Guidelines for Narrow Runway Operations

Rob Root

Flight Operations Engineer

Flight Technical Services

Boeing Commercial Airplanes

W037t.1

Agenda

- How narrow is narrow?
- A look at runway “offside” events
- Narrow runway issues
- Regulatory background
- Sample guidelines for 737-700 w/ 24k Engines
- Recommendations

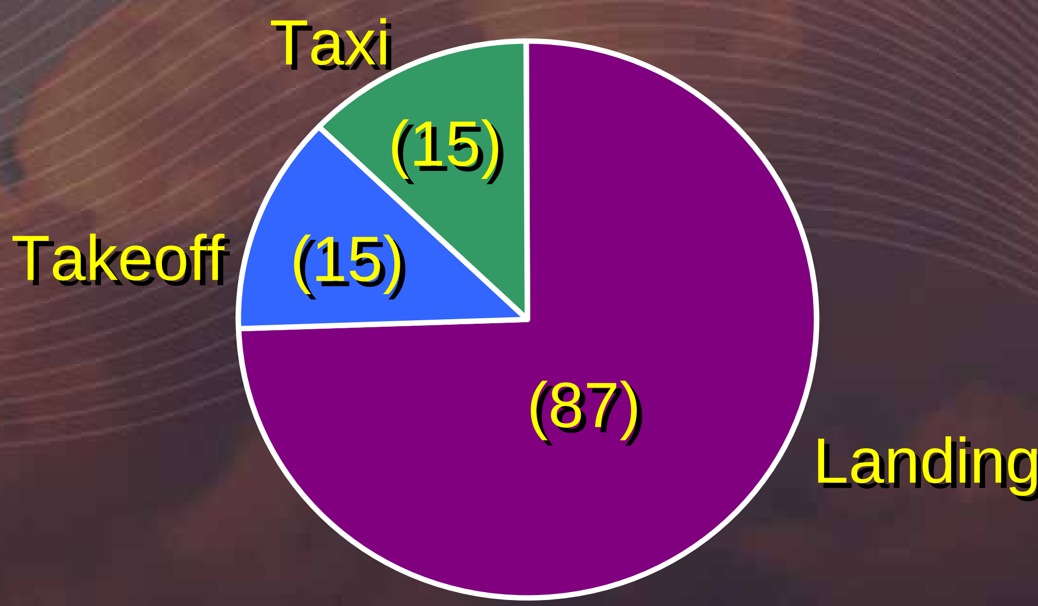
How Narrow Is Narrow?

- 45m is standard runway width (for most large commercial jet operations)
- As of March, 2002, there were at least 63 airports worldwide with runway width 30m or less, being served by 737,757 or 767 aircraft
- Boeing has received various requests from operators for guidance in operating aircraft on runways as narrow as 23m (75 ft)

Runway Offside Statistics

(Not Specifically Related to Narrow Runways…)

- 117 events involving Boeing airplanes between January 1995 and present …
- Majority occurred on landing…



Was Runway Width a Factor?

- Of the 117 events, one occurred on a 30m wide runway, and one occurred on a 42m wide runway
- Vast majority occurred on 45m wide runways
- 15 occurred on 60m wide runways

Potential Factors?

14 events - circumstances unknown

Potential Factors?

3 events - circumstances unknown

Consequences…

Out of 117 events, five resulted in injuries to passengers/crew

- Vast majority did not result in injury
- Most injuries were minor, resulting from evacuation
- *One fatal injury*

Airframe and engine damage ranged from nil to hull loss

- "Typical" damage includes engine FOD, cowl damage, gear and flap damage, occasionally accompanied by gear collapse

Events that cause neither damage nor injury may go unreported …

Narrow Runway Issues

- Takeoff:
  1. "GO" following engine failure
  2. "RTO" following engine failure
  3. Maximum recommended crosswind
- Landing:
  1. Adverse weather (pilot decision-making)
  2. Crosswind landing
  3. Crosswind and engine failure
  4. Autoland considerations
- MMEL/Inflight Failures affecting directional control
- Ground Maneuvering and increased risk of FOD to wing-mounted engines

