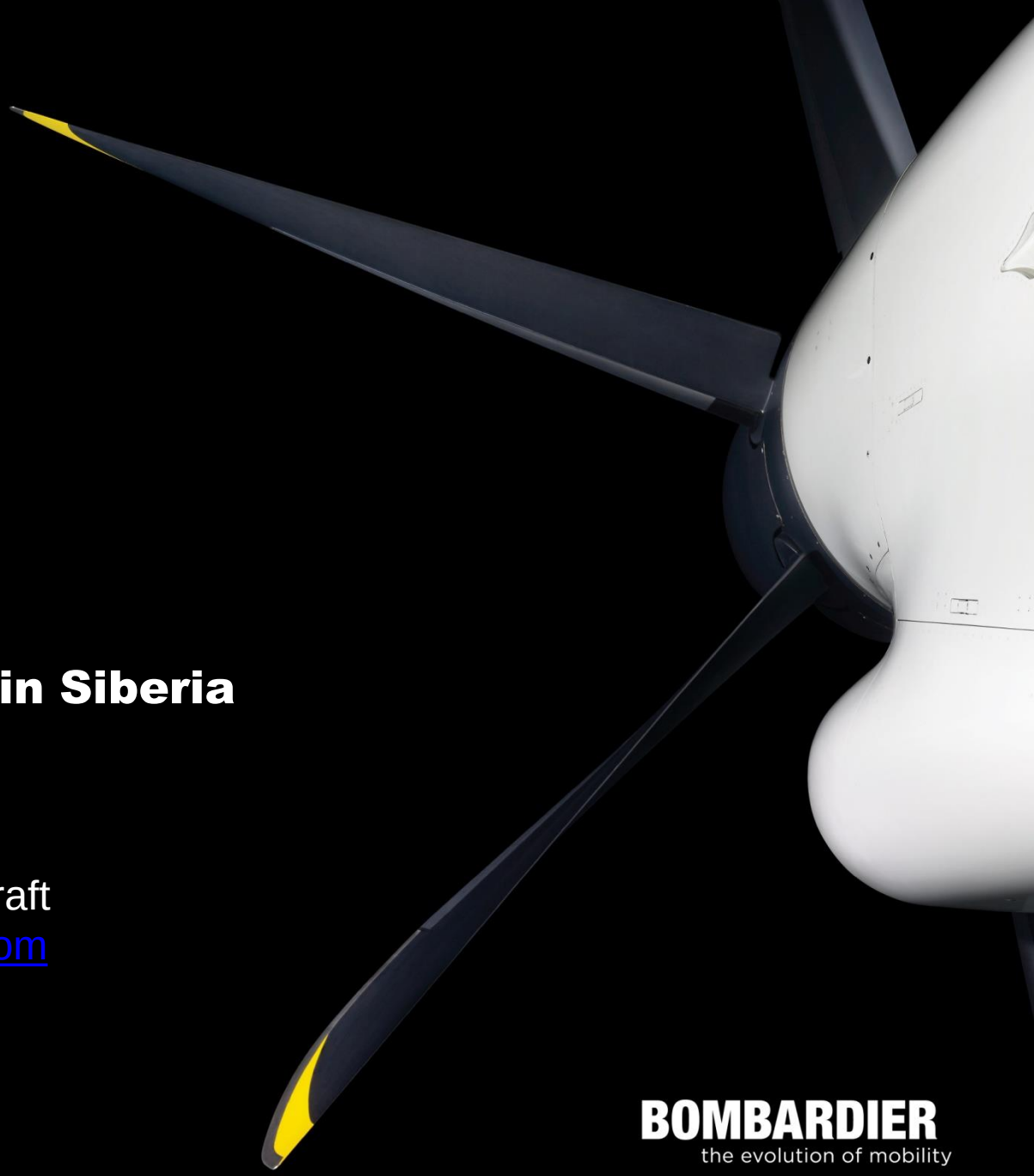
Ingenuity
in Flight.



