Anatomy of an Overrun
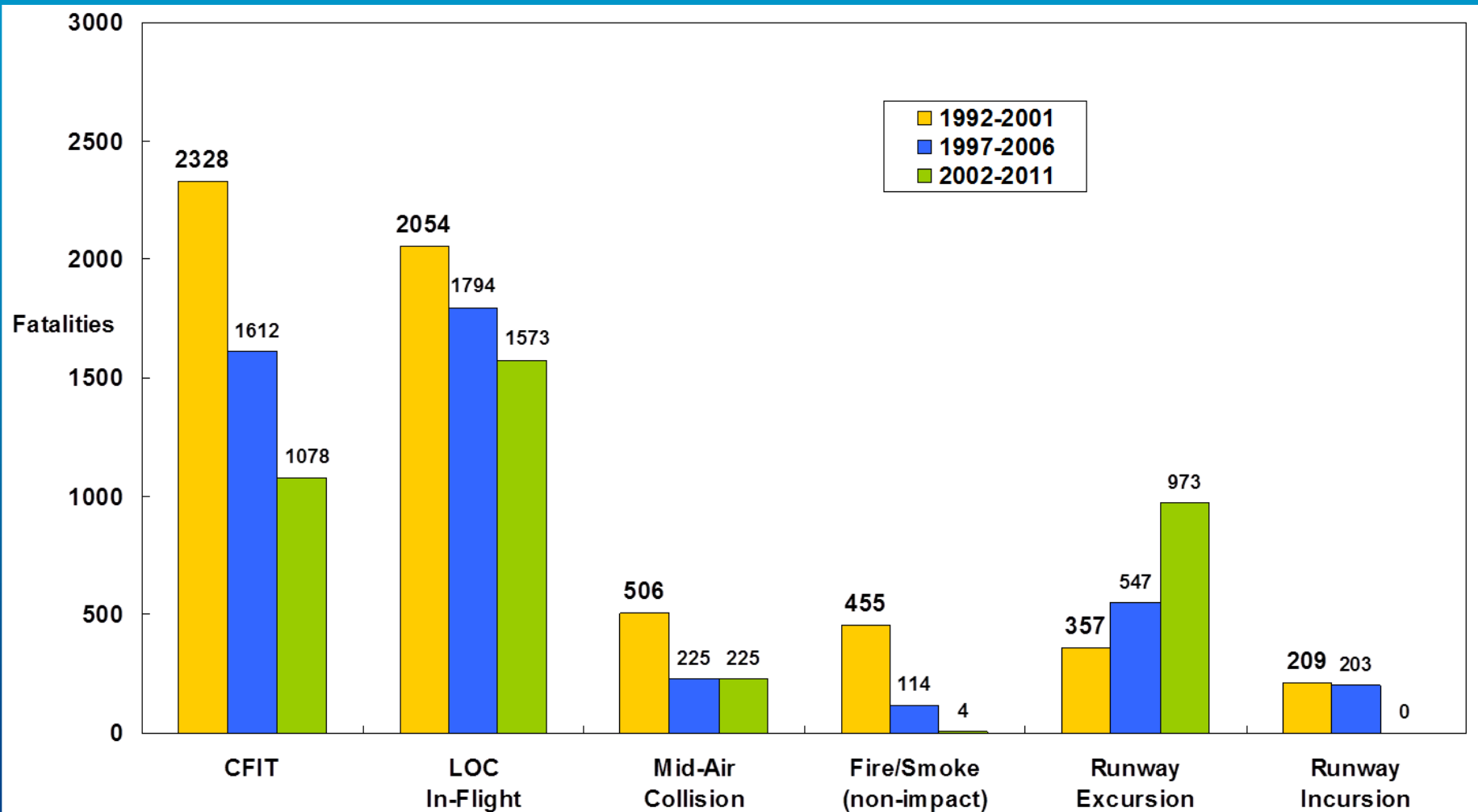## What is your Role?

Captain Linda Orlady
Chief Pilot, Flight Technical and Safety
The Boeing Company

National Airport Infrastructure Show & Civil Aviation
Moscow, Russia
12 February 2015

(Some material adapted from earlier presentation by Boeing Air Safety Investigator, Mark Smith)

Statistical Trends
Fatal Accidents – Worldwide Commercial Jet Fleet

What is Your Role?
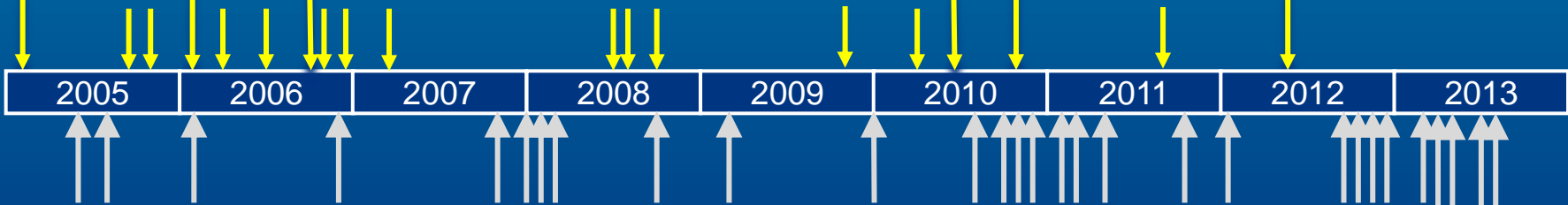
1) The pilot (Captain or F/O, PF or PM)

