FLIGHT SERVICES

Runway Roughness Evaluation- Boeing Bump Methodology

LIFECYCLE SOLUTIONS

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ALACPA Seminar of Airport Pavements

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Outline

- Types of Roughness and Boeing Bump Criteria
- Profiling Equipment Comparison
- Case Studies
- Standardization of Roughness Criteria
- Conclusions

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 exceeding once per flight fatigue criteria based on change in vertical acceleration
  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.**

Pavement Maintenance Priorities

Runway pavements should fill the following functions

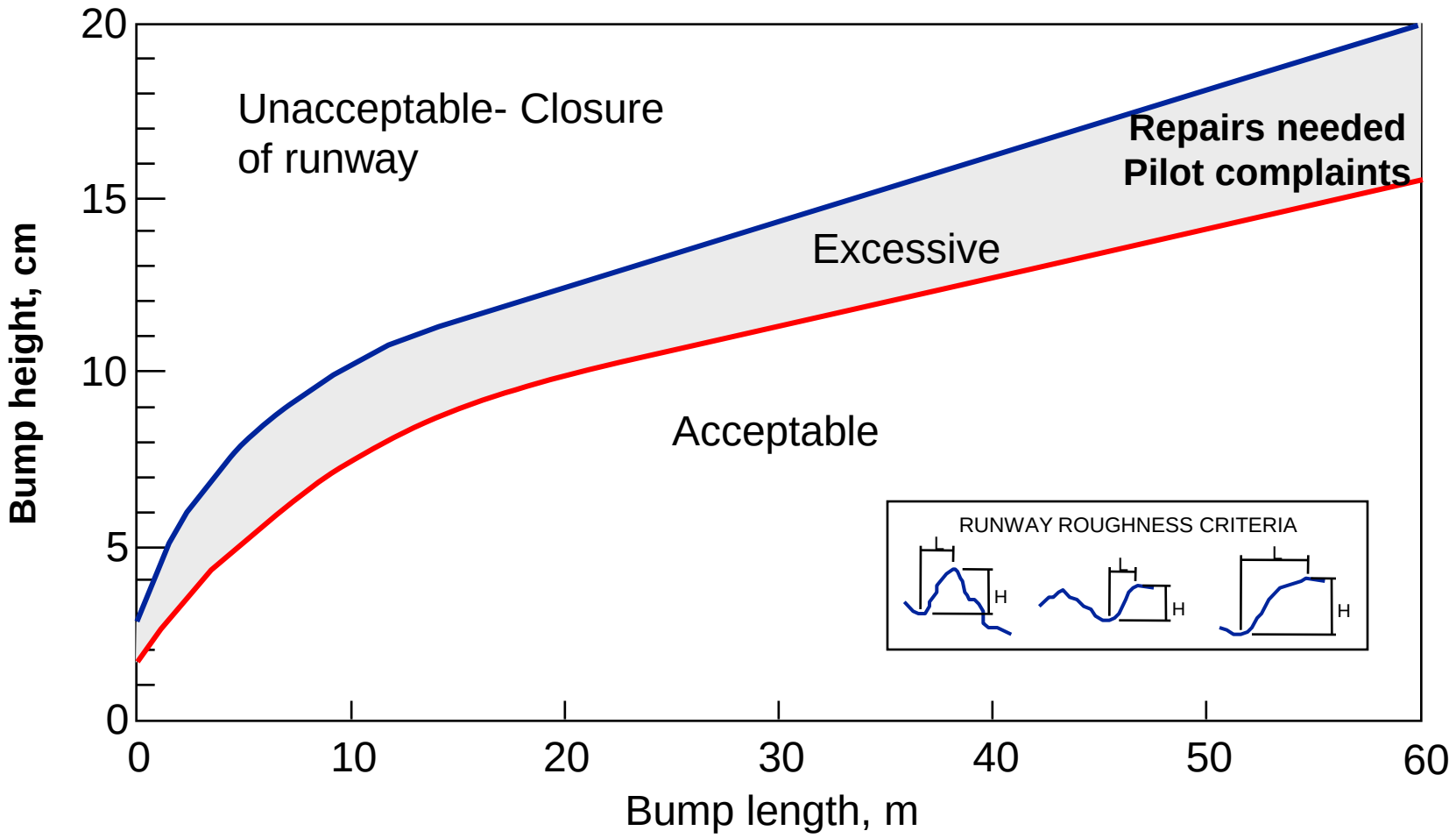
1.) Provide adequate bearing strength- addresses structure of pavement

2.) Provide good ride quality- addresses surface geometrics

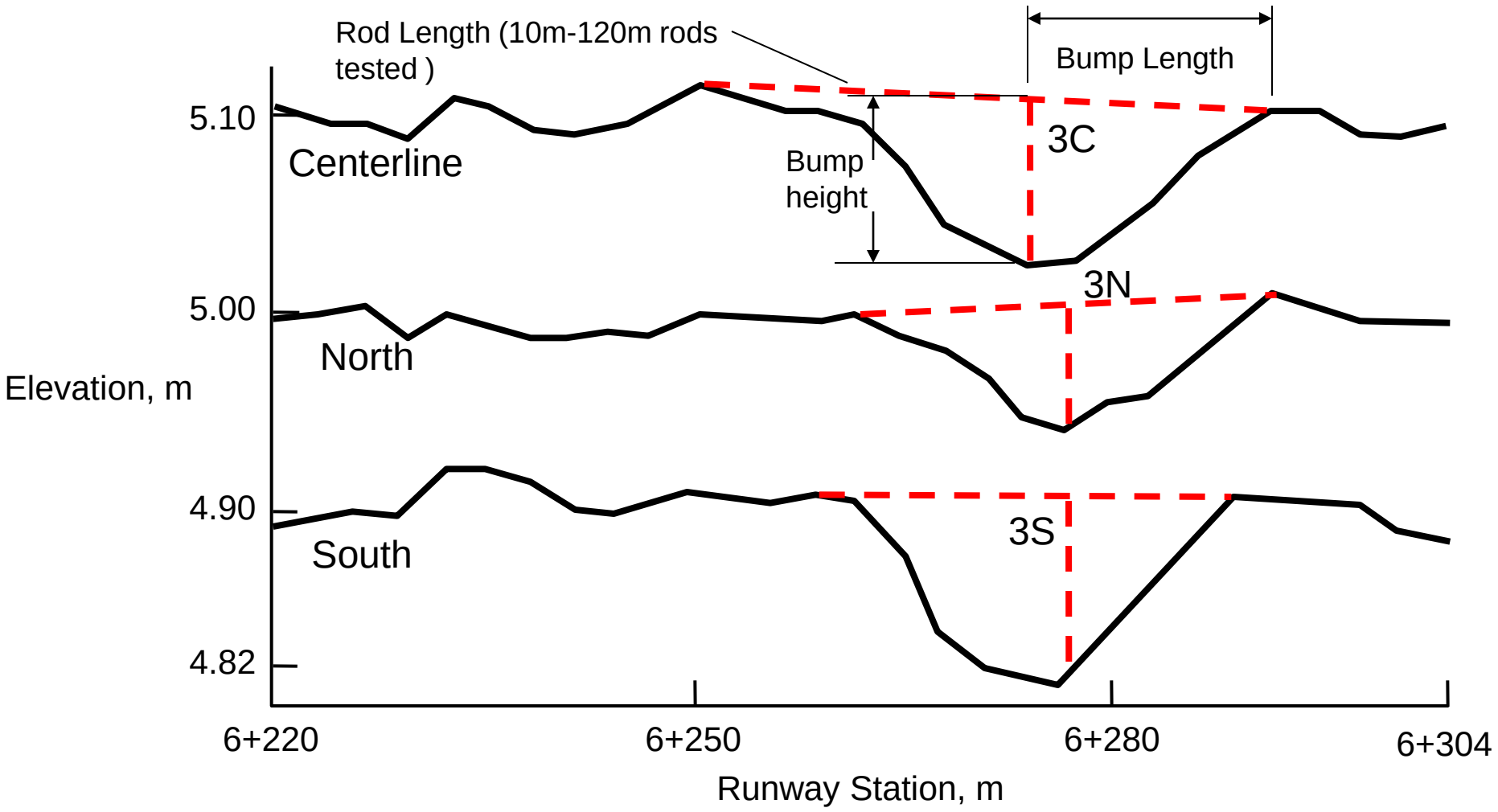
3.) Provide good surface friction characteristics- addresses texture and slope of pavement

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

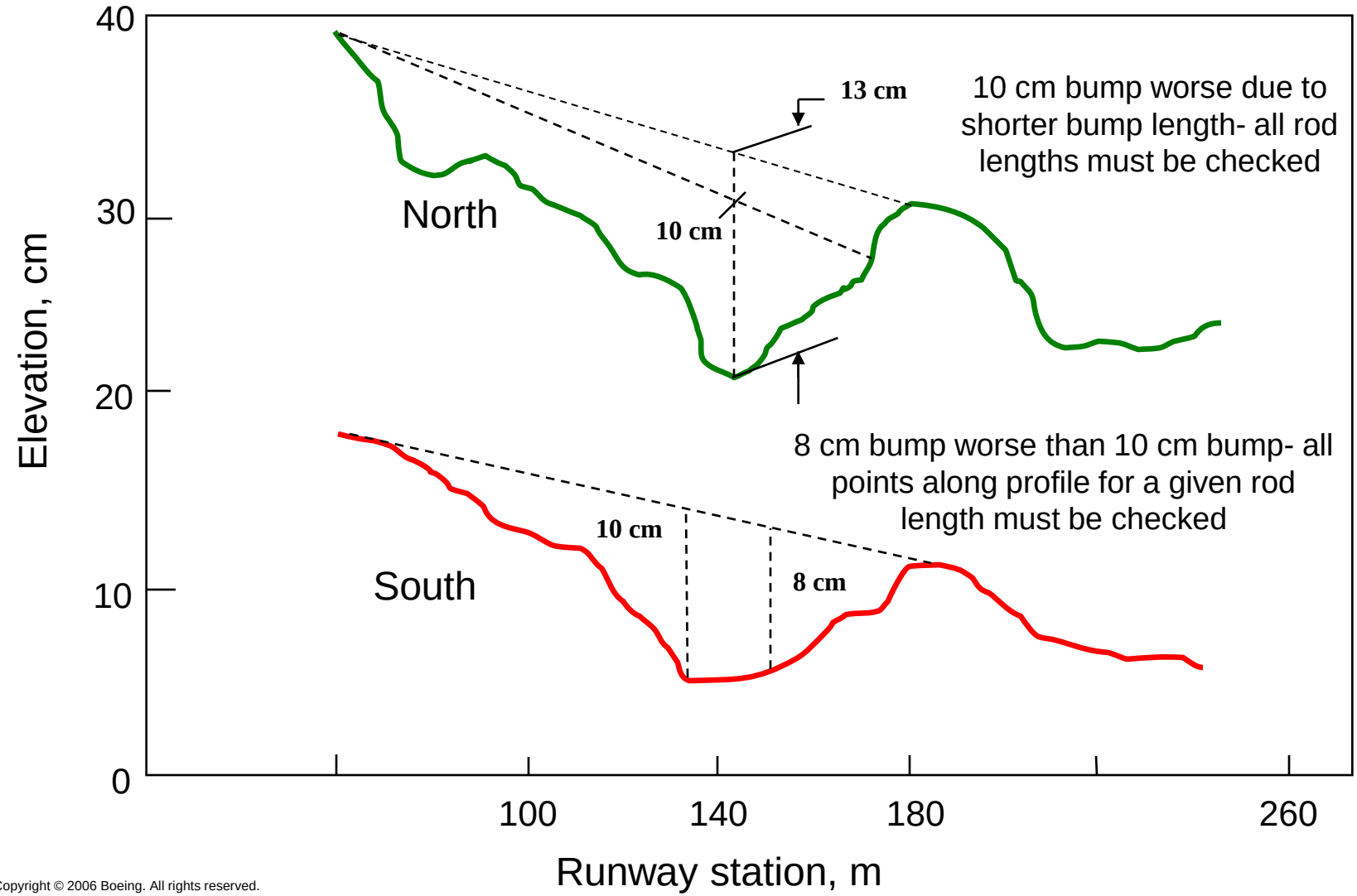
Boeing Runway Roughness Criteria-Single Event Limit Load