Regulatory Background

- In CFR 14 Part 25 and JAR 25, there are currently no requirements to define a minimum runway width as part of the certification of an airplane type
- No published AFM limitation
- FAA does publish recommended runway design criteria in Advisory Circular 150/5300-13
- ICAO also publishes recommended minimum runway width in Annex 14

Runway Design Criteria

FAA Recommended minimum runway width design guideline defined as a function of:

- Aircraft approach category (approach speed)
- Airplane design group (wingspan)

ICAO Recommended minimum runway width guideline defined as a function of:

- Reference takeoff field length (sea level, standard day, MTOW)
- More restrictive of wingspan or main gear track width

Runway Design Criteria for Boeing Jet Transports

Airplane	FAA AC-150/5300-13 Minimum Runway Width	ICAO Annex 14 Minimum Runway Width
707/720	45m	45m
717	30m	30m
727	45m	45m
737	30m/45m	30m/45m
747	45m	45m
757	45m	45m
767	45m	45m
777	45m	45m

** FAA recommended width shown for straight-in approach category*

Runway Design Criteria for Heritage Douglas Jet Transports

Airplane	FAA AC-150/5300-13 Minimum Runway Width	ICAO Annex 14 Minimum Runway Width
DC-8	45m	45m
DC-9	30m	45m
MD-80 Series	30m	45m
MD-90 Series	30m	45m
DC-10	45m	45m
MD-11	45m	45m

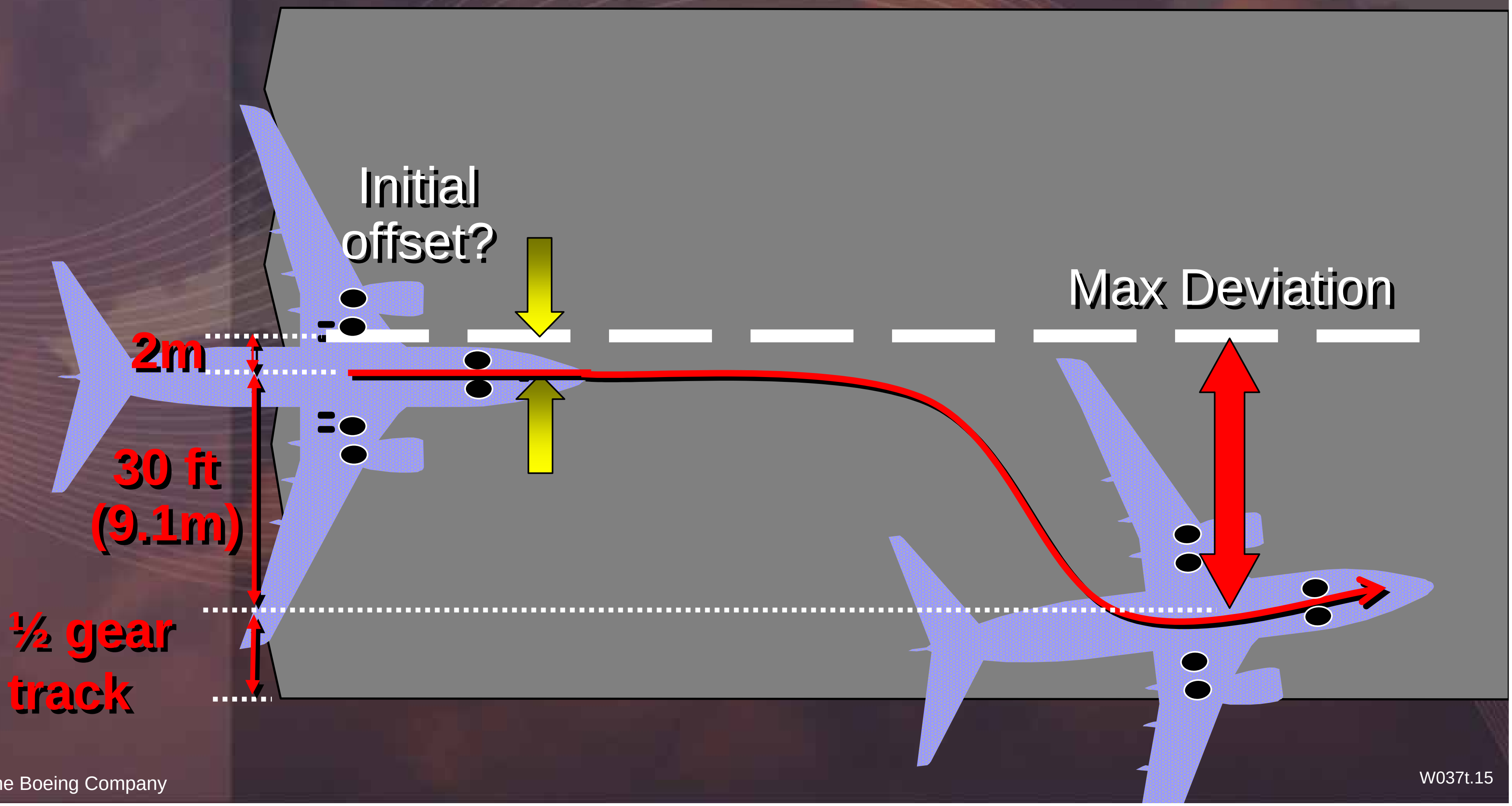
** FAA recommended width shown for straight-in approach category*

