Guidelines for Narrow Runway Operations

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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...

The pie chart shows:
- 15 events during Takeoff
- 15 events during Taxi
- 87 events during 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?

Landing Offsides (87 events)

- Heavy rain
- Strong/gusty winds
- Hydraulic problem
- Thunderstorm/windshear
- Slippery runway
- Intentional
- Gear/steering problem
- Hard landing
- Asymmetric reverse thrust
- Localizer incursion
- Runway incursion

14 events - circumstances unknown
Potential Factors?

- Asymmetric spin-up
- Engine failure
- Slippery runway
- Heavy rain
- Asymmetric reverse thrust
- Aft CG
- Engine inoperative ferry

Takeoff Offsides (15 events)

- 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

<table>
<thead>
<tr>
<th>Airplane</th>
<th>FAA AC-150/5300-13 Minimum Runway Width</th>
<th>ICAO Annex 14 Minimum Runway Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>707/720</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>717</td>
<td>30m</td>
<td>30m</td>
</tr>
<tr>
<td>727</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>737</td>
<td>30m/45m</td>
<td>30m/45m</td>
</tr>
<tr>
<td>747</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>757</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>767</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>777</td>
<td>45m</td>
<td>45m</td>
</tr>
</tbody>
</table>

*FAA recommended width shown for straight-in approach category*
### Runway Design Criteria for Heritage Douglas Jet Transports

<table>
<thead>
<tr>
<th>Airplane</th>
<th>FAA AC-150/5300-13 Minimum Runway Width</th>
<th>ICAO Annex 14 Minimum Runway Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-8</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>DC-9</td>
<td>30m</td>
<td>45m</td>
</tr>
<tr>
<td>MD-80 Series</td>
<td>30m</td>
<td>45m</td>
</tr>
<tr>
<td>MD-90 Series</td>
<td>30m</td>
<td>45m</td>
</tr>
<tr>
<td>DC-10</td>
<td>45m</td>
<td>45m</td>
</tr>
<tr>
<td>MD-11</td>
<td>45m</td>
<td>45m</td>
</tr>
</tbody>
</table>

*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...

- Initial offset?
- Max Deviation
- 2m
- 30 ft (9.1m)
- ½ gear track
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:

<table>
<thead>
<tr>
<th>Runway Width</th>
<th>Allowable deviation</th>
<th>VMCG Adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>45m (Baseline)</td>
<td>9.1m (30 ft)</td>
<td>baseline</td>
</tr>
<tr>
<td>30m</td>
<td>6.1m (20 ft)</td>
<td>Add 3-5 knots</td>
</tr>
</tbody>
</table>
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

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

Crosswind + Engine Failure

Max Deviation
Crosswind Accountability for Engine Failure on Takeoff

Boeing’s *Recommended Crosswind Guidelines* are intended to address crosswind and 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:

Center of Gravity - % MAC

Gross Weight

Flight Limit

Takeoff and Landing

AFT CG CURTAILMENT
DO NOT TAKE OFF IN THE SHADED AREA WHEN OPERATING ON A NARROW RUNWAY
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

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

*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 **must** 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