2) Airline management

3) Airport Manager

4) Air Traffic Controller

5) Regulator

Runway Overruns
Looking Back - What We've Seen

Accidents

Dusseldorf

Midway

Lagos

Mangalore

Jamaica

Guyana

Incidents

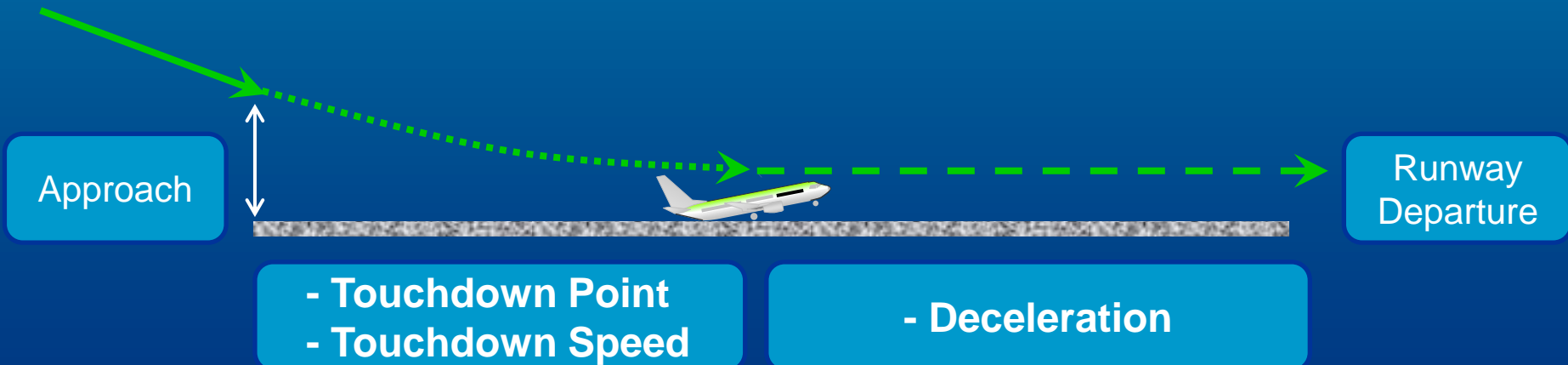| 2005	2006	2007	2008	2009	2010	2011	2012	2013

Primary Overrun Factors

2 of 3 primary factors are fixed at touchdown

1) **Touchdown Point**

2) **Touchdown Speed**

3) **Deceleration after Touchdown**

Approach

Runway Departure

- **- Touchdown Point**
- **- Touchdown Speed**

- Deceleration

39 Overruns

Category	Approach	Touchdown Point — Point (feet)	Runway Used (% LDA)	Touchdown Speed — Airspd >Vref (knots)	Tail Wind (knots)	Spdbrake When SB Deployed (sec)	Thrust Reversers When TR Deployed (sec)	When TR Reduced (feet)	Runway Braking Action	Overrun Speed (knots)	Hull Loss
Long	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
	Unstable	6200	70%	12	5	TD	never		Dry	50	no
	Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
	Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
	Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
	Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
	Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
	Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
	Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
	Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
	Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
	Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
	Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
	Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
	Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
	Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
	Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
20											
Fast	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
	Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
	Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
	Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
	Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
	Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
6											
Deceleration	Stable	2700	30%	0	0	never	never		Med	45	no
	Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
	Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
	Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
	Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
	Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
	Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
	Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
	Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
	---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
	Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
	Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
	Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
13											

	Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
						Spdbrake	Thrust Reversers		Runway		
		Point	Runway Used	Airspd >Vref	Tail Wind	When SB Deployed	When TR Deployed	When TR Reduced	Braking Action	Overrun Speed	Hull Loss
		(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
	Unstable	6200	70%	12	5	TD	never		Dry	50	no
	Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
	Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
	Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
	Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
	Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
	Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
	Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
	Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
	Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
	Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
	Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
	Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
	Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
	Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
	Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
		20									
Fast	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
	Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
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	Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
	Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
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Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
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Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
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Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
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Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
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		Point	Runway Used	Airspd >Vref	Tail Wind	Spdbrake When SB Deployed	Thrust Reversers When TR Deployed	When TR Reduced	Runway Braking Action	Overrun Speed	Hull Loss
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	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
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	20										
Fast	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
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	Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
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Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
					Spdbrake	Thrust Reversers		Runway		
	Point	Runway Used	Airspd >Vref	Tail Wind	When SB Deployed	When TR Deployed	When TR Reduced	Braking Action	Overrun Speed	Hull Loss
	(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long										
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Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
	20									
Fast										
Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
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	6									
Deceleration										
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Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
	13									