Regulatory Background – Airworthiness Standards

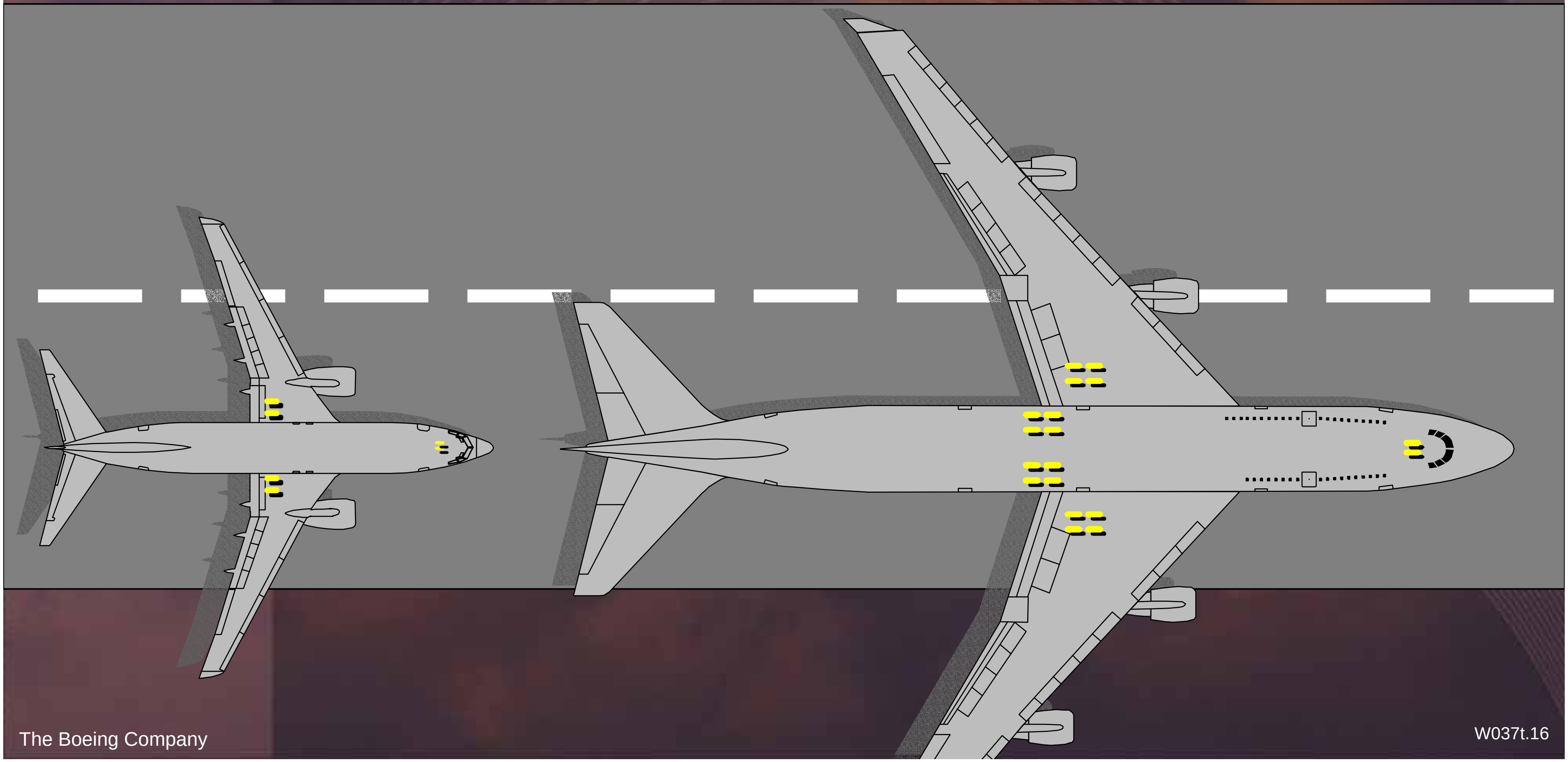
- Runway width not directly addressed in FAR/JAR Part 25
- FAR 25.149(e) does specify criteria to be used to determine minimum control speed on the ground (VMCG):
  - No credit for nose wheel steering…
  - Maximum 30 ft (9.14m) deviation from centerline during recovery