Q Series Operations in Siberia

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Customer Support
Bombardier Commercial Aircraft
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SWIFT Conference
Montreal 17th Sept. 2015

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Q Series – Unpaved Runway Operations

Yakutia Airlines

- Yakutia Airlines – first Q400 operator in Russia
- Also now Q3000 operator
- Q300 and Q400 replacing AN-24 and and AN-140
- Yakutia Airlines route structure – many unpaved runways over a vast inaccessible region
- Yakutia already Boeing operator but no experience of western aircraft on unpaved airfields

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An-24 Take-Off

Airports in Sakha Republic (Yakutia)

- Climatic conditions – very similar to Northern Canada
- Legacy from USSR – all unpaved runways were built during Soviet times
- Infrastructure for maintenance and upkeep of airport – old and need of urgent replacement
- Runways were built to Soviet standards – same as for gravel roads
- Q Series is main Part 25 aircraft that is operating in these conditions

Airports in Sakha Republic (Yakutia)

- Infrastructure in immediate need of upgrade
- Russian Government is working to provide funds for airport upgrade in remote regions

Runway Conditions

- Very variable runway conditions
  - Sand
  - Loam
  - Loam/sand mix
  - Loam/gravel mix
  - Gravel
  - Ungraded river gravel
- Variable strength
  - very soft (CBR < 20)
  - Very hard (CBR 50+)
- Variable smoothness
- Variable drainage

Runway Conditions

Suntar	Batagay	Chersky

Certification Status of Q Series

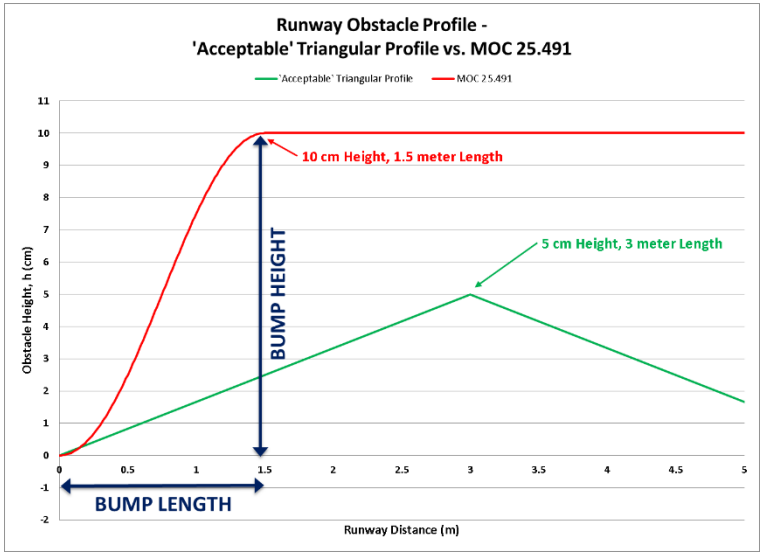
- DHC-8 Series 400 approved for operations from unpaved runways in 2002 by Transport Canada (TCCA)
- DHC-8 Series 100/200/300 approved for operations from unpaved runways in 1995 by Transport Canada (TCCA)
- Transport Canada Civil Aviation's Advisory Circular (AC) 525-006 is used to show compliance with the design standards
- Approved Flight Manual (AFM) Supplement 26 contains limitations, procedures and performance information

Certification Status of Q Series -Russia

- Operations from unpaved runways in Russia were not approved by Interstate Aviation Committee (IAC) for aircraft on Russian Aviation Registry (AR)

There is a difference between AP 25 and FAR 25/ AWM 525 requirements for the load conditions for unpaved runways, such as surface strength - CBR (American parameter) and soil strength (Russian parameter σ – kg/cm^2), and roughness characteristics (Russian parameter)

- Q Series was unable to comply with IAC AR guidance Means Of Compliance (MOC) 25.491 on certification by analysis – too severe for existing design



FAA Certification Basis

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: TAXI, TAKEOFF AND LANDING ROLL DESIGN LOADS	**Date:** 10/30/00 **Initiated By:** ANM-110	**AC No:** 25.491-1 **Change:**

(i) Bump wavelengths equal to the mean longitudinal distance between nose and main landing gears, or between the main and tail landing gears, as appropriate; and separately.

(ii) Bump wavelengths equal to twice this distance.