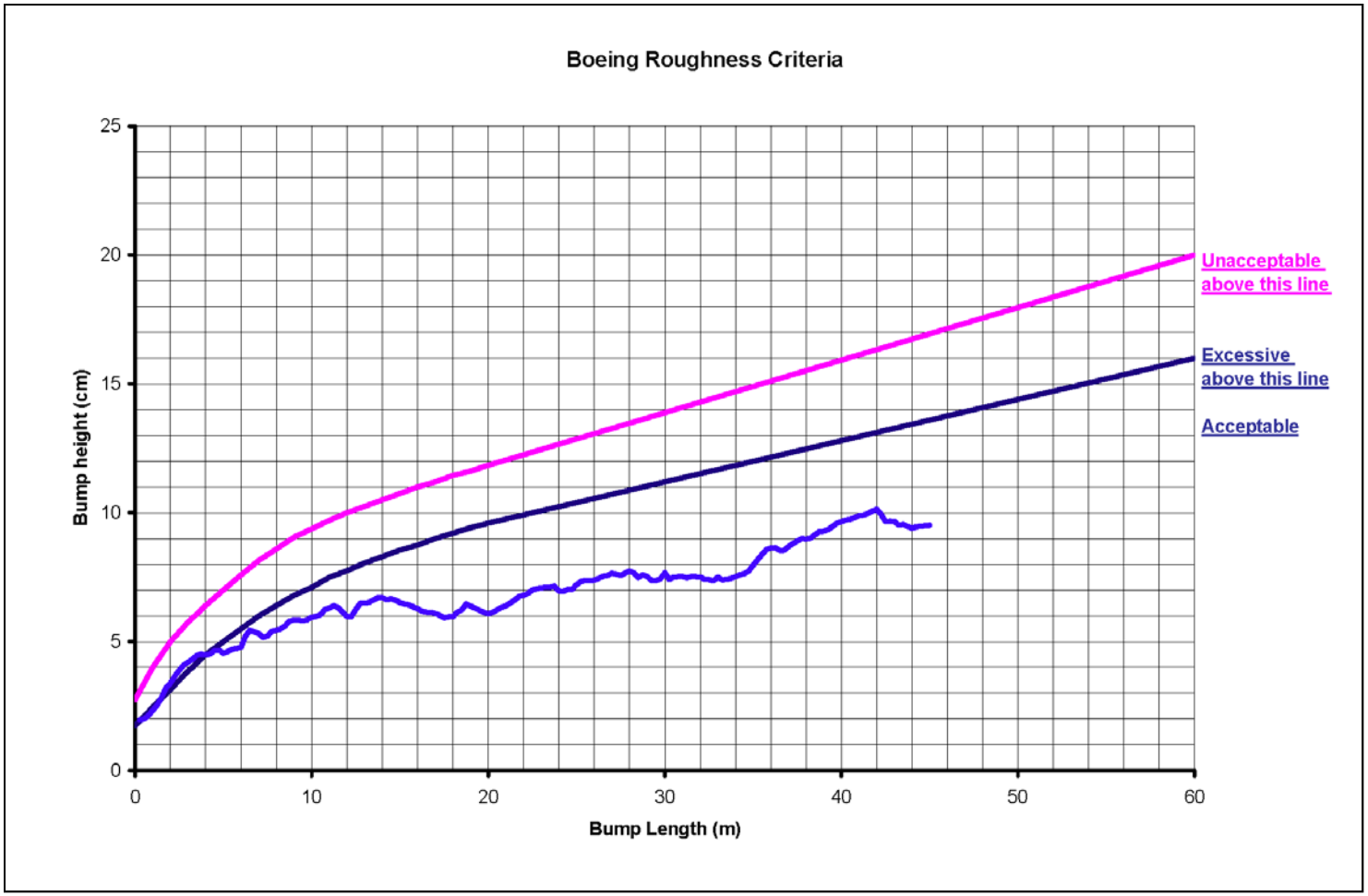
Long Wave Depression
Bump Definition



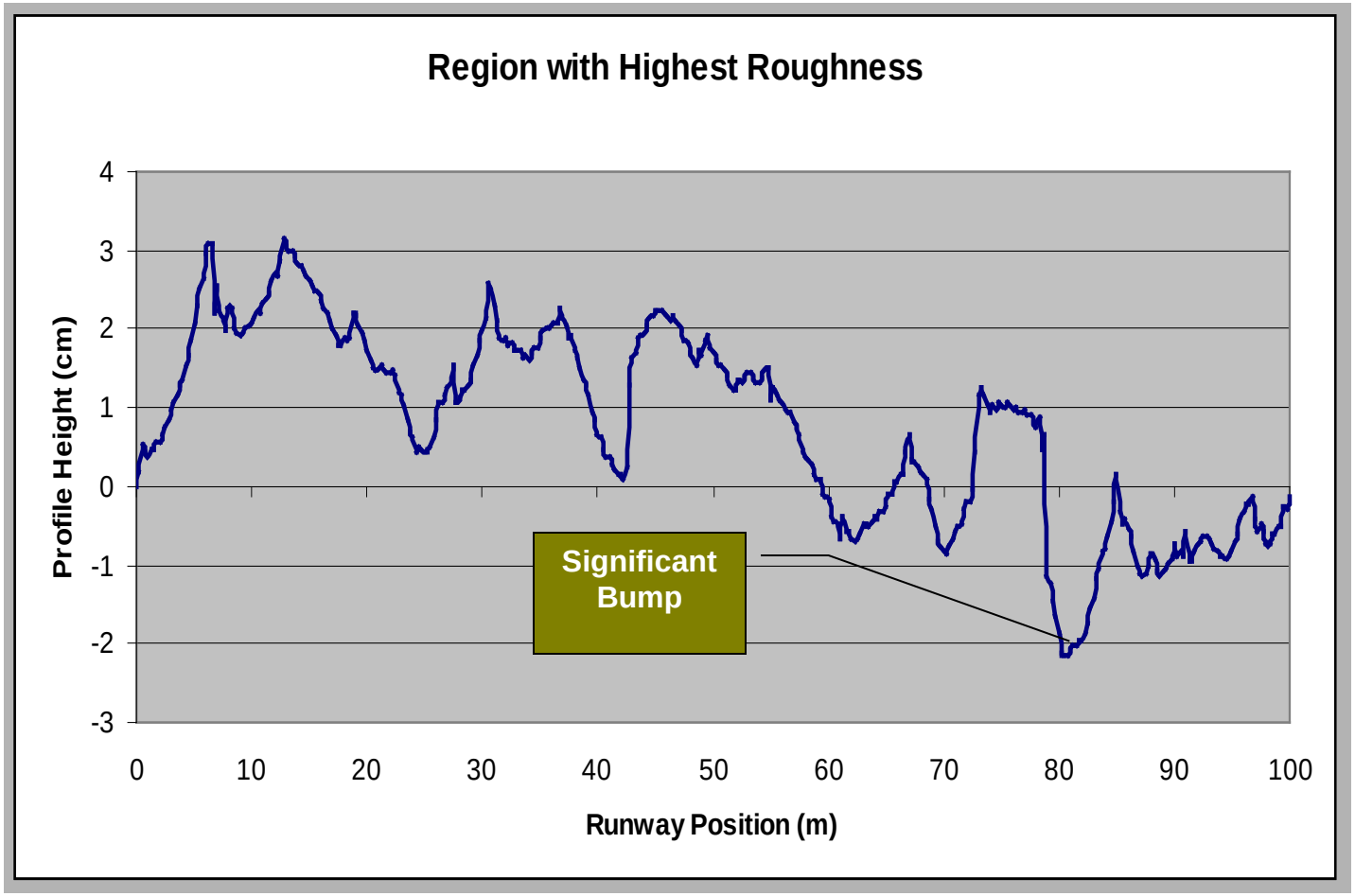
Details of the Boeing Method- Long Wave Depression