Grouped by Primary Overrun Factor

1) **Touchdown Point**

2) **Touchdown Speed**

3) **Deceleration after Touchdown**

| Approach | Touchdown Point | | Touchdown Speed | | Deceleration | | | | Result | |
	Point	Runway Used	Airspd >Vref	Tail Wind	Spdbrake — When SB Deployed	Thrust Reversers — When TR Deployed	When TR Reduced	Runway — Braking Action	Overrun Speed	Hull Loss
	(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long										
Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Unstable	6200	70%	12	5	TD	never		Dry	50	no
Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
	20									
Fast										
Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
			6							
Deceleration										
Stable	2700	30%	0	0	never	never		Med	45	no
Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
							13			

Touchdown Zone

3000 ft

OR

1/3
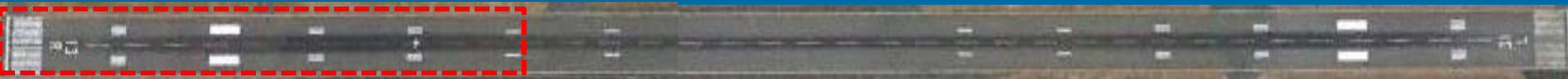
Touch down in this zone or Go-around

Long Touchdown
Issues we see in the data

Long touchdowns generally fall into two categories:

- **Path control**
  - about half crossed the threshold significantly high
  - with thrust near idle

- **Thrust control**
  - about half crossed the threshold at correct height
  - but maintained advanced thrust well beyond the threshold

Grouped by Primary Overrun Factor
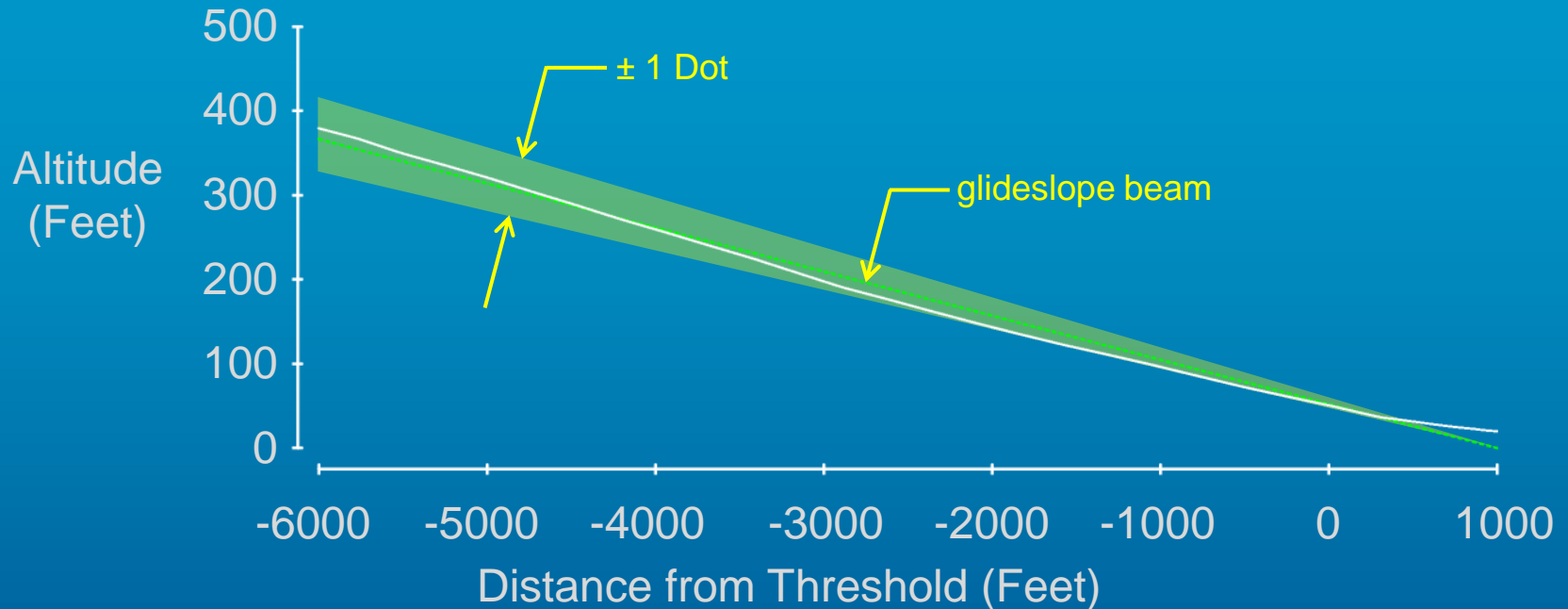
1) **Touchdown Point**

