Outline

- Foreign Object Debris and Damage
  - Sources of FOD
  - Engine Jet Blast Concerns
  - FOD Prevention - FAA and ICAO guidance
  - Cost to the airlines

- Pavement maintenance Issues and recent Boeing experience

- Surface roughness effects on aircraft ride quality

- Surface friction and the effects on aircraft performance
What is FOD?

1. **Foreign Object Debris:**
   A substance, debris, or article alien to a vehicle or system which would potentially cause damage

2. **Foreign Object Damage:**
   Any damage attributed to a foreign object that can be expressed in physical or economic terms which may or may not degrade the products safety and/or performance characteristics

Definition Source: National Aerospace FOD Prevention Inc.

Sources of FOD

- FOD at the Gate-Aircraft Servicing and Maintenance Operations
- Primary source of FOD-Pavement debris
Sources of FOD

A re-treaded tire that delaminated and left debris behind- airline responsibility

Container blown into engine of L-1011 from adjacent aircraft engine thrust

Sources of FOD

Tire debris impacted bottom of the wing causing this damage.
FAA and ICAO Guidance

US airports are under Part 139 requirements which specify a FOD control program in their certification manual

- Advisory Circular 150/5210-24 “Airport Foreign Object Debris Management”
- Advisory Circular 150/5380-6 “Guidelines and Procedures for Maintenance of Airport Pavements”
- Advisory Circular 150/5200-18 “Airport Safety Self Inspection”

ICAO guidance

- ICAO Annex 14, Aerodrome Design and Operations, Chapter 10.2.1, 2.9.2
- ICAO Part 3 Pavements and Airport Services Manuals

Costs to the Airlines

<table>
<thead>
<tr>
<th>Engine Cost Data Estimates</th>
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<tbody>
<tr>
<td>Purchase cost of MD-11 engine</td>
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<tr>
<td>Purchase cost of MD-80 engine</td>
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<tr>
<td>MD-11 engine overhaul to correct FOD damage</td>
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<td>MD-80 engine overhaul to correct FOD damage</td>
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<tr>
<td>MD-11 fan blades per set</td>
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<td>MD-80 fan blades per set</td>
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Airframe-Engine Integration

- Engine installations similar to previous Boeing twin-engine airplanes
- Foreign object damage susceptibility equivalent to existing below-wing configurations

<table>
<thead>
<tr>
<th>Engine</th>
<th>Forward clearance</th>
<th>Minimum ground clearance</th>
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<tbody>
<tr>
<td>PW4074</td>
<td>48.0 in (122 cm)</td>
<td>36.2 in (92 cm)</td>
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<tr>
<td>Trent 875</td>
<td>53.2 in (135 cm)</td>
<td>41.4 in (105 cm)</td>
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<tr>
<td>GE90-75B</td>
<td>43.5 in (110 cm)</td>
<td>32.1 in (82 cm)</td>
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<table>
<thead>
<tr>
<th>Airplane</th>
<th>Forward clearance</th>
<th>Minimum ground clearance</th>
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<tbody>
<tr>
<td>737NG</td>
<td>21.5 in (55 cm)</td>
<td>18.0 in (46 cm)</td>
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<tr>
<td>757</td>
<td>43.7 in (111 cm)</td>
<td>32.7 in (83 cm)</td>
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<tr>
<td>767-300</td>
<td>31.5 in (80 cm)</td>
<td>21.9 in (56 cm)</td>
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Jet Blast Concerns- Takeoff Thrust

At full power the typical exhaust wake 60 meters beyond the aircraft can reach 240 km/hr (150 mph), similar to a category 5 hurricane.
Operational FOD Sources

- Jet blast from aircraft turning at RW/TW intersections can blow FOD onto runway
- Ingestion potential exists over unpaved shoulders

Jet Blast Concerns - Ground Maneuvering

747-400 and 747-8F

10.5 m 23-meter Taxiway 10.5 m

Inner engine CL over full strength shoulder - Outer engine over stabilized shoulder

A380

10.5 m 23-meter Taxiway 10.5 m
Jet Blast Concerns-Breakaway Thrust

Exhaust contour within the 44 m Code E shoulder width requirement

- Sea level, standard day
- Static A/P
- No wind
- All engines running
- 1.5% ground up-slope
- Steady state contours

Distance from A/P center line

- 75 mph (120 km/h)
- 50 mph (80 km/h)
- 35 mph (56 km/h)

Distance downstream of engine nozzle exit

Pavement Maintenance Issues-Recent Boeing Experience
Pavement Maintenance Priorities