Boeing Bump Analysis- Plot of Worst Bumps



Boeing Bump Analysis- Detail of Excessive Bumps



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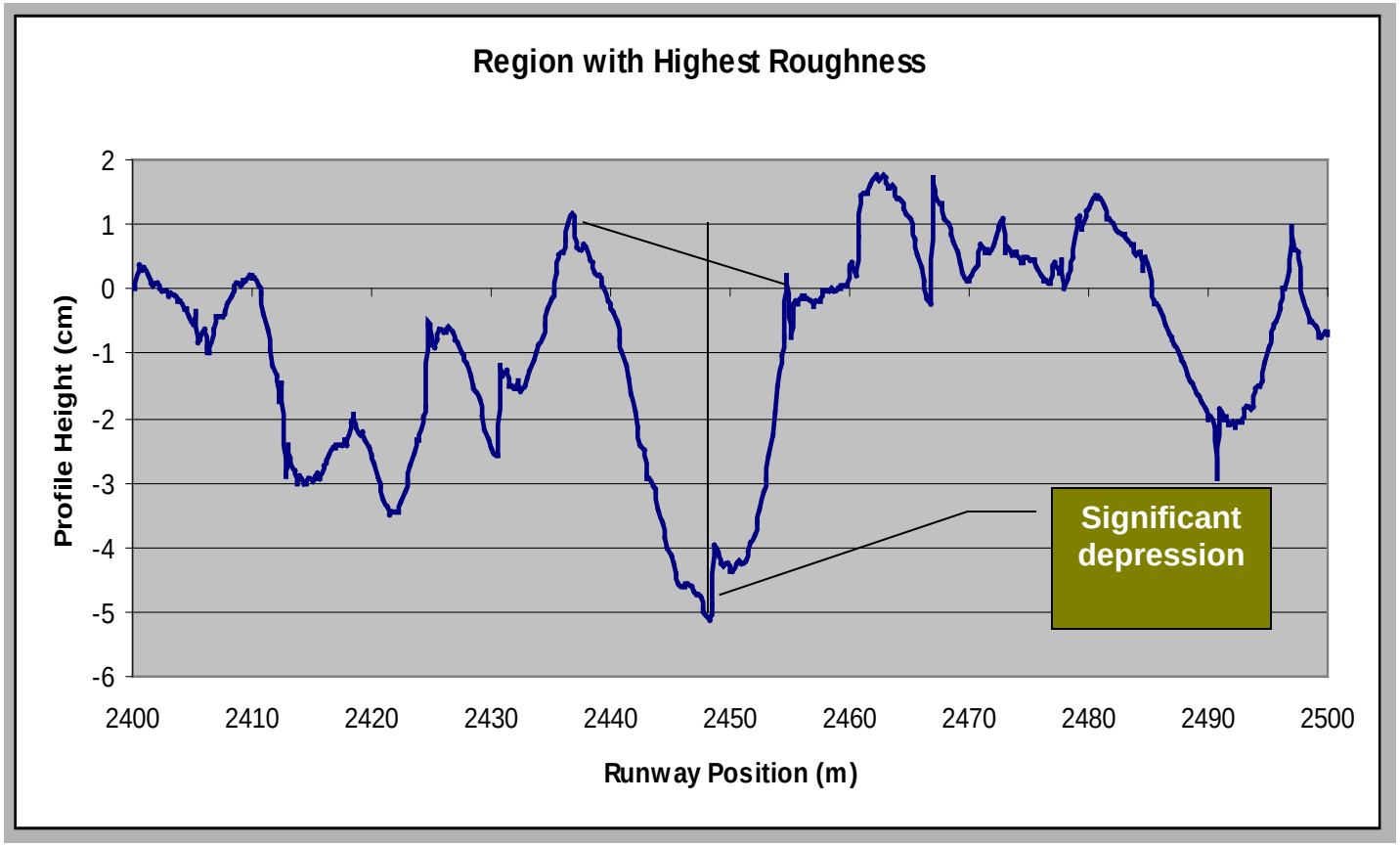
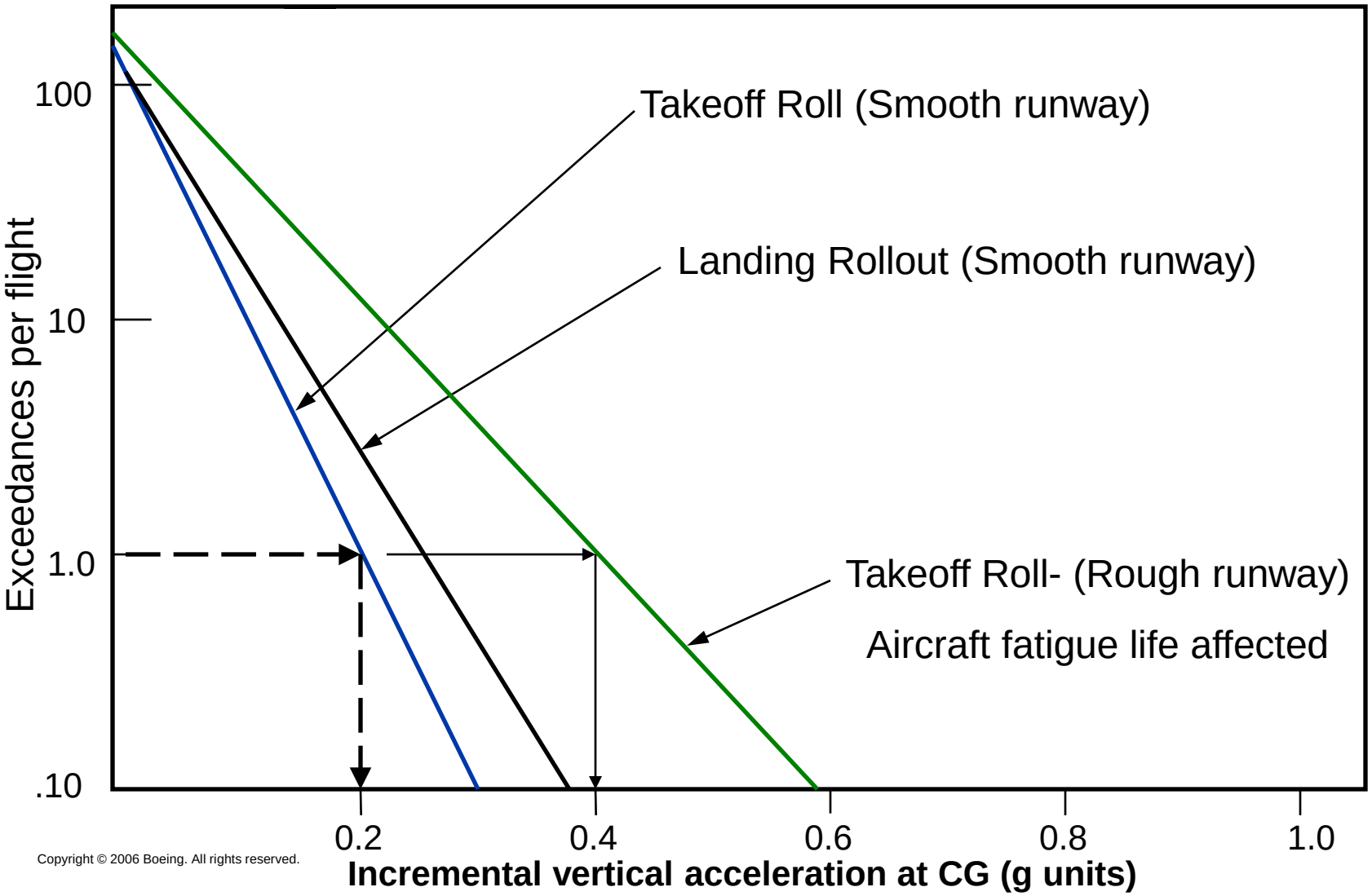
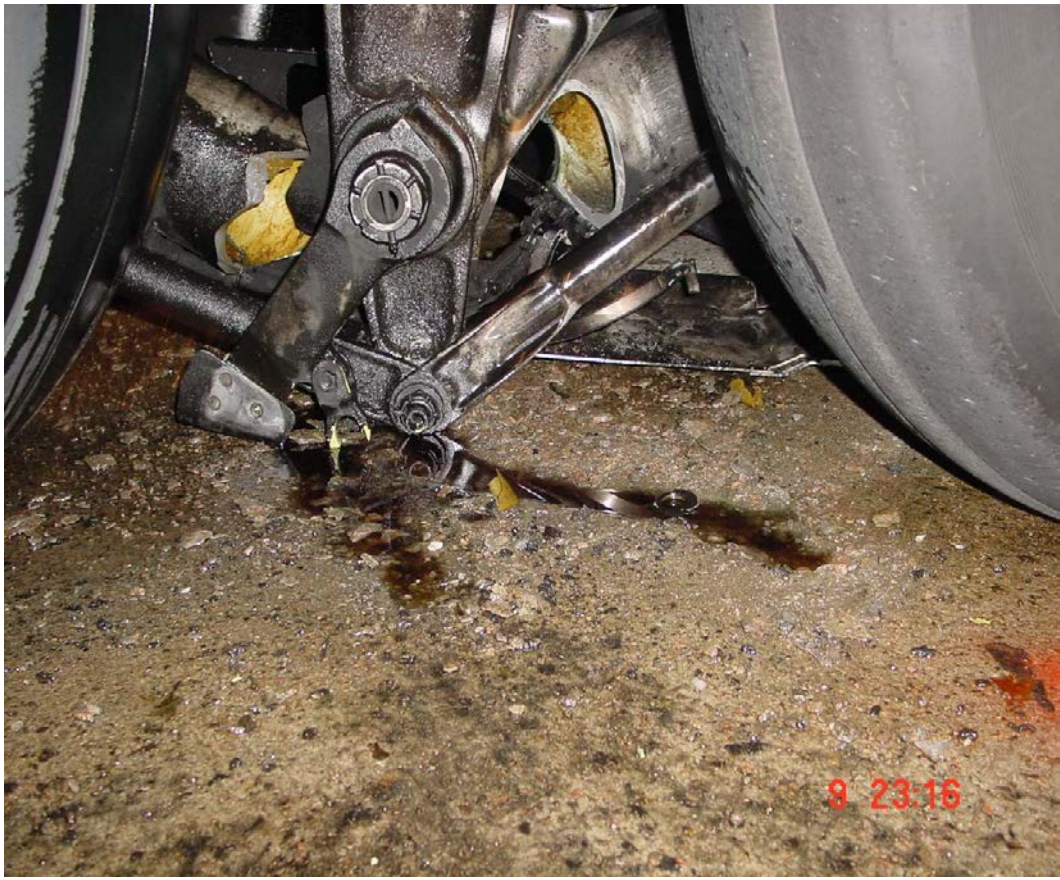


Fatigue Life – Exceedance of Airplane Load Factors



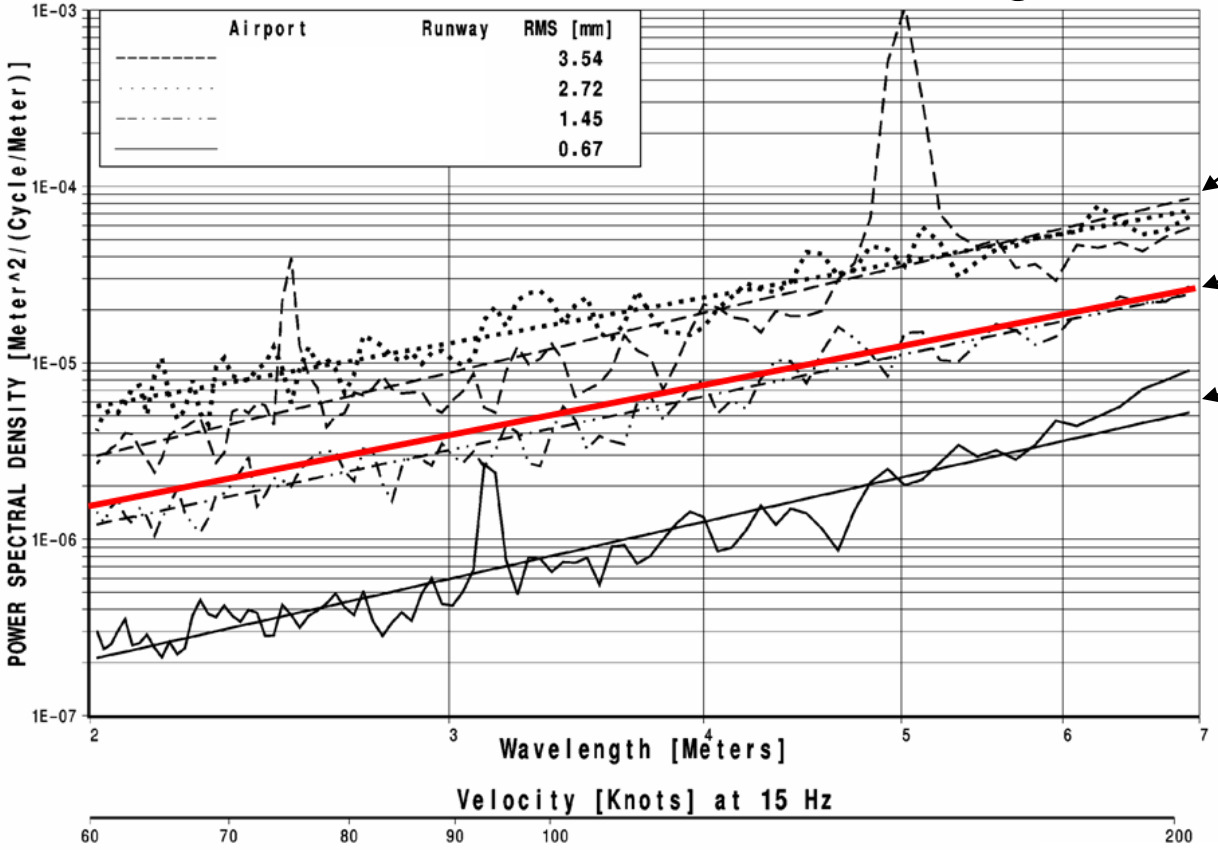
Landing Gear Truck Beam Failure- Short wave Roughness Issue



Short Wavelength Runway Profile Analysis

Power Spectral Density (Overall Runway)