2) **Touchdown Speed**

3) **Deceleration after Touchdown**

Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
	Point (feet)	Runway Used (% LDA)	Airspd >Vref (knots)	Tail Wind (knots)	Spdbrake When SB Deployed (sec)	Thrust Reversers When TR Deployed (sec)	When TR Reduced (feet)	Runway Braking Action	Overrun Speed (knots)	Hull Loss
Long										
Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Unstable	6200	70%	12	5	TD	never		Dry	50	no
Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
			20							
Fast										
Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
			6							
Deceleration										
Stable	2700	30%	0	0	never	never		Med	45	no
Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
								13		

Touchdown Fast
What We've Seen

Altitude (Feet) vs Distance from Threshold (Feet)

- ± 1 Dot
- glideslope beam

- **"Duck Under" maneuver**
  - Intending to assure short touchdown
  - +20 knots   airspeed increase at touchdown resulted
  - +10 knots   unreported tailwind was also present
  - +30 knots   fast at touchdown Total

Grouped by Primary Overrun Factor
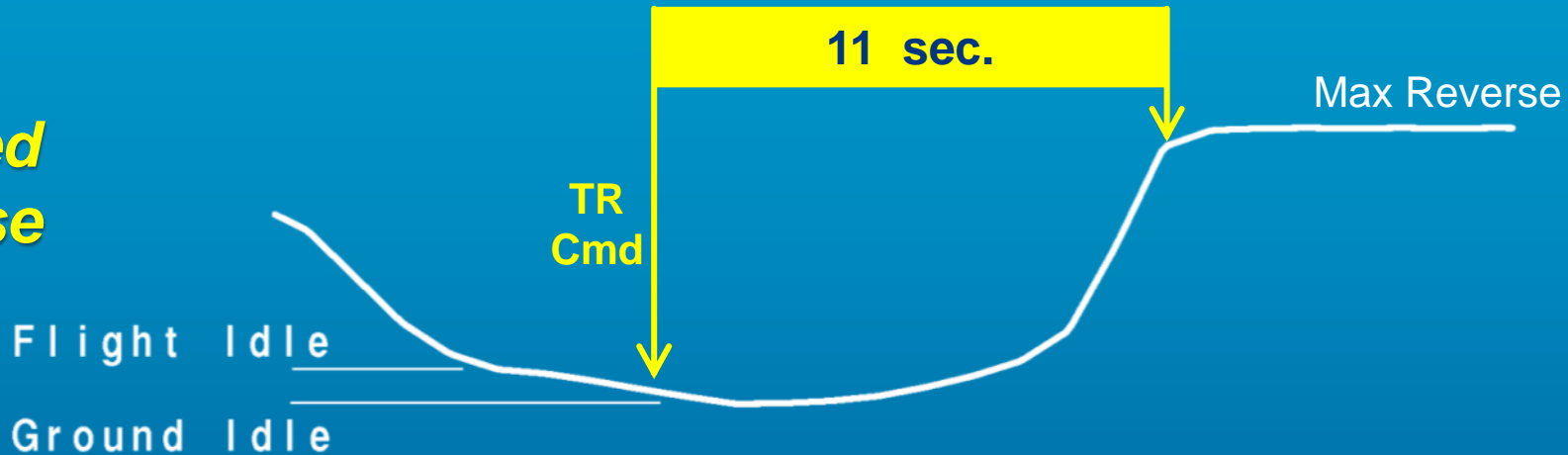
1) **Touchdown Point**

2) **Touchdown Speed**

3) **Deceleration after Touchdown**

Approach	Touchdown Point Point (feet)	Runway Used (% LDA)	Touchdown Speed Airspd >Vref (knots)	Tail Wind (knots)	Spdbrake When SB Deployed (sec)	Thrust Reversers When TR Deployed (sec)	When TR Reduced (feet)	Runway Braking Action	Result Overrun Speed (knots)	Hull Loss
Long										
Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Unstable	6200	70%	12	5	TD	never		Dry	50	no
Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
	20									
Fast										
Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
	6									
Deceleration										
Stable	2700	30%	0	0	never	never		Med	45	no
Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
	13									

