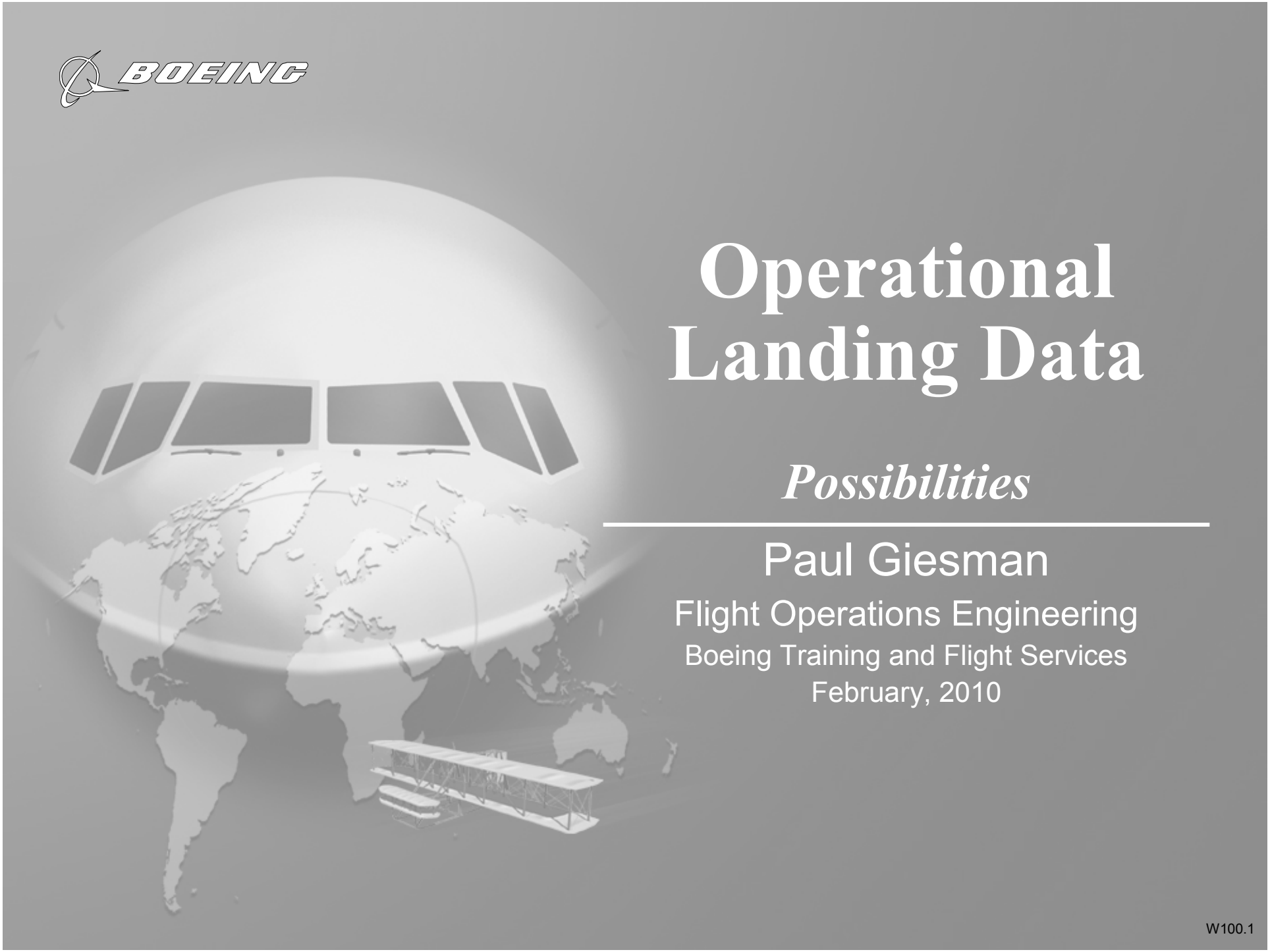

Operational Landing Data

Possibilities

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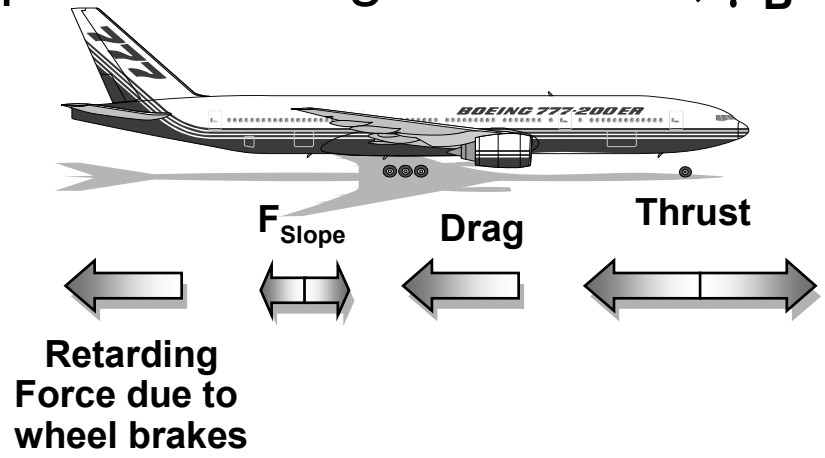
Obtaining data from the airplane

- Modern airplanes records a tremendous amount of information
- Question: Can the airplane braking coefficient (μ_B) be computed for each landing from the parameters recorded?
- If it is computed, what is the accuracy and use for this information?

Computing Airplane Braking Coef.

- The airplane has the data required to compute an airplane braking coefficient, μ_B

