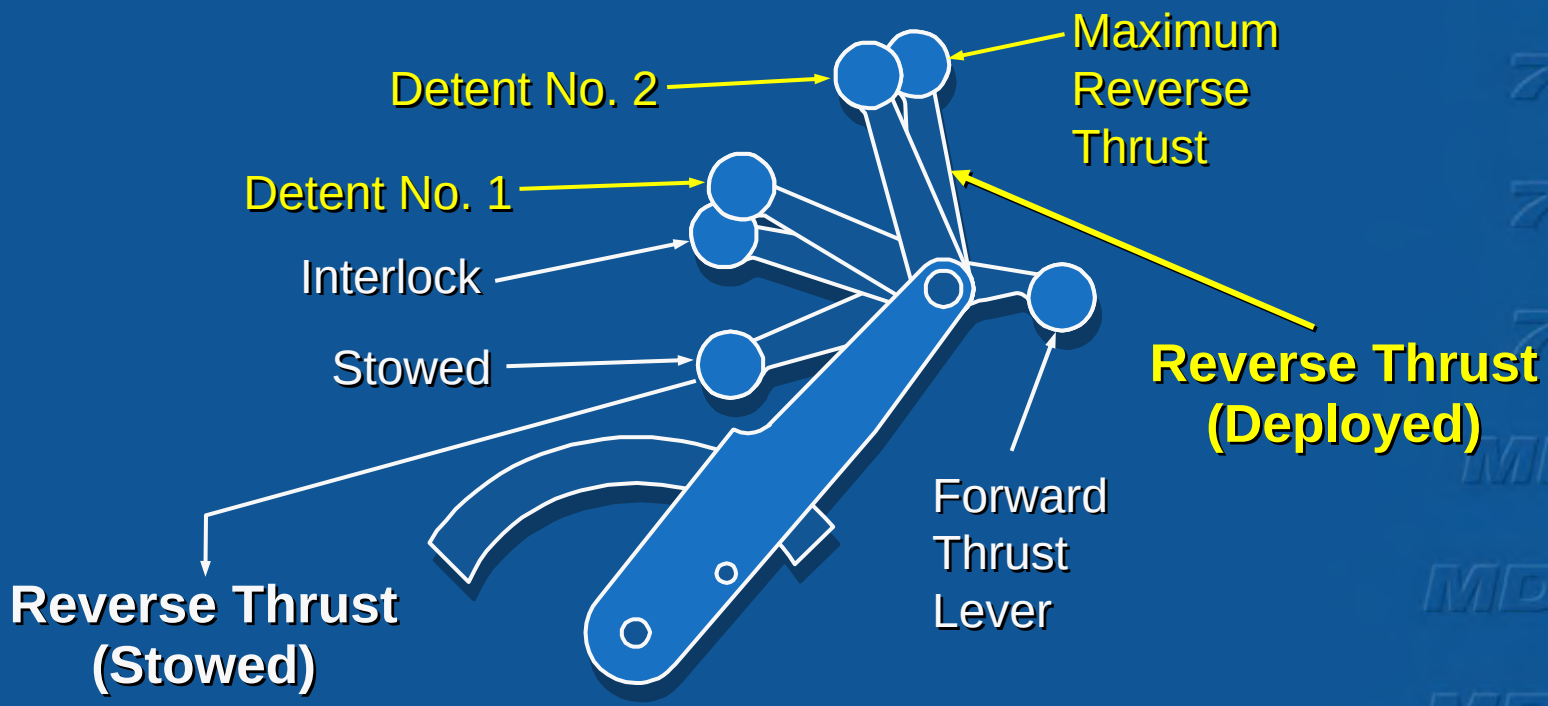
- Automatic wheel brakes
  - 3 or 4 should be used for wet or slippery runways
  - Immediate initiation of reverse thrust at main gear touchdown
    - Reduces brake pressure to minimum level
    - Reduces stopping distance on slippery runways

Flying the Airplane

- Manual wheel brakes
  - Immediately after touchdown apply a constant brake pedal pressure
  - Short or slippery runways – use full brake pedal pressure
    - Do not attempt to modulate, pump, or improve braking by any other special technique
    - Do not release brake pressure until the airplane has been reduced to safe taxi speed
    - The antiskid system stops the airplane for all runway conditions in a shorter distance than is possible with either antiskid off or brake modulation

Flying the Airplane

- Reverse thrust
  - After main gear touchdown rapidly raise the reverse thrust levers to the interlock position



Flying the Airplane

- Reverse thrust
  - After touchdown rapidly raise the reverse thrust levers to the interlock position
  - Apply reverse thrust as required (up to maximum)
  - Reverse thrust always reduces the “brake only” stopping distance
  - Reverse thrust is most effective at high speed

“The importance of establishing the desired reverse thrust in a timely manner on slippery runways can not be overemphasized.”

(Reference: Boeing Flight Crew Training Manual, section on use of automatic wheel brakes for all conditions)