Inadequate Deceleration
Delayed Thrust Reverser (TR) Usage
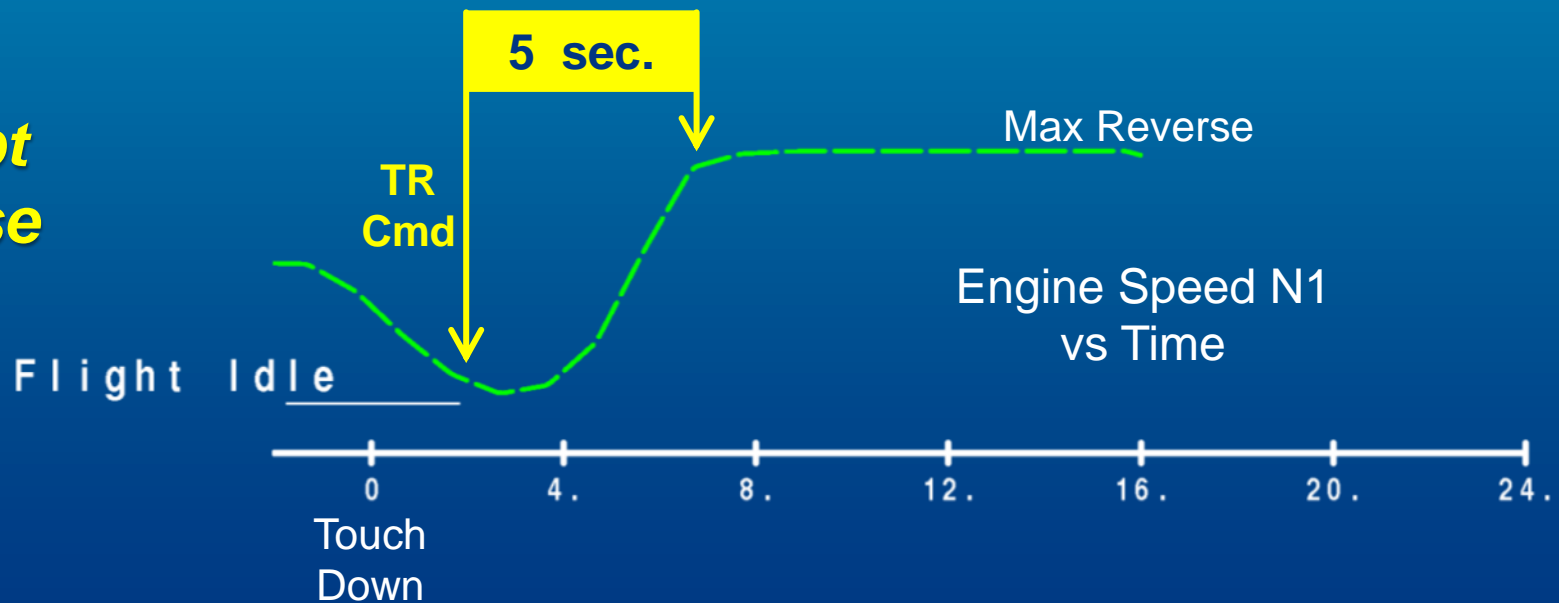
11 sec.

Max Reverse

Delayed Reverse

TR Cmd

Flight Idle

Ground Idle

5 sec.

Max Reverse

Prompt Reverse

TR Cmd

Flight Idle

Engine Speed N1 vs Time

0   4.   8.   12.   16.   20.   24.

Touch Down

Grouped by Primary Overrun Factor

1) **Touchdown Point**

2) **Touchdown Speed**

3) **Deceleration after Touchdown**

4) **Other observations**

Seasonal Effects

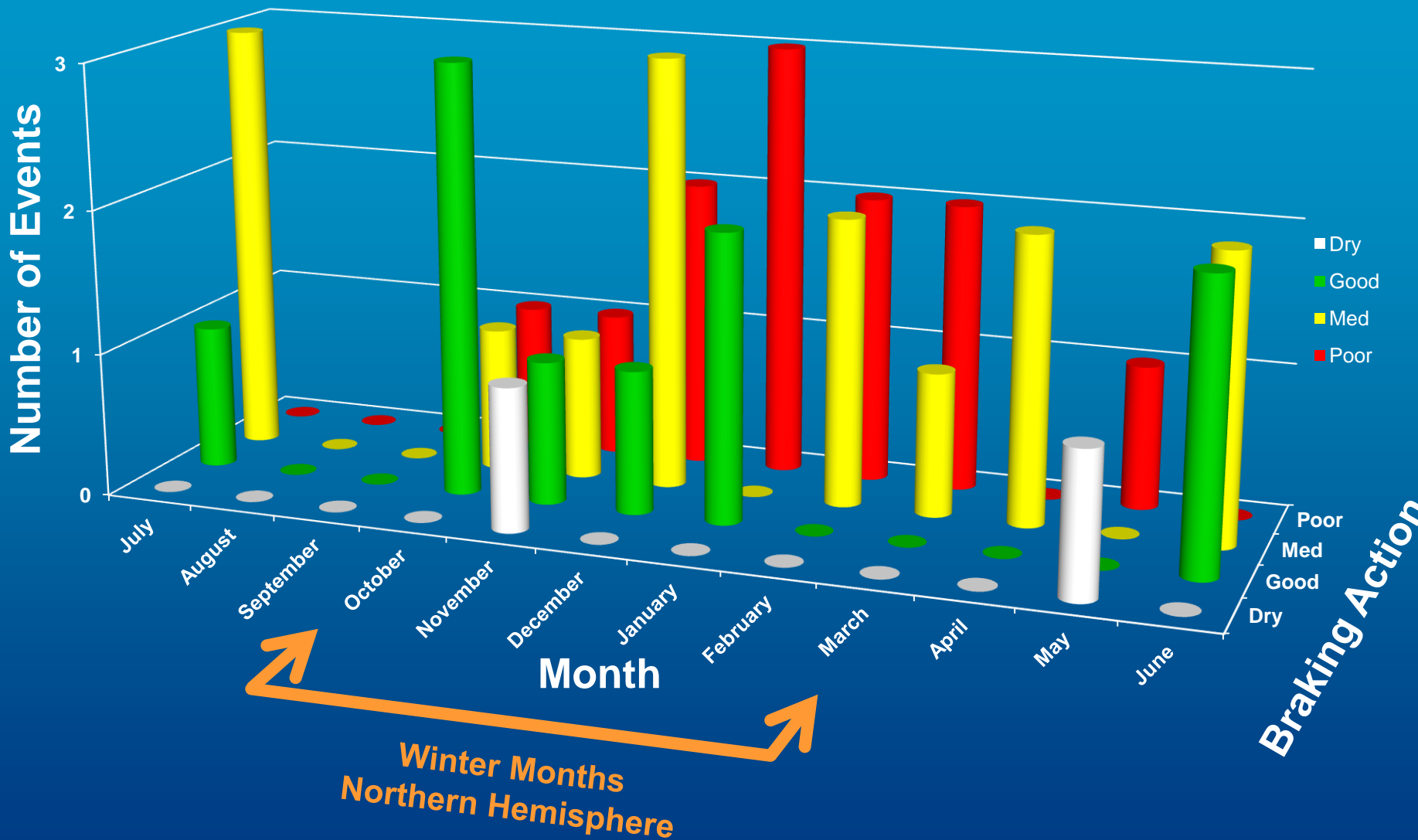| Ambient Light		Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
			Point	Runway Used	Airspd >Vref	Tail Wind	Spdbrake When SB Deployed	Thrust Reversers When TR Deployed	When TR Reduced	Runway Braking Action	Overrun Speed	Hull Loss
			(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Night	Long	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Twilight		Unstable	6200	70%	12	5	TD	never		Dry	50	no
Night		Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
Day		Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Night		Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
Day		Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Night		Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Day		Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
---		Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Night		Unstable	4000	30%	0	10	TD	TD + 3	departure	Med	40	no
Night		Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
Twilight		Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
Day		Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
---		Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
Night		Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
Day		Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
---		Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Day		Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
Day		Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
---		Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
			20									
Night	Fast	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Day		Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Day		Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
---		Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
Night		Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
Twilight		Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
			6									
---	Deceleration	Stable	2700	30%	0	0	never	never		Med	45	no
Day		Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Day		Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Night		Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Day		Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Night		Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Night		Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Twilight		Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Twilight		Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---		---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Day		Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Day		Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
---		Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
			13									