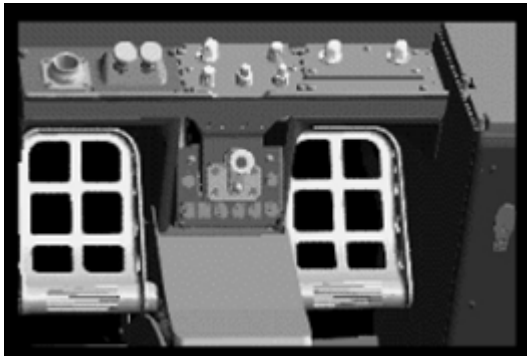


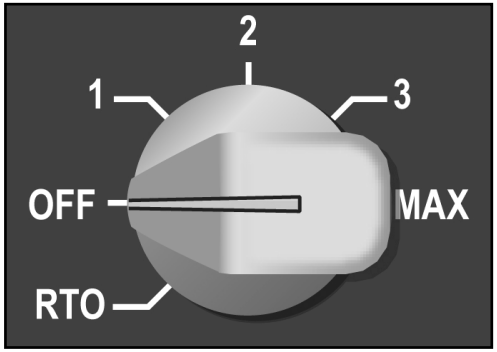
$$\Sigma F = ma$$

$$\mu_B = \frac{T - D - W \sin \phi - a \frac{W}{g}}{(W - L)}$$

Is the computed airplane braking coefficient useable?

- Is the deceleration limited by the runway friction?
  - Did the pilot or autobrake demand enough brake pressure to activate the anti-skid?
    - Sometimes it is obvious the stop contains friction limited segments
    - Sometimes it is obvious the stop doesn't contain any friction limited segments
    - Often it is somewhere in-between