- Shows frequency of occurrence of short wave bumps- 2 to 7 meter range



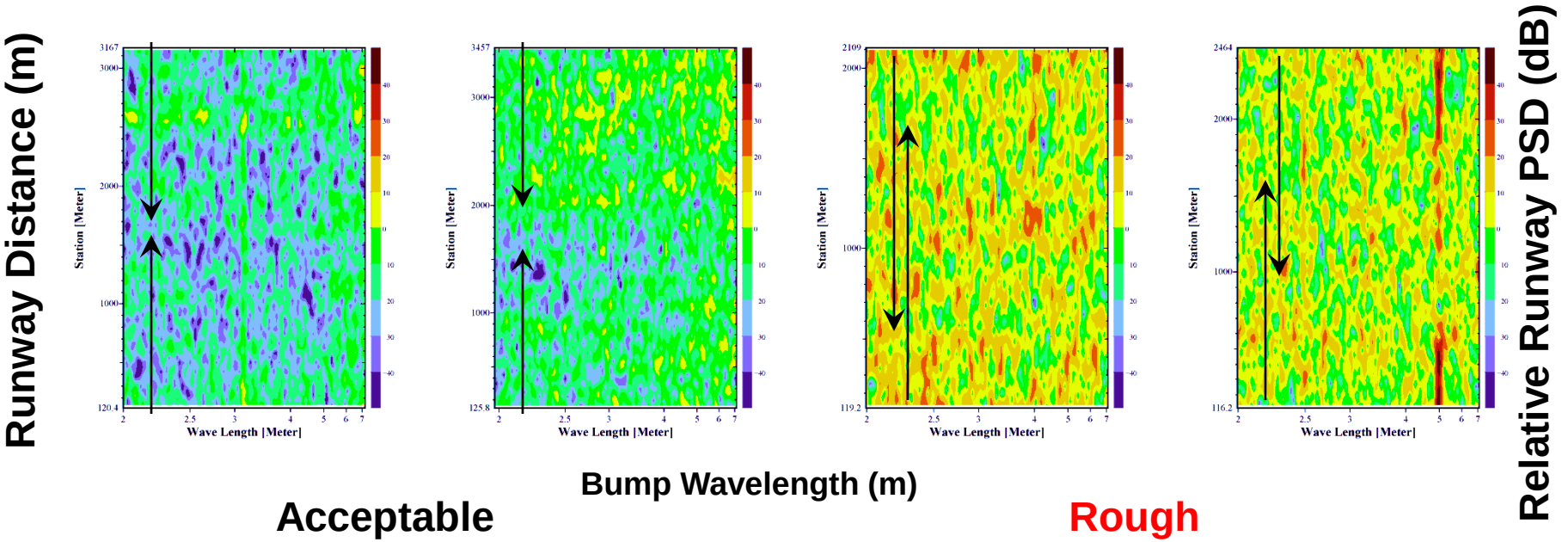
Rough runway- Above threshold

Acceptable threshold RMS = 1.45

Smooth runway- Below threshold

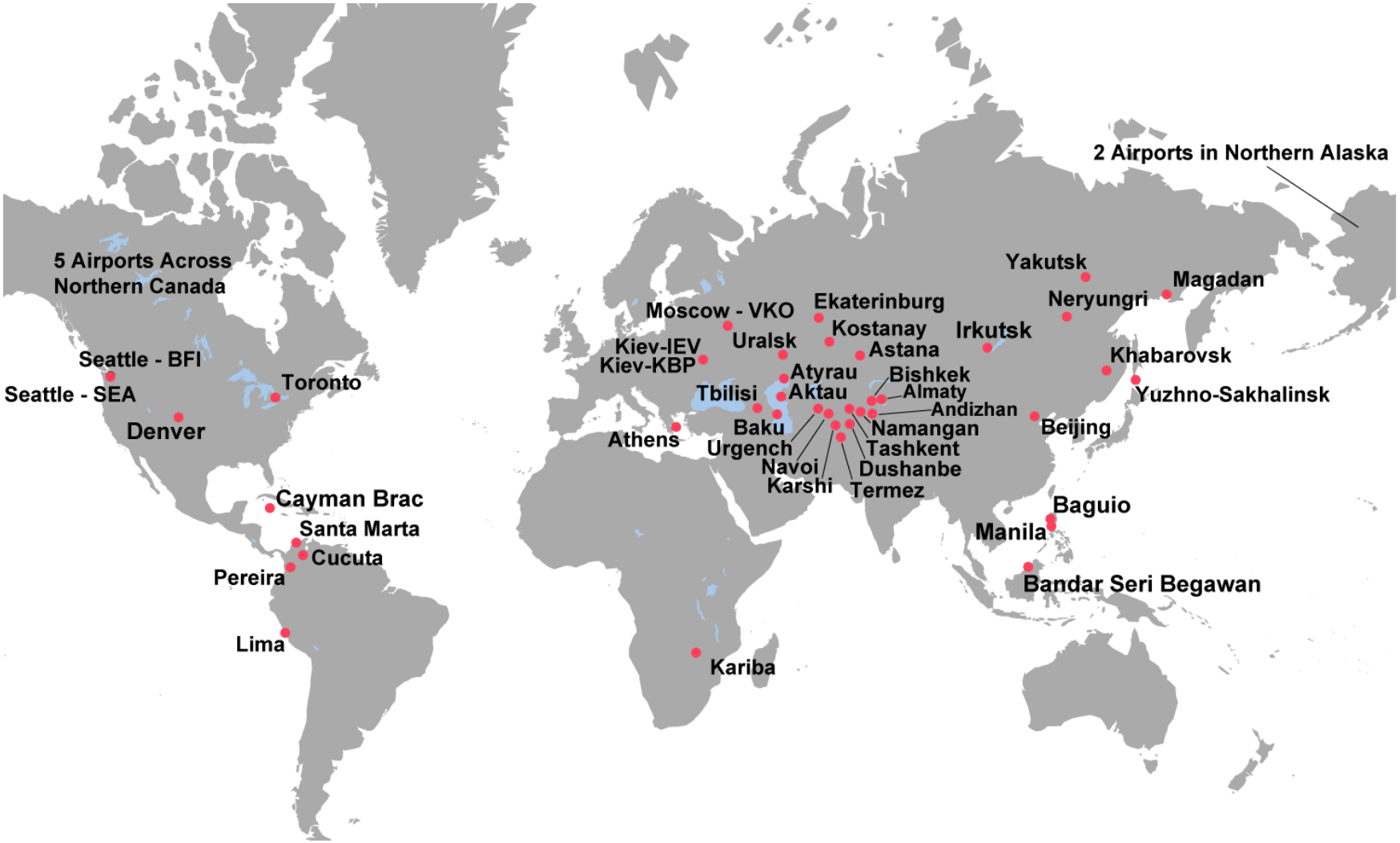
Runway Profile Analysis

3D Relative Power Spectral Density

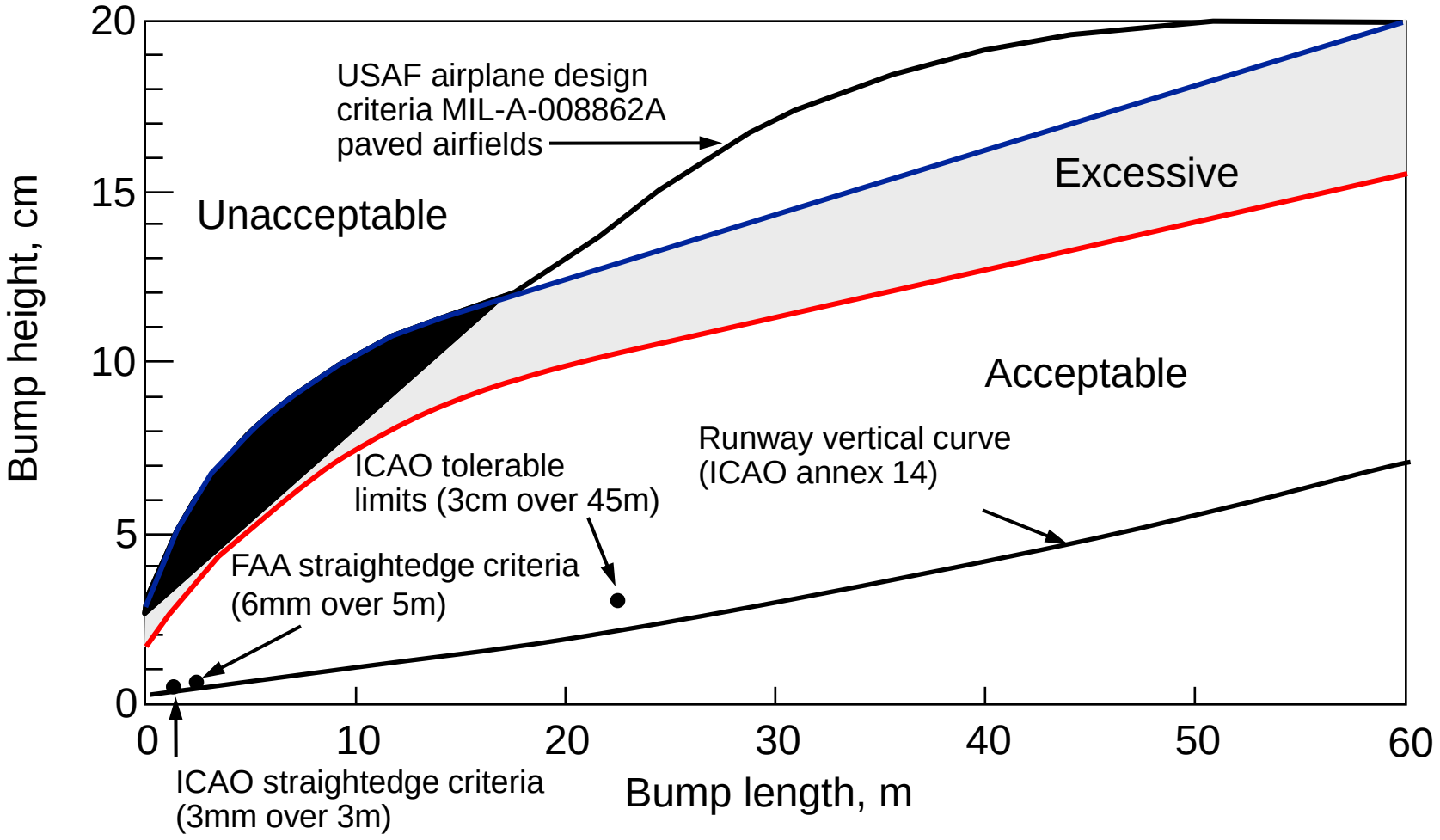


Runways in CIS countries identified having short wave roughness exceeding the PSD threshold must be serviced periodically(i.e. inspect and lube) by airline