ILS Tuned?	AP Disc Altitude	Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
							Spdbrake	Thrust Reversers		Runway		
			Point	Runway Used	Airspd >Vref	Tail Wind	When SB Deployed	When TR Deployed	When TR Reduced	Braking Action	Overrun Speed	Hull Loss
			(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long												
yes	1800	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
yes	500	Unstable	6200	70%	12	5	TD	never		Dry	50	no
---	500	Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
yes	500	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
no	2000	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
---	---	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
no	900	Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
yes	2300	Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
---	250	Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
RNAV	250	Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
yes	700	Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
yes	2000	Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
no	1000	Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
---	1200	Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
yes	---	Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
yes	210	Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
yes	400	Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
yes	700	Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
yes	300	Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
yes	900	Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
			20									
Fast												
yes	600	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
yes	500	Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
yes	500	Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
---	400	Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
yes	500	Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
yes	300	Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
			6									
Deceleration												
yes	---	Stable	2700	30%	0	0	never	never		Med	45	no
yes	400	Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
yes	1000	Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
yes	---	Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
yes	---	Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
yes	1100	Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
yes	250	Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
yes	---	Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
yes	1500	Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	900	---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
yes	360	Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
yes	300	Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
yes	300	Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
			13									

Who was flying?		Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
			Point	Runway Used	Airspd >Vref	Tail Wind	Spdbrake When SB Deployed	Thrust Reversers When TR Deployed	When TR Reduced	Runway Braking Action	Overrun Speed	Hull Loss
			(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long												
---	---	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Capt	---	Unstable	6200	70%	12	5	TD	never		Dry	50	no
Capt	---	Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
---	FO	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Capt	---	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
---	---	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Capt	---	Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Capt	---	Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
---	---	Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Capt	---	Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
Capt	---	Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
---	---	Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
---	---	Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
---	---	Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
Capt	---	Stable	3260	41%	20	-1	TD	TD + 3	2000		40	no
---	---	Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
---	---	Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Capt	---	Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
---	---	Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
---	---	Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
			20									
Fast												
Capt	---	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Capt	---	Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Capt	---	Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
---	---	Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
---	FO	Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
---	---	Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
			6									
Deceleration												
---	---	Stable	2700	30%	0	0	never	never		Med	45	no
---	FO	Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Capt	---	Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Capt	---	Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Capt	---	Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
---	FO	Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
---	FO	Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
---	---	Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
---	FO	Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	---	---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Capt	---	Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
---	FO	Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
---	---	Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
			13									