Note: Regulatory VMCG basis assumes zero crosswind

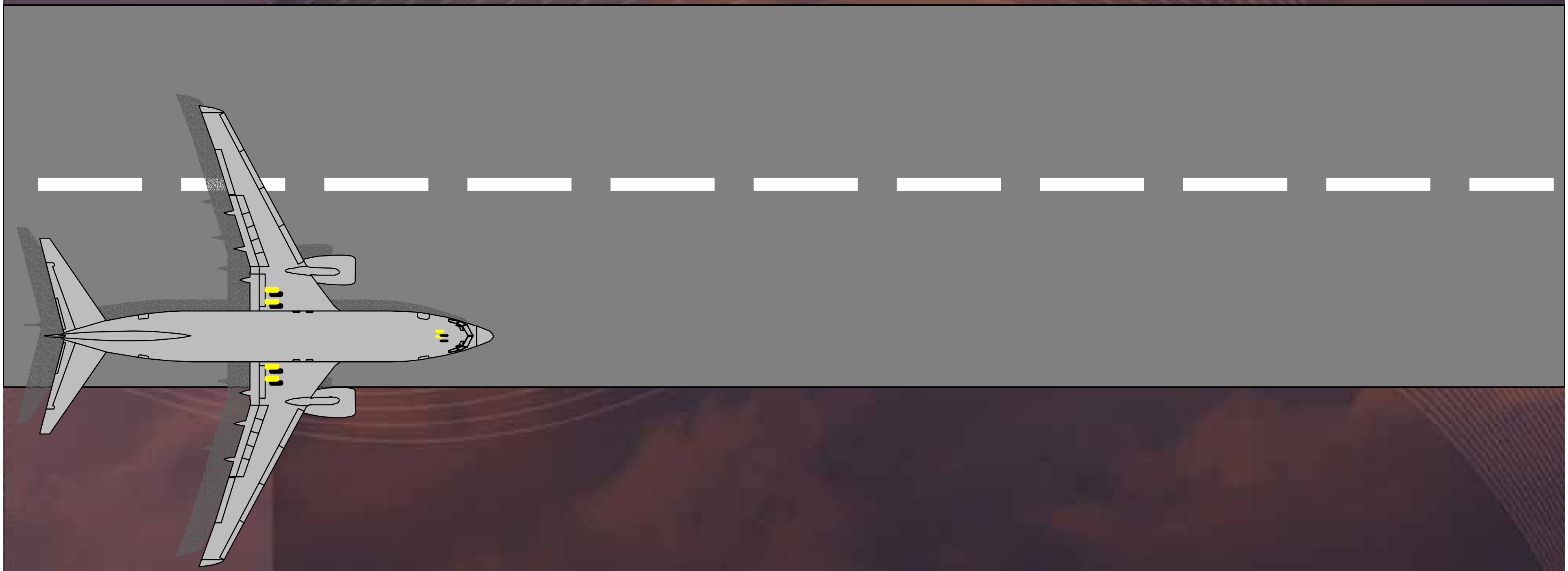
Maximum Allowable Deviation and Runway Width…