Airports Surveyed by Boeing for Roughness



Comparison Between Boeing Criteria and other Criteria



Runway Profiling Equipment Comparison

High Speed Inertial Laser profiler

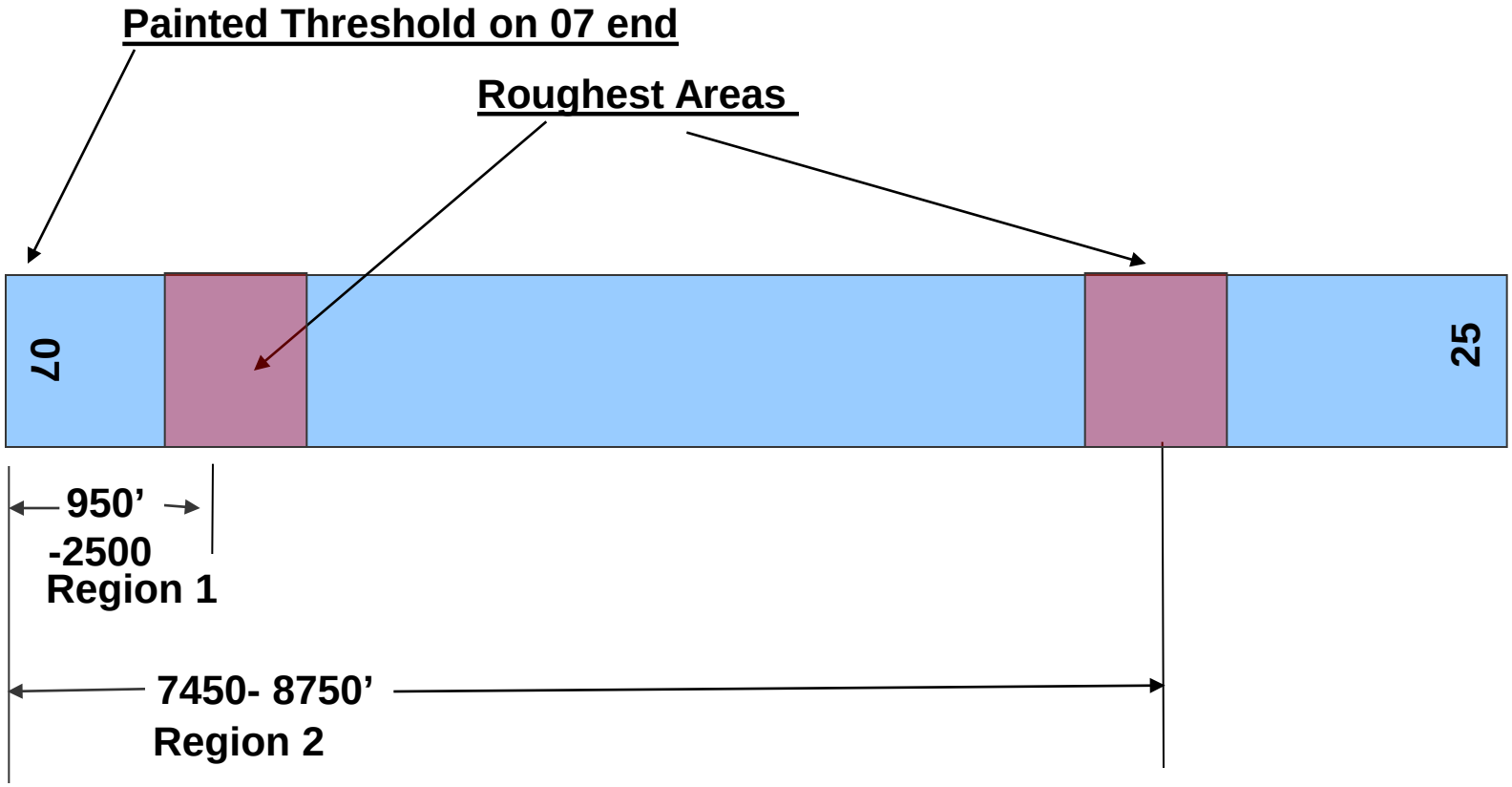
Manual rolling inclinometer profiler

Manual rod and level device

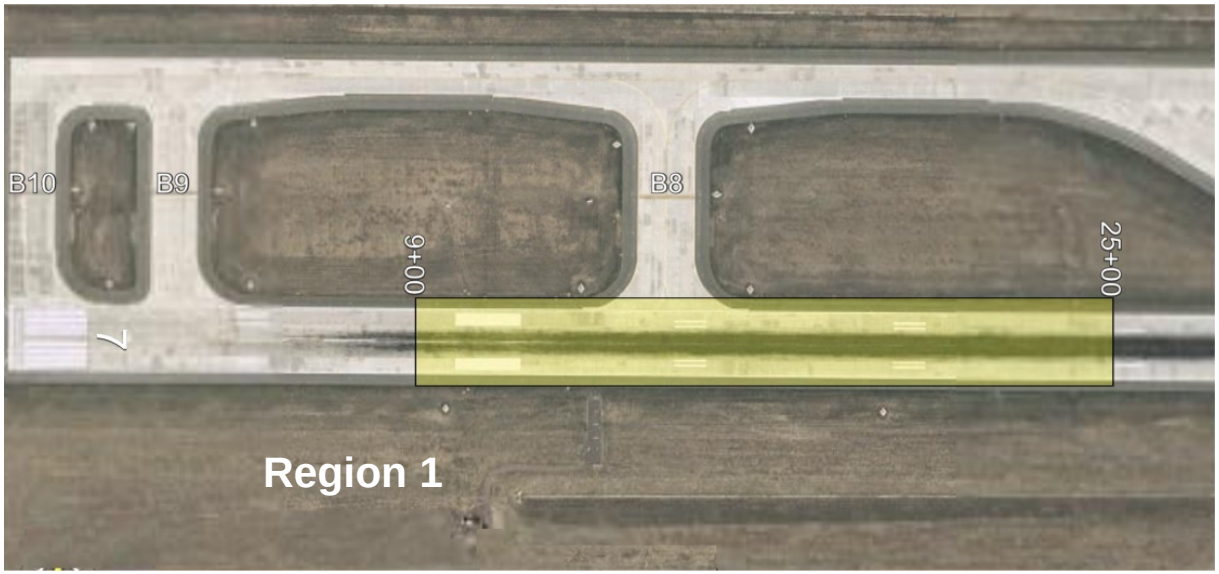
Pavement Assessment Process

- Compare profiles from 3 profiling devices
- Verify that the regions of roughness along the profile were similar in magnitude for all profilers
- Compare 2 Lines of Survey (CL and 15 Feet Left of CL)
- Roughness determined using Boeing Bump Criteria was compared for all 3 devices
- Initial consultant request to review runway 07/25 came to Boeing in 2007. Main concern was fatigue, primarily region 1 dual bump exceeding the once per flight fatigue limit.

Areas of Roughness from APR survey- 2006



Areas of Roughness from APR survey- 2006



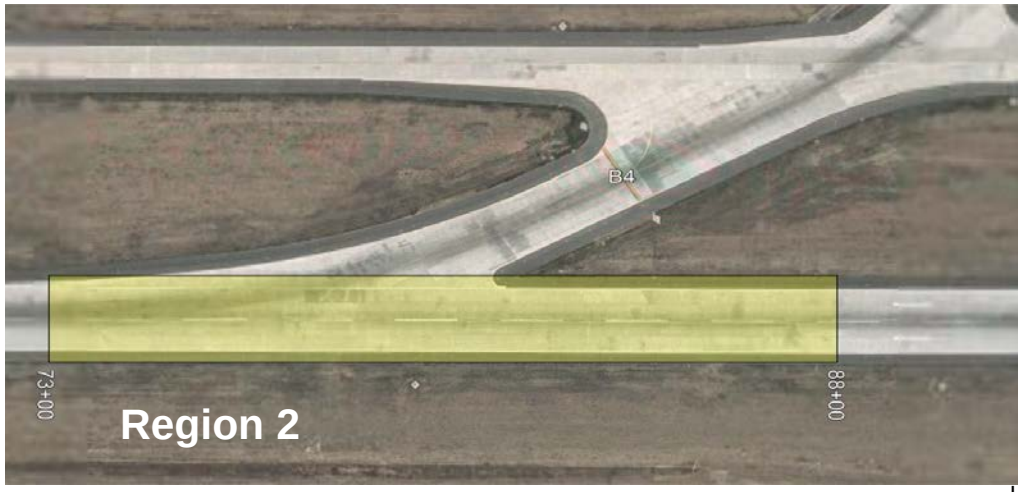
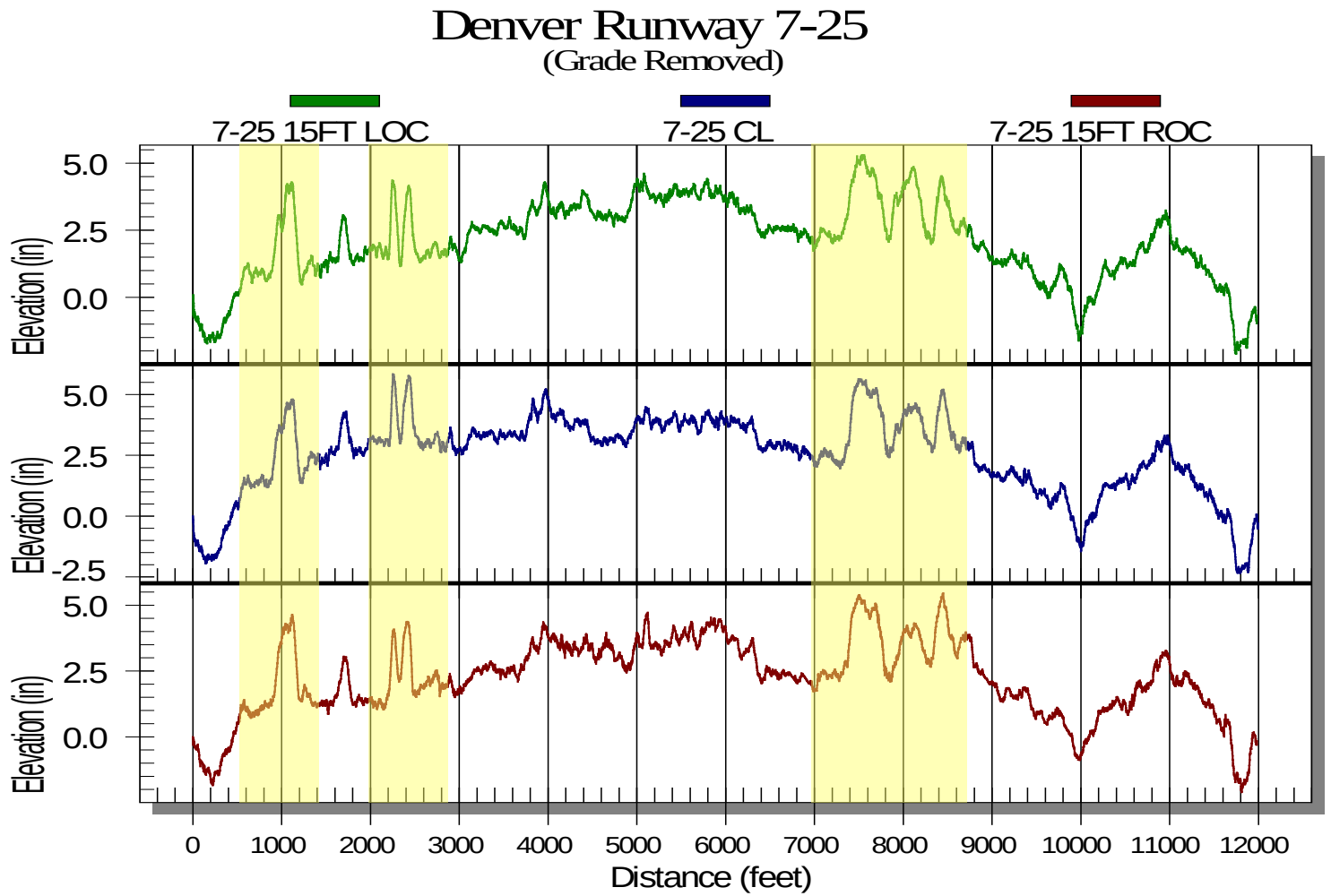
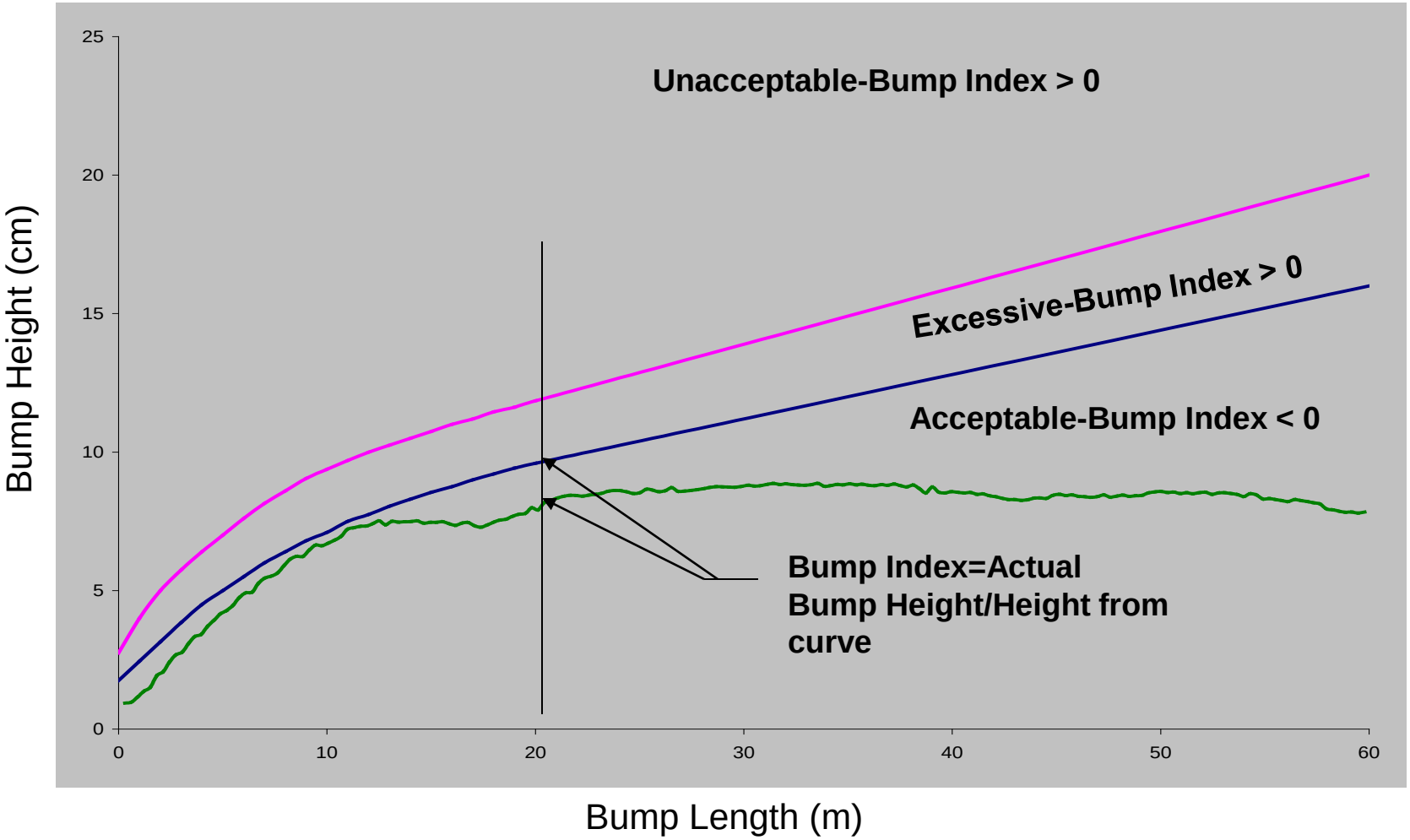