Approach	Touchdown Point		Touchdown Speed		Deceleration				Result	
	Point (feet)	Runway Used (% LDA)	Airspd >Vref (knots)	Tail Wind (knots)	Spdbrake When SB Deployed (sec)	Thrust Reversers When TR Deployed (sec)	When TR Reduced (feet)	Runway Braking Action	Overrun Speed (knots)	Hull Loss
Long										
Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
Unstable	6200	70%	12	5	TD	never		Dry	50	no
Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
Stable	3700	32%	0	10	TD	TD + 3	departure	---	50	no
Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
	20									
Fast										
Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
	6									
Deceleration										
Stable	2700	30%	0	0	never	never		Med	45	no
Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
Stable	1250	21%	0	9	TD	TD + 16	departure	Poor	42	no
Unstable	1720	27%	6	5	TD + 9	TD + 13	departure	Good	20	no
Unstable	1800	23%	10	2	with TR	TD + 11	departure	Poor	28	no
Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no

Deceleration from Brakes & Thrust Reversers

from Thrust Reversers

Reverse Thrust

Max. Brakes

from Brakes

Dry

Good — 1/2 of **Dry**

Med — 1/4 of **Dry**

Poor — 1/8 of **Dry**

← Less

Deceleration Available

More →
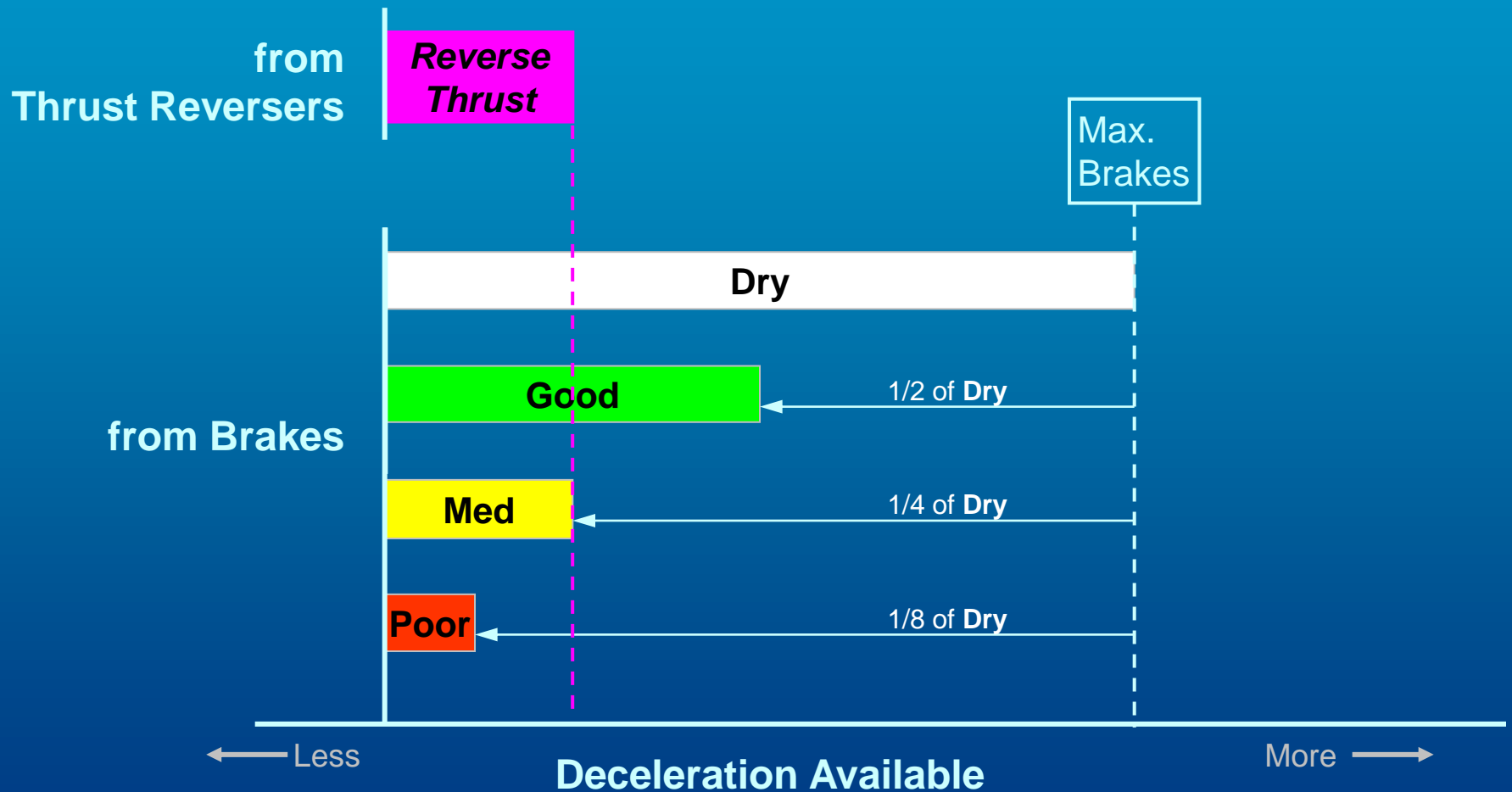
Reverse Thrust and Landing Distance
Dispatch Calculation vs QRH Landing Distance