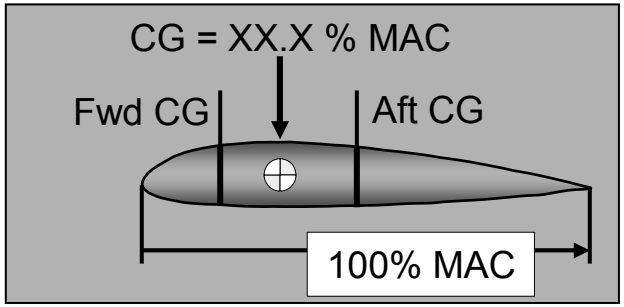


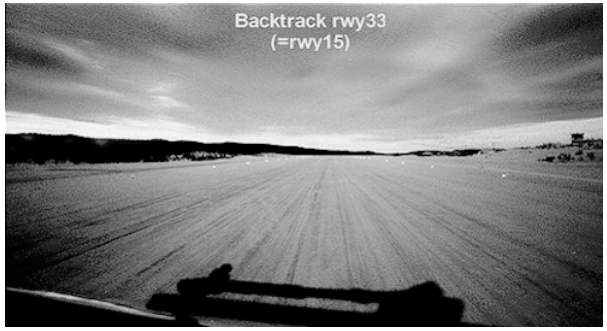
Accuracy of data recorded

- What is the accuracy of the measured parameters?
  - Sensor errors, bias
  - Sample rate

Accuracy of derived airplane braking coefficient

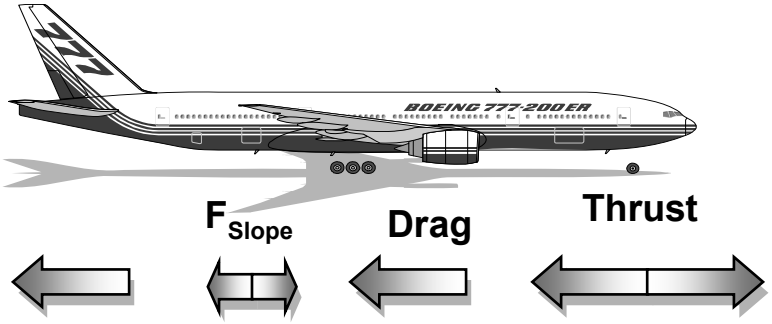
- Local runway slope
- C. G. location
- Runway contamination
  - Deceleration is measured
  - Decel includes contaminant drag
- Airplane GW
- Changing reverse thrust levels as modulated by the pilot





Is computed μ_B consistent with airplane performance data?

- To be useful the computed airplane braking coefficient, μ_B, needs to have been determined using data which is consistent with the airplane performance definition.
  - Is airplane lift and drag consistent with the values used to compute airplane performance?
  - Is the reverse thrust definition consistent with the data used in computing performance?



ADVISORY INFORMATION

Normal Configuration Landing Distance
Flaps 30
Dry Runway

	LANDING DISTANCE AND ADJUSTMENTS (FT)											
BRAKING CONFIGURATION	REF DIST* 450000 LB LANDING WT	WT ADJ PER 10000 LB ABOVE/ BELOW 450000 LB	ALT ADJ PER 1000 FT ABOVE S.L.	WIND ADJ PER 10 KTS HEAD WND	TAIL WIND	SLOPE ADJ PER 1% DN HILL	UP HILL	TEMP ADJ PER 10°C ABV ISA	BLW ISA	VREF ADJ PER 10 KTS ABOVE VREF30	REVERSE THRUST ADJ ONE REV	NO REV
MAX MANUAL	2940	+70/-40	60	-120	440	40	-30	60	-60	230	50	100
MAX AUTO	3980	+60/-40	90	-170	610	0	0	90	-100	410	0	0
AUTOBRAKE 4	4940	+80/-60	130	-240	850	20	-20	130	-130	520	0	0
AUTOBRAKE 3	5970	+100/-80	160	-290	1060	40	-60	160	-160	590	10	20
AUTOBRAKE 2	6670	+120/-100	190	-340	1220	90	-130	180	-180	540	140	140
AUTOBRAKE 1	7070	+140/-120	220	-380	1370	150	-190	200	-200	540	410	500
Good Reported Braking Action												
MAX MANUAL	4060	+70/-70	110	-200	750	110	-90	100	-100	330	200	450
MAX AUTO	4460	+70/-70	110	-210	780	80	-60	110	-100	410	210	480
AUTOBRAKE 4	4960	+80/-80	130	-240	880	40	-30	130	-130	520	20	70
AUTOBRAKE 3	5970	+100/-100	160	-290	1060	40	-60	160	-160	590	10	20
Medium Reported Braking Action												
MAX MANUAL	5470	+100/-100	170	-320	1260	270	-200	150	-140	420	540	1320
MAX AUTO	5730	+100/-100	160	-310	1250	240	-160	150	-140	490	520	1290
AUTOBRAKE 4	5730	+100/-100	170	-320	1260	250	-150	150	-150	510	520	1350
AUTOBRAKE 3	6280	+110/-110	180	-340	1340	190	-130	170	-170	590	270	900
Poor Reported Braking Action												
MAX MANUAL	7050	+150/-140	230	-470	2010	680	-390	200	-190	480	1160	3110
MAX AUTO	7400	+150/-140	230	-470	1990	680	-390	200	-190	490	1170	3140
AUTOBRAKE 4	7400	+150/-140	230	-470	2000	680	-400	200	-190	470	1190	3180
AUTOBRAKE 3	7430	+150/-140	230	-480	2020	650	-340	200	-200	590	1070	3070