The bump height in each case should be defined as:

$$H = 1.2 + 0.023\sqrt{L}$$

Where--
H = the bump height (inches)
L = the bump wavelength (inches)

SAN FRANCISCO RUNWAY 28R

ONE TRACK
LENGTH: 3880 FEET
NUMBER OF POINTS: 1941
POINT SPACING: 2 FEET
ELEVATIONS: FEET
REFERENCE SOURCE: REPORT TO NASA (EFFECTS OF RUNWAY UNEVENNESS ON THE DYNAMIC RESPONSE OF SUPERSONIC TRANSPORTS), JULY 1964, U. OF CALIF. BERKLEY.
RUNWAY ELEVATION POINTS IN FEET:

Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.	Dist.	Elev.
0	10.3	776	10.99	1552	10.92	2328	11.16	3104	11.93
2	10.31	778	10.98	1554	10.92	2330	11.15	3106	11.92
4	10.3	780	10.99	1556	10.91	2332	11.14	3108	11.92

Russian Airfield Standards

- РЭГА РФ **94** Руководство по эксплуатации гражданских
- аэродромов Российской Федерации
- Russian REGA 94 Operating Instructions for Civil Russian airfields

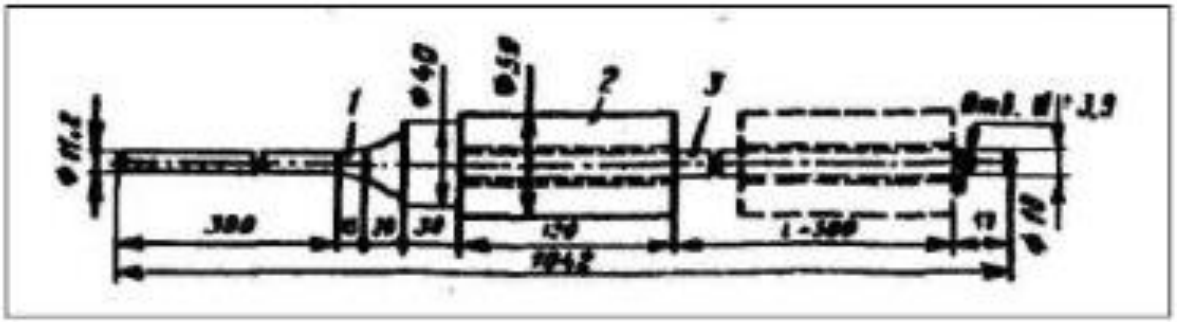
Руководство по эксплуатации гражданских аэродромов Российской федерации (РЭГА РФ-94)

Москва "Воздушный транспорт" 1996

Russian Airfield Standards

Приложение 12
ОПРЕДЕЛЕНИЕ ПОКАЗАТЕЛЯ ПРОЧНОСТИ И ПЛОТНОСТИ ГРУНТОВ
ЛЕТНОГО ПОЛЯ
Appendix 12
Airfield Soil Strength and Density Parameters

Udanrik – U1



Russian Airfield Standards

Таблица 1

Песчаные и мелкие		Песчаные, супесчаные		Пылеватые, супесчаные, подзолистые грунты		Пылевые, суглинистые тяжелые, суглинистые, суглинистые пылеватые и глинистые грунты						Черноземы, каштановые и бурые засоленые грунты					
n 10	*σ* 10	*n* 30	*σ* 30	*n* 30	*σ* 30	*n* 10	*σ* 10	*n* 30	*σ* 30	*n* 30	*σ* 30	*n* 10	*σ* 10	*n* 30	*σ* 30	*n* 30	*σ* 30
1,0	3,9	7,0	3,0	29	11,9	1,0	2,2	7	2,0	29	11,9	1,0	1,9	7	1,4	29	9,5
1,6	4,8	8	4,5	30	12,0	1,5	3,4	8	2,2	30	12,,0	1,5	2,8	8	1,5	30	9,7
2,0	6,0	9	5,3	31	12,,1	2,0	4,7	9	3,0	31	12,,1	2,0	4,0	9	1,5	31	9,8
2,5	7,3	10	6,2	32	12,2	2,5	5,8	10	3,6	32	12,2	2,5	5,0	10	1,8	32	10,0
3,0	8,2	11	6,8	33	12,3	3,0	7,0	11	4,3	33	12,3	3,0	5,7	11	1,9	33	10,3
3,5	9,0	12	7,3	34	12,4	3,5	8,0	12	5,0	34	12,4	3,5	6,3	12	2,2	34	10,6