Image: Courtesy Google Maps

APR Profiles-Regions 1 and 2 as noted

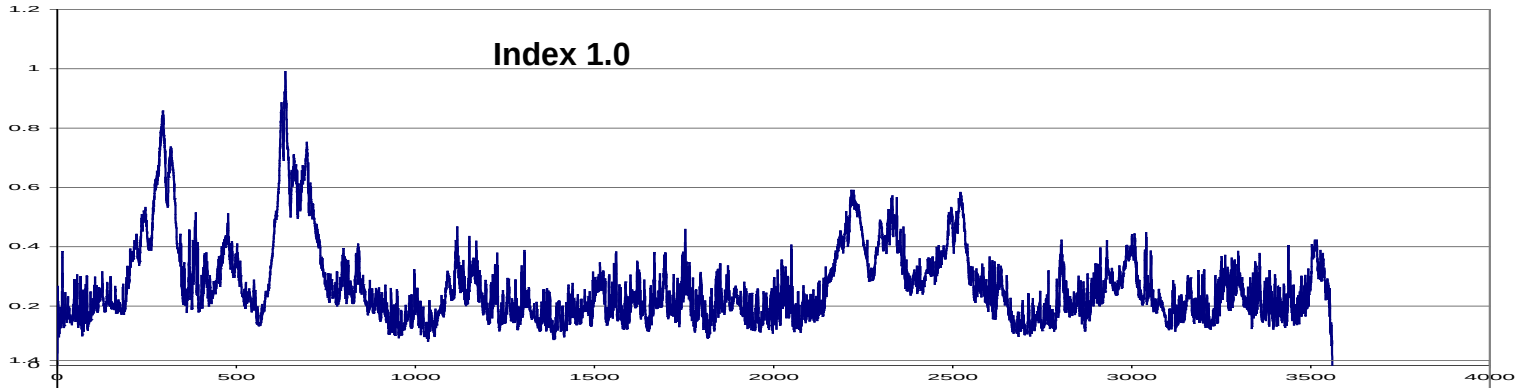


Bump Index Definition

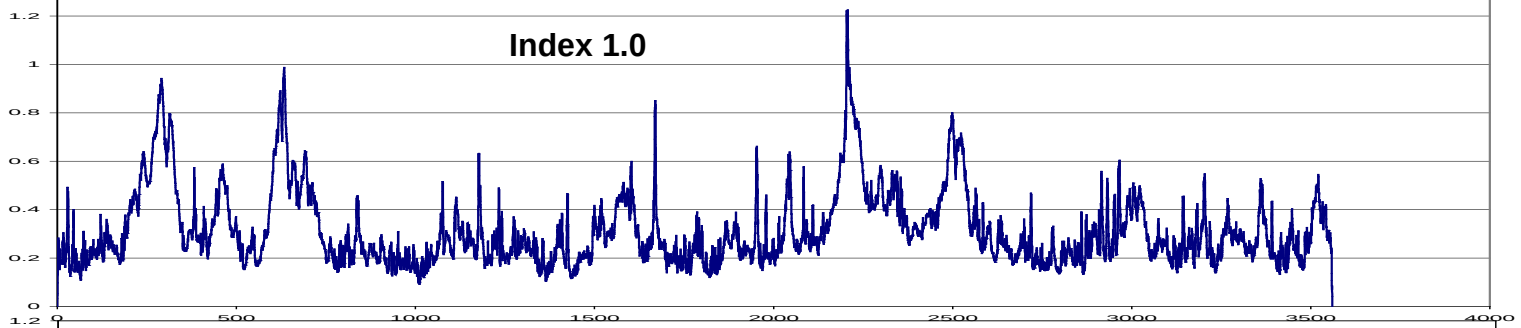


Runway 07/25 Centerline Profile- Bump Index Comparison

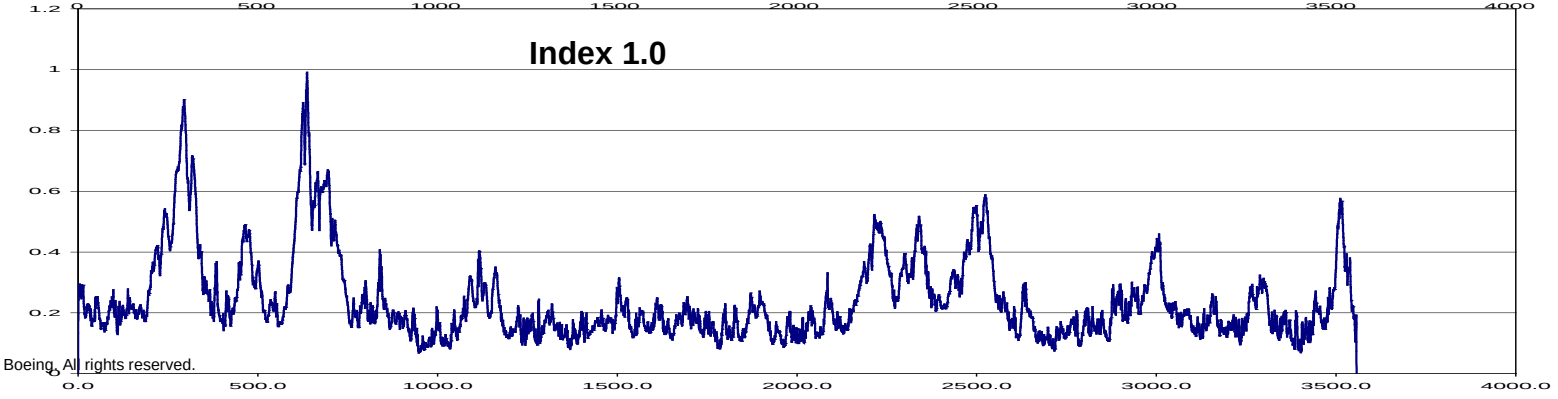
APR



Boeing



FAA

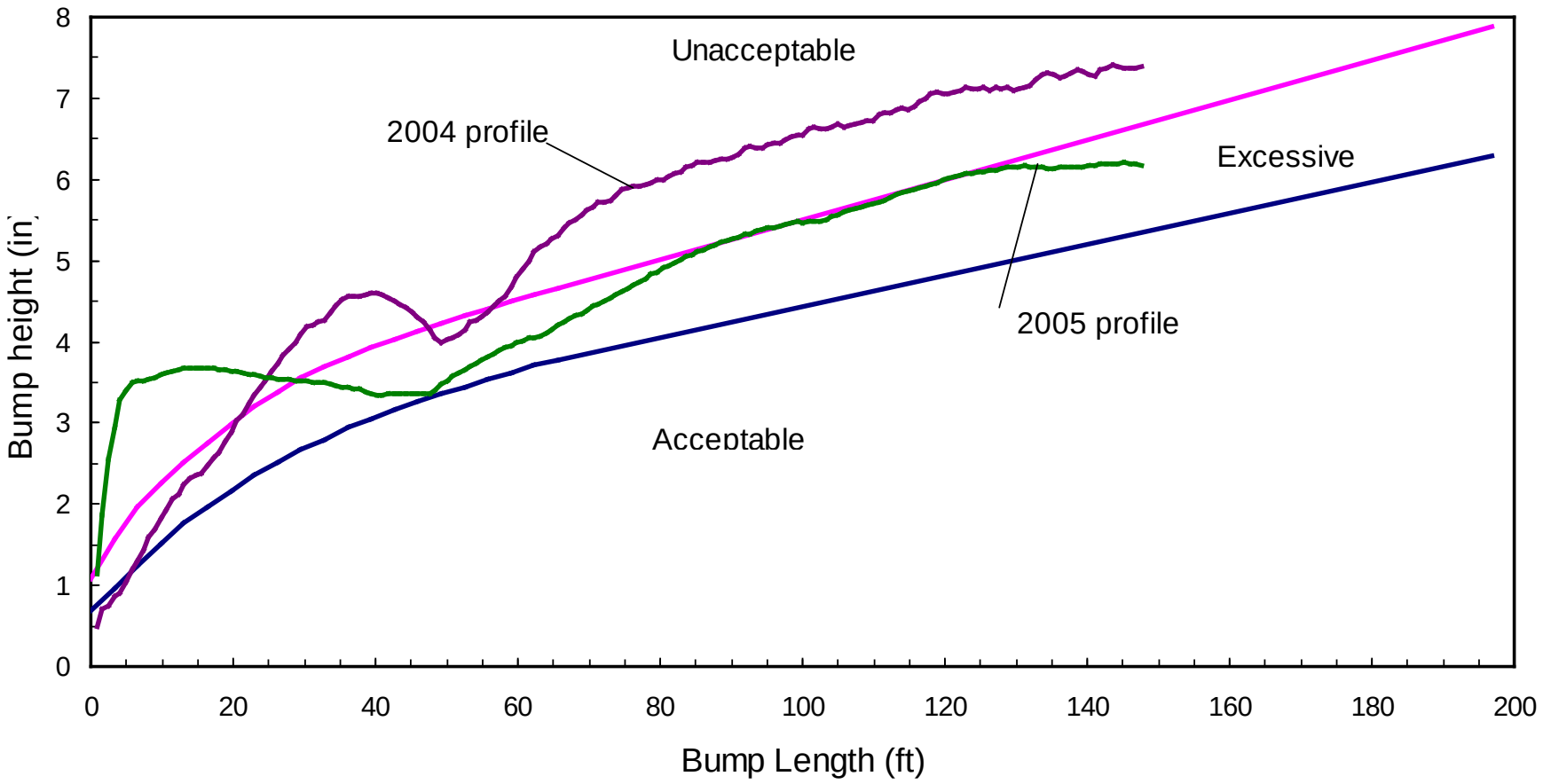


Conclusions

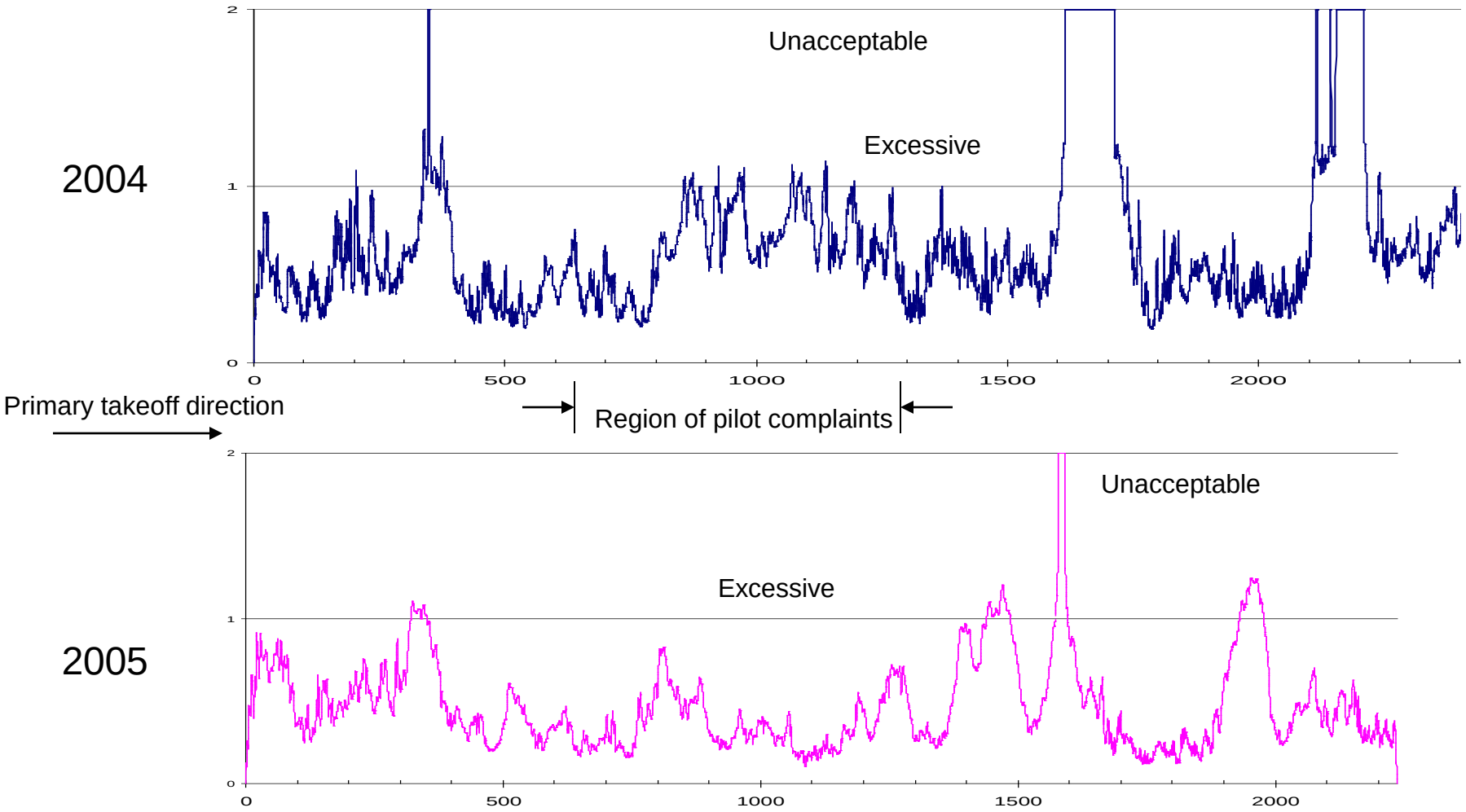
- Profiles from all three devices seem to match well- areas of roughness on runway correlate between all three.
- Boeing bump analysis consistent – bump index values, although differing in magnitude, are maximum at the same locations along the runway
- Locations of overall worst bumps in same areas for all three profiling devices
- All three profilers are useful in determining general areas of roughness needing repair