Runway pavements should fill the following functions

1.) Provide adequate bearing strength- addresses structure of pavement

2.) Provide good ride quality- addresses surface geometrics

3.) Provide good surface friction characteristics- addresses texture and slope of pavement

All of these functions are tied to proper pavement maintenance and the availability of the pavement for safe aircraft operations

Unsealed Reflection Cracks

Asphalt overlay on concrete slabs had deteriorated and reflection cracks extended entire length of runway

Lack of pavement maintenance-sealing led to jet blast incident
Unsealed Reflection Cracks- Jet Blast Damage

Groove Degradation and FOD Issue

- Newly overlayed runway experienced severe FOD problems
- Groove breakdown exacerbated the problem
- Aircraft deliveries suspended until solution was found
Groove Degradation and FOD Issue

- August 21 – Airport Technology notified by Everett Delivery Center and Flight Test that aircraft were sustaining serious FOD damage
- The recently reconstructed section of the runway was the suspected source of the FOD
- Airport Technology confirmed the poor construction and identified interim solutions which minimized disruption to numerous Boeing deliveries.
- Worked with the FAA, airport authorities and consulting engineers to identify a permanent fix.
- September 11 - Runway repair of the damaged area (over one mile long) completed. No FOD damage reported since.

Lack of Proper Transverse Slope-Runway Contamination

- Standing water due to improper transverse gradient suspected of causing loss of 777 junction box clamps
- Water depth in some areas as high as 2.5 cm and in high speed braking areas. Flight performance manual suggests not taking off when contamination exceeds 1.25 cm, water impingement concern.
Lack of Proper Transverse Slope

Junction box clamps on 777 truck beam susceptible to water impingement due to ponding.

Station 0+606

Station 0+630
Improper Reflective Bead Application-
FOD Issue

Improper glass bead placement led to a foreign object debris (FOD) issue.

Damage to 10 new 737 aircraft engines cost $50 mil US dollars.

Surface Roughness Effects on Aircraft
What Types of Roughness are We Concerned About at Boeing?

- Three Types of Structural Concerns Affecting Aircraft:
  1. **Limit Loads** – Single Discrete Bumps which could lead to structural failure. Currently addressed by Boeing Bump Criteria
  2. **Fatigue Loads** – Continuous Large Wavelength Bumps
  3. **Landing Gear Truck Pivot Joint** – Continuous Short Wavelength Bumps. Only a real concern in Russia and CIS countries

- Each type imposes a different runway roughness criteria. Types 2 and 3 require dynamic analysis.
- Current standards address mainly first two types.
- Third type is relatively unknown, and not directly addressed in current standards.
Surface Roughness Effects on Aircraft

Surface Roughness Effects - Short Wave Bumps

- Shows bump height intensity versus bump wavelength

Acceptable Threshold
Airports Surveyed by Boeing for Roughness

FAA and Boeing SurPro Profilers
FAA Guidance on Roughness

FAA Advisory Circular
150/5380-9 (released 9/30/09)

Surface Friction Effects on Aircraft
Aircraft Excursions are typically the result of multiple factors

- Excursions are not the result of a single issue
  - Typically 2, 3 or more issues are involved
  - Weather conditions
  - Pilot technique
  - Runway conditions
  - Performance capability of the airplane
  - Often if 1 of the multiple issues were changed a successful stop would occur
- Focus on landing

Runway condition affects aircraft stopping performance

- Ability of the airplane to stop on a runway is a function of:
  - Amount of wheel braking used
    - Manual or Auto brake
  - Remaining tire tread
  - How wet is wet?
    - Saturated
      - 3mm generally accepted threshold for dynamic hydroplaning
    - Heavy rain
  - Runway condition - texture
    - Grooved / PFC or Wet smooth (non-grooved runways)
    - Rubber build up
    - Polishing

Stopping capability on a wet runway can vary significantly due to surface condition
Runway Condition Measurements

- Runway texture (roughness)-microtexture
  - “OPEN, HIGH”
  - “CLOSED, LOW”
- Periodically measure friction using CFME - macrotexture
Recent 737-900 Overrun

Area of airplane braking

12 M right of c/l

3 M right of c/l
As macrotexture affects the high speed tire braking characteristics, it is of most interest when looking at runway characteristics for friction when wet.

Simply put, a rough macrotexture surface will be capable of a greater tire to ground friction when wet than a smoother macrotexture surface.
Questions?

Thank You!