Russian Airfield Standards

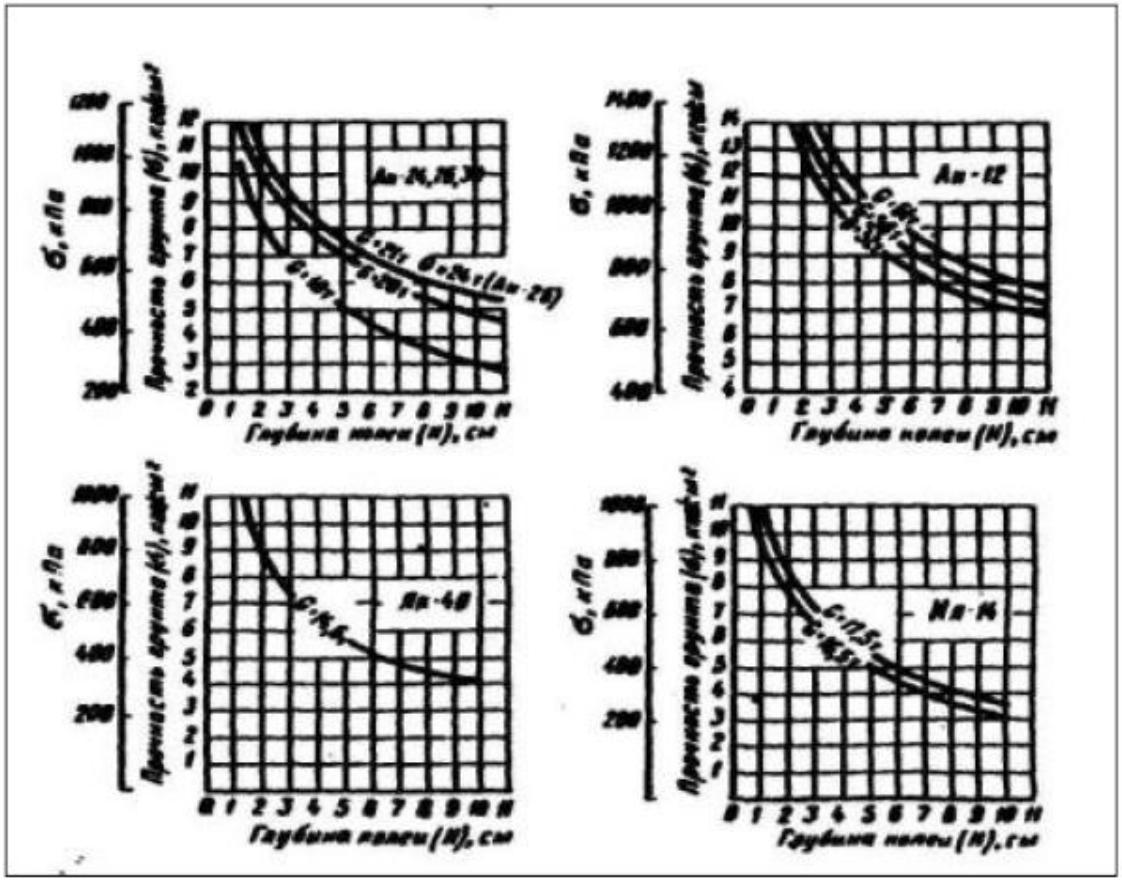


Рис. 6.б. Графики зависимости прочности грунта от глубины колеи для самолетов Ан-24, Ан-26, Ан-30, Ан-12, Як 40, Ил-14

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Strategy for Enabling Q Series to Operate in Russia

- Agreement between Rosaviatsya (Russian Federal Aviation Authority), IAC, Yakutia Airlines and Bombardier
- Determine correlation between σ and CBR methodologies and include both values in AR Version of AFM
- Determine allowable smoothness characteristics for safe and continuing Q Series operation in Russia
- Runway-by-runway approval to be given by Bombardier based on measured strength and smoothness
- Runway smoothness to be assessed on the basis of technical flight to each runway and FDR acceleration analysis
- Continuing loads survey from FDR download from all scheduled flights to and from approved runways (up to 1 year)
- On-going assessment of unpaved runways loads on aircraft systems and structure to determine increased inspection intervals if necessary

Runway Surveys in Sakha Republic (Yakutia)

- Strength and smoothness surveys were carried out in 5 priority runways in Yakutia Airlines route structure
- ProgressTech from Moscow were contracted to undertake survey and produce report on runway strengths (using Boeing Penetrometer, Udarnik & ATMS drop hammers) and smoothness

Why ProgressTech?