Boeing Runway Analysis-Case History 1 Unacceptable Condition

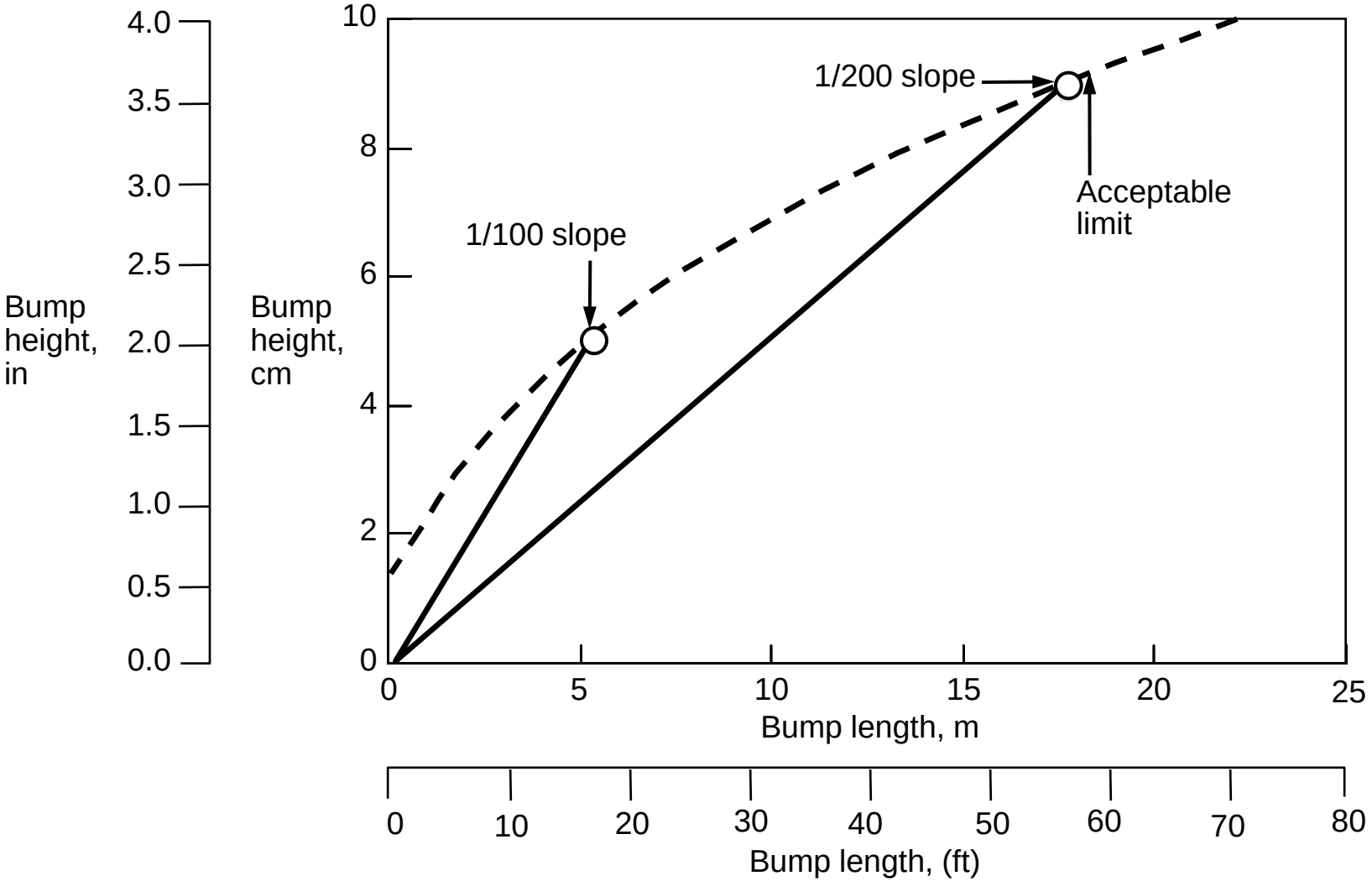
Boeing Runway Roughness Assessment- Unacceptable Condition-Plot of worst bumps



Boeing Runway Roughness Assessment- Unacceptable Condition 2004 vs. 2005 Survey

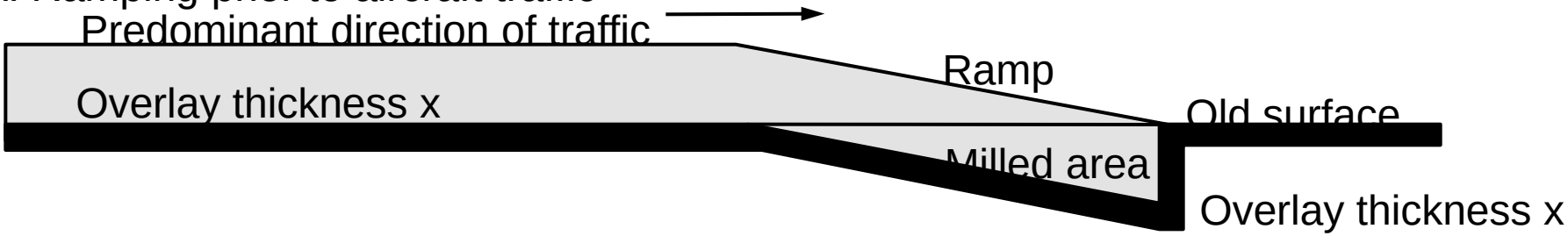


Boeing Roughness Criteria Applied to Temporary Construction Ramps

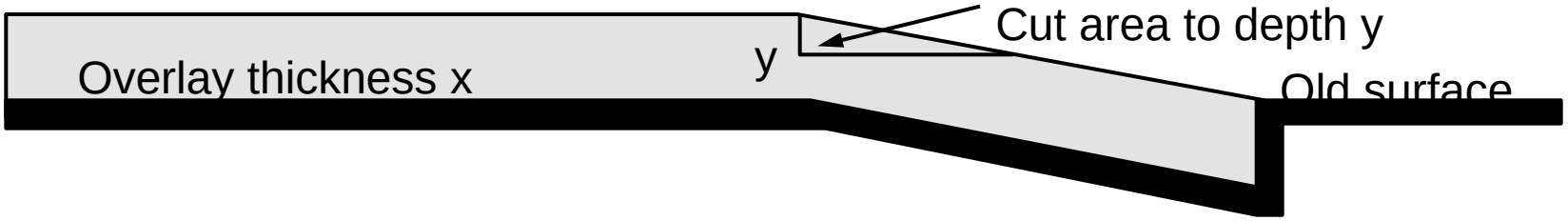


Runway Ramping Recommendations

A. Ramping prior to aircraft traffic



B. Surface preparation prior to resumption of paving



Notes
1. When overlay thickness x < = 5 cm, then ramp slope = 1.0%
2. When overlay thickness x > 5 cm, then ramp slope = 0.5%
3. Depth y should be at least 2 times the maximum aggregate size