VMCG on a 45m Runway



VMCG on a 30m Runway



VMCG and Dispatch Runway Width

- No regulatory link between VMCG definition and actual runway width, so the maximum 30ft deviation could result in reduced (or non-existent) clearance between outboard main landing gear tire[s] and runway edge…
- Continued takeoff edge margin is reduced on a narrow runway at V1 limited by VMCG

Narrow Runway VMCG

VMCG should be increased to provide adequate margins on narrow runways…

Our approach is to scale the permissible deviation to the runway width, and then quantify the affect on VMCG:

737-700 sea level example:

Runway Width	Allowable deviation	VMCG Adjustment
45m (Baseline)	9.1m (30 ft)	baseline
30m	6.1m (20 ft)	Add **3-5** knots

What About Rejected Takeoff?

- Notice that the increased VMCG we just discussed protects us for a continued takeoff after V1, following engine failure, but it slightly increases our potential exposure to an RTO
- An equally important consideration is the effect of a narrow runway on the RTO

RTO Physics

- Engine failure below V1 → STOP!
- Retard thrust on the operating engine as quickly as possible to remove thrust asymmetry
- Largest deviations occur on RTO…

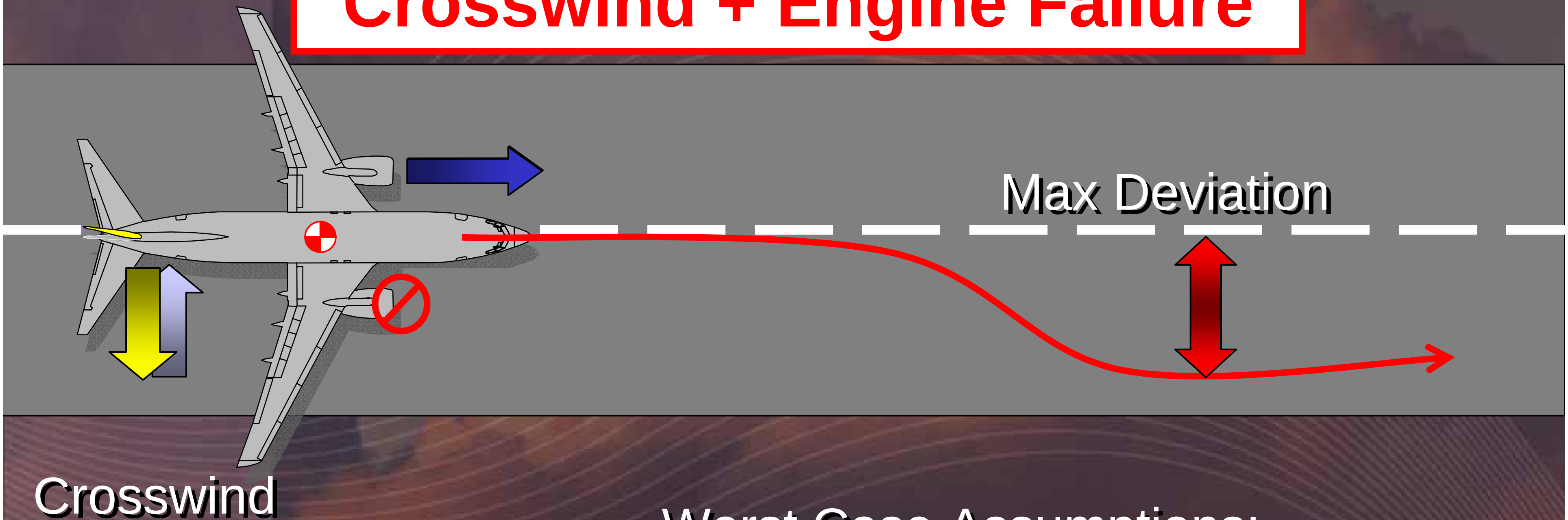
Airspeed Effect on Maximum Deviation During RTO