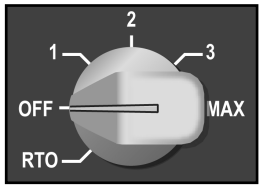
*Reference distance is for sea level, standard day, no wind or slope, VREF30 approach speed and 2 engine reverse thrust.
Max Manual braking data valid for auto speedbrakes. For manual speedbrakes, increase reference landing distance by 200 ft.
Autobrake data valid for both auto and manual speedbrakes.
Actual (unfactored) distances are shown.
Includes distance from 50 ft above threshold (1000 ft of air distance).

Study of operational landings

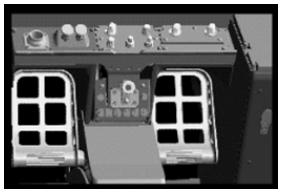
- Studied ~ 140,000 landings from Jan.-Mar. 2009
  - 82 landings - very confident they contain friction limited segments
  - 14 landings - confident they contain friction limited segments
  - METAR report – reports precipitation at a time reasonably close to the time of operation
  - Do **NOT** know runway condition
  - Do **NOT** know PIREP
  - Cannot separate out slush/snow drag

Data not provided

Observations based on this 737 dataset



- Autobrake usage
  - Typically autobrake-Max required to get friction limited at high speed on anything but the slipperiest runway.
  - If autobrake-3 is used, typical friction limitation occurs when the pilot takes over wheel braking at lower speeds (below 50 – 80 ktgs)
    - At high speed (greater than 100 ktgs) only obtain friction limited data at very very low airplane braking coefficients



- Manual flight crew wheel braking often had significant asymmetric wheel brake application

Observations based on this 737 dataset

- Length of friction limited stop segment
  - Average of 11 seconds – the slipperier the runway the longer the friction limited section
- Reverse thrust
  - In ~ 30% of the stops with friction limited segments:
    - Friction limited segment occurred while:
      - » Reverse thrust had been reduced to reverse idle
      - » A low level of reverse thrust was used for the stop
    - In the rest of the friction limited stops:
      - » Typically reverse thrust was increasing or decreasing during the friction limited segment

Observations based on this 737 dataset

- The maximum airplane braking coefficient is obtained only for the specific section of the runway where enough wheel braking was used to be friction limited.
- Saw one very slippery wet runway
  - Nellis Air Force Base – low texture runway
  - Jepp chart warns about possibility of hydroplaning

Summary

- We have started looking at in-service data
  - Proof of concept
  - What are the possibilities and possible problems
  - What are the accuracy issues
- Still evaluating the data we have obtained
  - Crew survey in the future
- Eventual use for data
  - Learn more about the effect of various contaminants on the airplane
    - What bucket they belong in
    - Are there significant unidentified gotchas