Moscow based

Experienced in region

Familiar with western aircraft

Fast reaction time

Five regional airports of Republic of Sakha (Yakutia), Russian Federation were surveyed:

✓Olekminsk
✓Chersky
✓Suntar
✓Batagai
✓Lensk

ПРОГРЕССТЕХ
PROGRESSTECH

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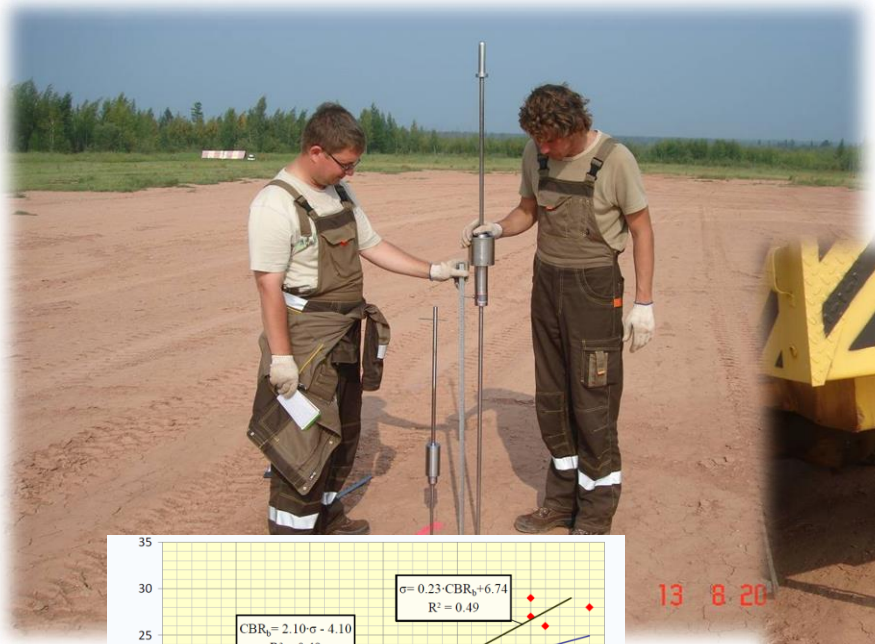
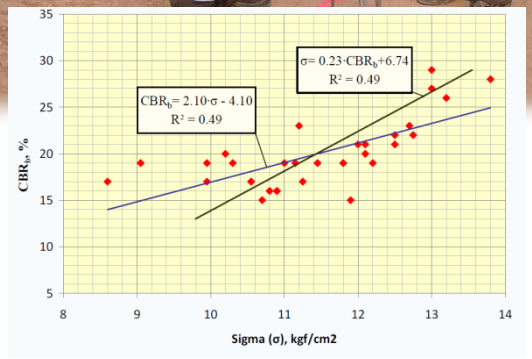
Runway Surveys in Sakha Repubic (Yakutia)