Dispatch Landing Distance

Factored Distance - Wet / Slippery

Dry, No Reverse

÷ 60%

+15%

Actual Performance (QRH)

Dry — **With Reverse** — No Reverse

Good — **With Reverse** — No Reverse

Med — **With Reverse** — No Reverse

Poor — **With Reverse** — No Reverse

Reverse Thrust is Critical on MED & POOR Runways

Approach		Touchdown Point		Touchdown Speed		Deceleration				Result	
	Approach	Point	Runway Used	Airspd >Vref	Tail Wind	Spdbrake When SB Deployed	Thrust Reversers When TR Deployed	When TR Reduced	Runway Braking Action	Overrun Speed	Hull Loss
		(feet)	(% LDA)	(knots)	(knots)	(sec)	(sec)	(feet)		(knots)	
Long	Unstable	7000	72%	22	0	TD	TD + 3	departure	Good	81	yes
	Unstable	6200	70%	12	5	TD	never		Dry	50	no
	Unstable	5630	57%	11	14	TD	TD + 3		Med	100	yes
	Unstable	5300	60%	16	3	TD	TD + 4	departure	Good	35	no
	Unstable	5150	48%	20	0	TD + 5	TD + 7	900	Med	70	no
	Unstable	4700	52%	30	-1	TD	TD + 2	1000	---	100	yes
	Unstable	4500	60%	-3	1	TD	TD + 2	departure	Good	47	yes
	Unstable	4500	56%	6	3	TD	TD + 3	400	Dry	90	yes
	Unstable	4380	55%	46	4	TD	TD + 2	departure	Good	65	no
	Unstable	4000	30%	0	10	TD	TD + 2	departure	Med	40	no
	Stable	3950	44%	0	14	TD	TD + 3	departure	Med	63	yes
	Unstable	3935	49%	7	10	TD	TD + 3	departure	Med	4	no
	Unstable	3840	48%	20	-8	TD	TD + 3	departure	Med	34	no
	Stable	3700	32%	0	10	TD	TD + 2	departure	---	50	no
	Stable	3260	41%	20	-1	TD	TD + 3	2000	Med	40	no
	Stable	3200	48%	-7	4	with TR	TD + 2	departure	Good	30	no
	Stable	3120	42%	10	10	TD	TD + 2	departure	Good	50	no
	Stable	3000	37%	-5	6	TD	TD + 2	departure	Med	30	no
	Stable	3000	34%	3	5	TD	TD + 3	departure	Med	5	no
	Stable	2770	35%	0	12	TD	TD + 2	1000	Good	15	no
		20									
Fast	Stable	1500	20%	20	10	TD	TD + 3	600	Med	5	no
	Stable	1450	20%	11	15	TD	TD + 3	1250	Med	20	no
	Stable	1600	20%	12	10	TD	TD + 27	departure	Good	25	no
	Stable	1500	23%	5	10	TD	TD + 2	1550	Med	30	no
	Stable	1450	20%	6	9	TD	TD + 3	departure	Med	0	no
	Stable	1250	18%	4	11	TD	TD + 2	departure	Poor	45	no
		6									
Deceleration	Stable	2700	30%	0	0	never	never		Med	45	no
	Stable	400	6%	2	-6	never	TD + 22	departure	Med	48	no
	Stable	500	8%	3	4	with TR	TD + 20	departure	Med	32	no
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	Stable	1900	26%	6	-2	TD	TD + 8	departure	Med	20	no
	Stable	1150	24%	5	-5	TD	TD + 6	100	Med	12	no
	Stable	2900	28%	0	-6	TD + 3	TD + 5	2800	Poor	10	no
	---	1480	20%	0	8	TD	TD + 3	1300	---	30	no
	Stable	2500	31%	0	2	TD	TD + 2	2250	Good	25	no
	Stable	2200	27%	5	7	TD	TD + 2	2000	Med	45	no
	Stable	1250	14%	2	4	TD	TD + 1	2400	Poor	15	no
		13									

Conclusions and Some Questions

- **Pilots:**
  - **Land in the Touchdown Zone or Go-Around !**
  - **Use Thrust Reversers promptly – and until stop is assured !**

- **Management**
  - **How are you receiving and sharing information?**
  - **What messages are you sending that might contribute?**

- **Air Traffic Control**
  - **Safe guidance, timely reports**

- **Airport managers**
  - **Timely information about runway conditions, NOTAMS, markings**

Last Thoughts

- **Don't miss opportunities to learn!**

- **Guidance available**
  - **Flight Safety Foundation (www.flightsafety.org)**
  - **Skybrary (www.skybrary.aero)**
  - **European Action Plan for the Prevention of Runway Excursions (EAPPRE)**
  - **Boeing Flight Crew Training Manual**

- **Boeing is here to help with your investigations**
  - **Have been through ~30 of these analyses in the past several years**
  - **Provided at no cost by Boeing for incidents/accidents with Boeing products**
  - **Data from individual investigations helps us understand industry issues**

Thank you!