Working Toward an Industry Standard

Pavement Roughness- Current Situation

- There is no industry standard which clearly defines when a airfield pavement has become “too rough”
- Problems can be aircraft specific
- New construction smoothness criteria is no longer applicable as pavement deteriorates
- Action by the airport is typically initiated by pilot complaints- FAA currently doing aircraft simulator research to assess pilot feedback on runways of varying roughness.

US Guidance on Roughness

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

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Guidelines and Procedures for Measuring Airfield Pavement Roughness | **Date:** 9/30/2009 **Initiated by:** AAS-100 | **AC No:** 150/5380-9 **Change:**

1. **PURPOSE.** This Advisory Circular (AC) provides guidelines and procedures for measuring and evaluating runway roughness as identified by surface profile data of rigid and flexible airport pavements. The guidance in this AC provides technical procedures to quantify surface irregularities and to determine how surface irregularities may affect specific categories of airplanes.

2. **APPLICATION.** The FAA recommends the guidelines and standards in this AC for evaluating the roughness of new and existing paved surfaces. In general, use of this AC is not mandatory. However, use of this AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, "Policies, Standards, and Specifications," and PFC Assurance No. 9, "Standards and Specifications."

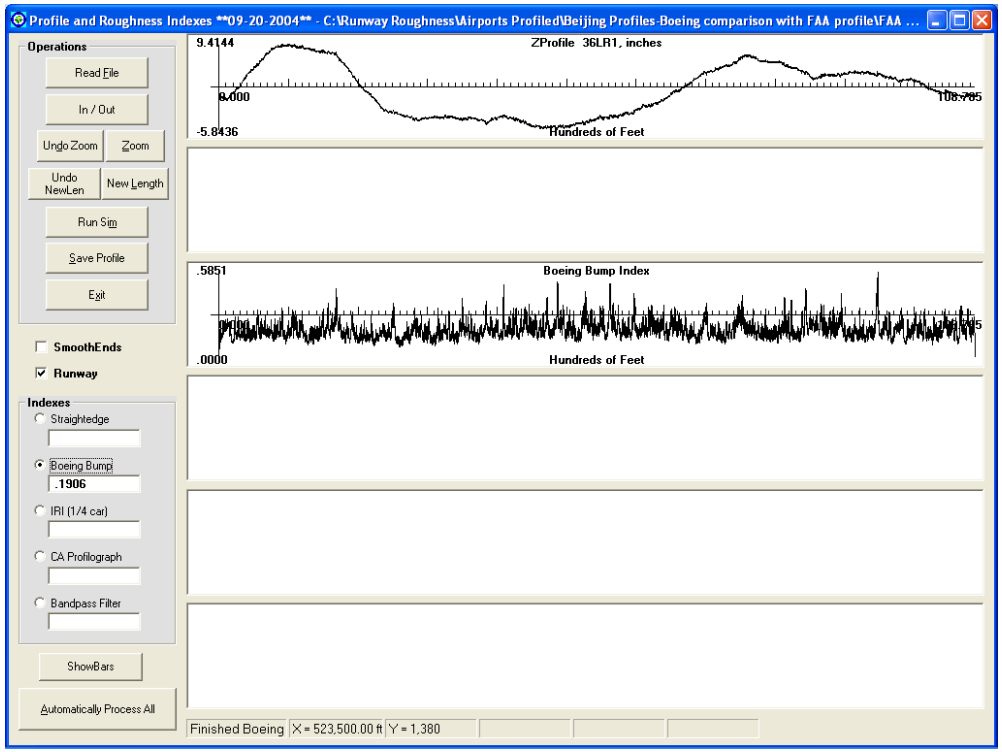
3. **RELATED READING MATERIAL.** Appendix 1, Bibliography, lists further guidance and technical information.

4. **METRIC UNITS.** To promote consistency with International Civil Aviation Organization (ICAO) guidance, the text and figures include both metric and English dimensions. Dimensions are provided first in metric units. Readers should keep in mind that English units are based on operational significance and

ASTM INTERNATIONAL

FAA Software PROFAA

Includes Boeing Bump



FAA Guidance on Roughness

NEW CONSTRUCTION

AC 150/5300-13, Airport Design

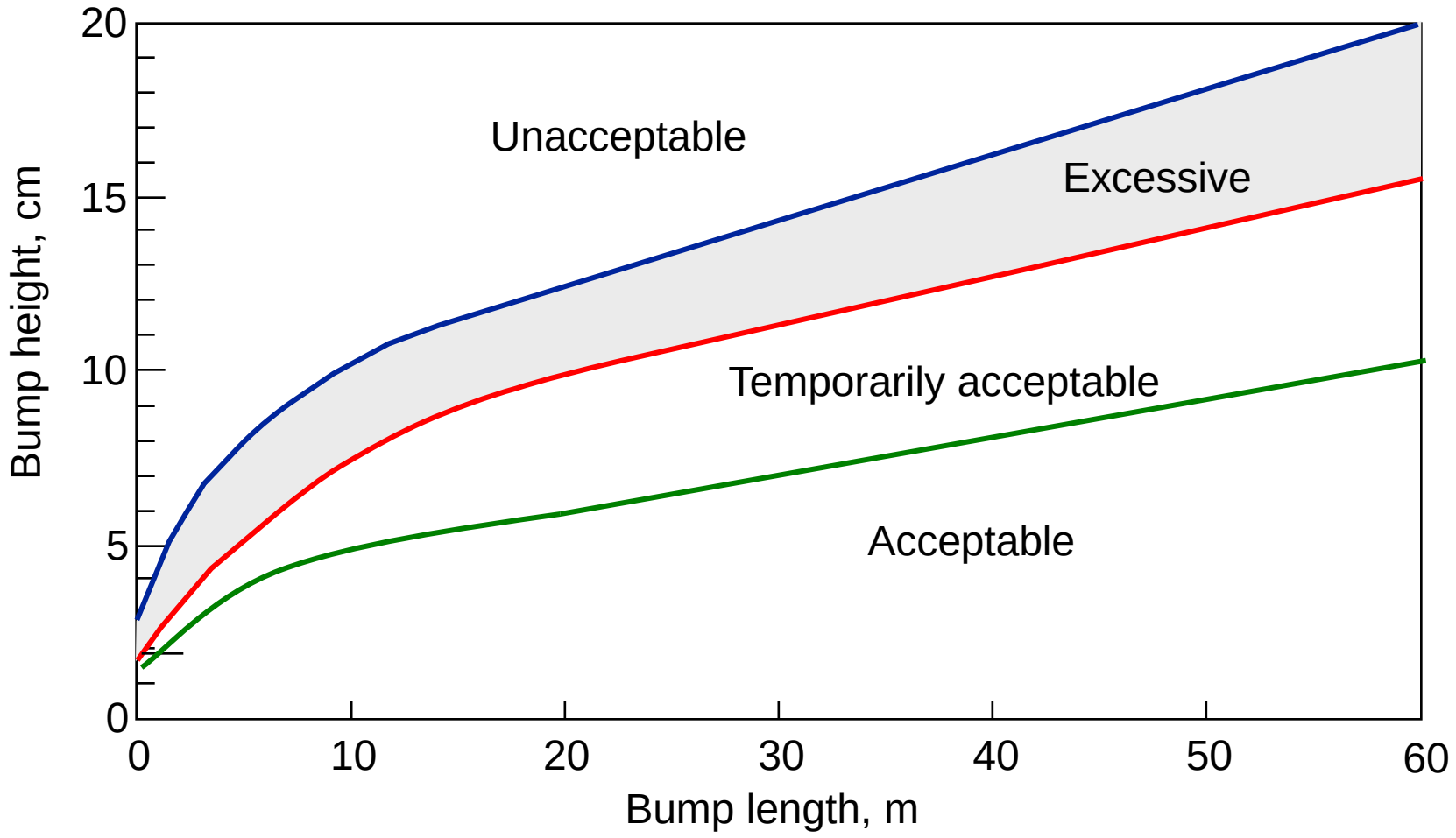
- Surface Gradient
- Maximum grade allowance
- Change in grade provisions

AC 150/5370-10F, Standards for Specifying Construction of Airports

- Construction tolerances must be met
- Acceptance criteria for smoothness- straightedge or profilograph

Experience has shown that the current FAA grade and straightedge criteria provide pavements that are safe for aircraft operations.

ICAO Roughness Curve Approved for Annex 14, Amendment 10, 4th Edition



ICAO Guidance- Annex 14, Attachment A Surface Unevenness

Surface Irregularity	Minimum acceptable length of irregularity (m)								
	3	6	9	12	15	20	30	45	60
Maximum surface irregularity height (cm)	2.9	3.8	4.5	5	5.4	5.9	6.5	8.5	10
Temporary acceptable surface irregularity height (cm)	3.9	5.5	6.8	7.8	8.6	9.6	11	13.6	16
Unacceptable surface irregularity height (cm)	5.8	7.6	9.1	10	10.8	11.9	13.9	17	20

If the maximum limits are exceeded, corrective action should be undertaken as soon as reasonably practicable to improve the ride quality. If the temporarily acceptable limits are exceeded, the portions of the runway that exhibit such roughness should have corrective measures taken immediately if aircraft operations are to be continued. If the unacceptable limits are exceeded and the roughness resides in the area of aircraft operations, then the runway should be closed until repairs are made to restore the condition to the acceptable region.

The maximum permissible step type bump, such as that which could exist between adjacent slabs, is simply the bump height corresponding to zero bump length at the upper end of the acceptable region of the roughness curve. The bump height at this location is 1.75 cm.

Conclusions

- Runways may become intolerably rough due to
  - The onset of pavement structural failure (age)
  - Adverse environmental conditions
  - Improper repairs or non-standard temporary construction ramps
- Airport operators are not usually aware of the impact of roughness on aircraft- pilot complaints typically initiate action
- The Boeing criteria will enable airports to:
  - Determine the extent of roughness
  - Locate the source of roughness
  - Make rational decisions for the best course of action
- Standardizing the roughness criteria for both US and international airports through FAA advisory circulars and ICAO documentation provides proper guidance for developing an airport's pavement management system

BOEING

Thank you!

"Why be worried about tomorrow if it will be finished the day after tomorrow"