- Higher speed increases rudder effectiveness and increases airplane momentum prior to engine failure
- Thrust asymmetry reduces at higher speeds

Conclusion: Worst case for directional control is encountered on RTO when engine fails at slow speed

The Critical Condition for RTO

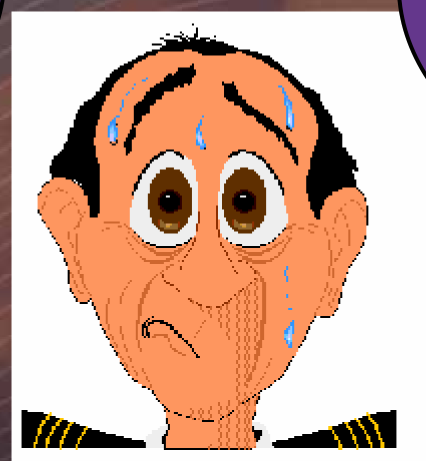
Crosswind + Engine Failure



Worst Case Assumptions:
- High Thrust
- Light Weight, Aft CG
- Max Takeoff Flap

Crosswind Accountability for Engine Failure on Takeoff

FAR/JAR Part 25 VMCG definition assumes zero crosswind…



Maximum Demonstrated Crosswind does not address engine failure…

Boeing's Recommended Crosswind Guidelines are intended to address crosswind <u>and</u> engine failure… but they are based on a 45m wide runway

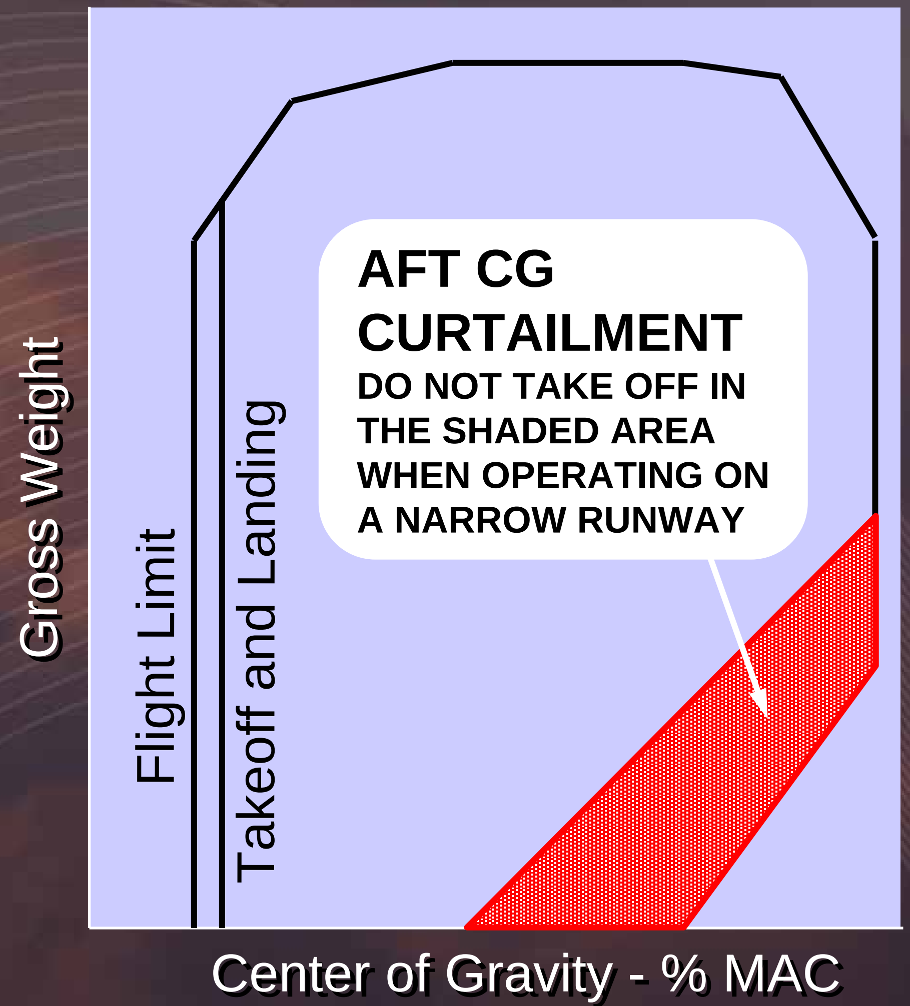
Performance Adjustments

- Adjust VMCG appropriately to protect “go”
- Adjust crosswind guidelines appropriately on narrow runway to preserve 45m wide runway capability

What if these limitations are too restrictive to be operationally viable?

Improving Narrow Runway Performance

Restrict WT/CG to increase crosswind capability if necessary, to improve crosswind capability:



Improving Narrow Runway Performance

- Select derated takeoff thrust to increase crosswind capability and/or to lessen WT/CG restriction required, when performance permits
- Assumed temperature takeoff thrust reduction also provides improved directional control, but cannot be used to improve WT/CG envelope, crosswind, or VMCG limitations, because the thrust reduction may be cleared at the pilot’s discretion

737-700/24K Results on 30m Runway

Runway Condition	45m Rwy Crosswind (kts)	30m Rwy Crosswind* (kts)
Dry	36	24
Wet	23	13
Standing water/slush	16	4
Snow - no melting	21	11
Ice – no melting	7	**

*Includes credit for Weight/Aft CG restriction for takeoff
**Operation is NOT RECOMMENDED

Landing on Narrow Runways

- Engine inoperative straight-in and sidestep approaches and landings with crosswind were evaluated
- Takeoff crosswind limits are conservative for landing (assuming stabilized approach)
- Pilot judgment is critical on landing!
- Tendency to flare late on narrow runways due to optical effect should be addressed
- Autoland has not been demonstrated on less than 45m wide runway

Ground Maneuvering and Foreign Object Damage

- Unique airport characteristics <u>must</u> be considered
- Ground Maneuvering should be carefully considered (i.e. ramp, taxiway, back-taxi, radius restrictions)
- Flight Crew Training Manual and Airplane Characteristics for Airport Planning contain detailed ground maneuvering procedures and geometry information
- Increased risk of Foreign Object Damage (FOD) to wing-mounted engines

MEL Dispatch and Inflight Failures

- All landing gear steering, thrust reverser, braking, and flight control systems other than yaw damper shall be operational for narrow runway operations
- Company MEL should address narrow runway limitations for dispatch
- Crews should be given guidance for en route diversions for critical inflight failures

Summary: Operational Recommendations

- Adjust VMCG and recommended crosswind guidelines appropriately for narrow runway
- Use reduced takeoff thrust (when performance permits) to minimize thrust asymmetry following engine failure
- Load to more forward CG to improve directional control
- Address narrow runway appropriately in MEL

Summary: Flight Crew Recommendations

- Provide dedicated training and qualification for narrow runway operations (properly validated simulator can be very effective device for this)
- Be vigilant for and aggressive in responding to asymmetric spin-up or engine failure on takeoff roll
- Be aware that differential braking may be required for RTO below 65 knots
- Exercise conservative judgment with respect to approach and landing, especially in adverse weather

Hold That Centerline!

Questions and Comments