CBR-σ correlation

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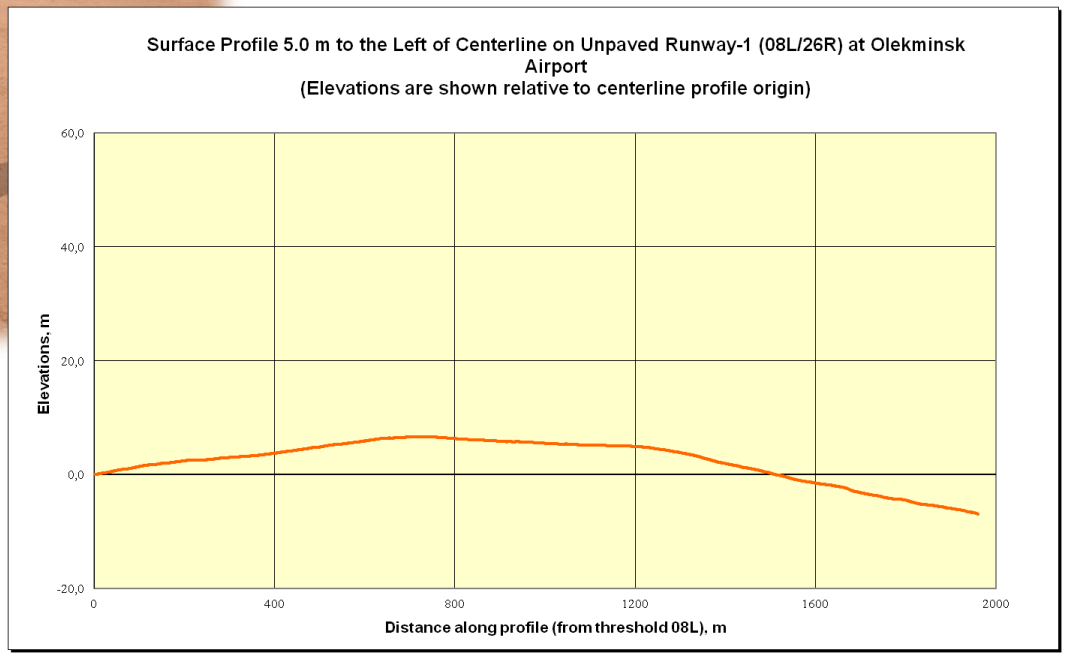
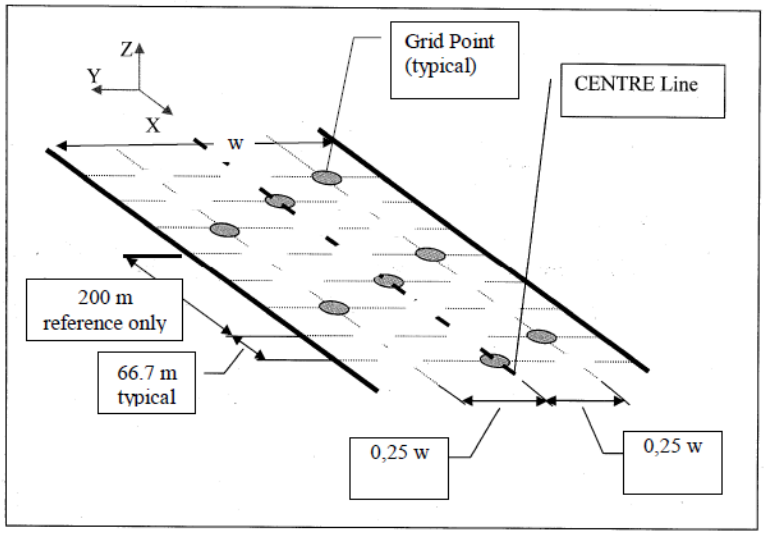
Runway Surveys in Sakha Repubic (Yakutia)

Runway profile measurement

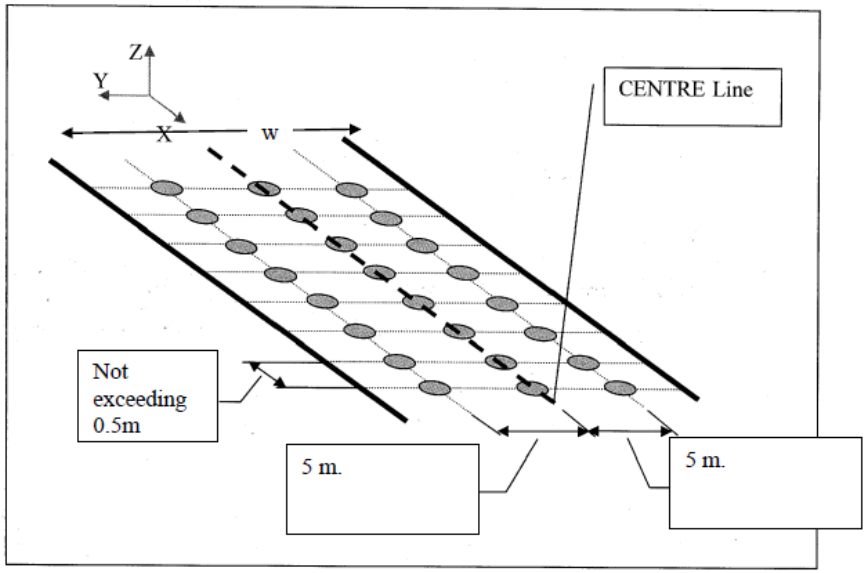


Progress Tech Surveys of Sakha Airfields

Runway strength Measurement



Runway Profile Measurement

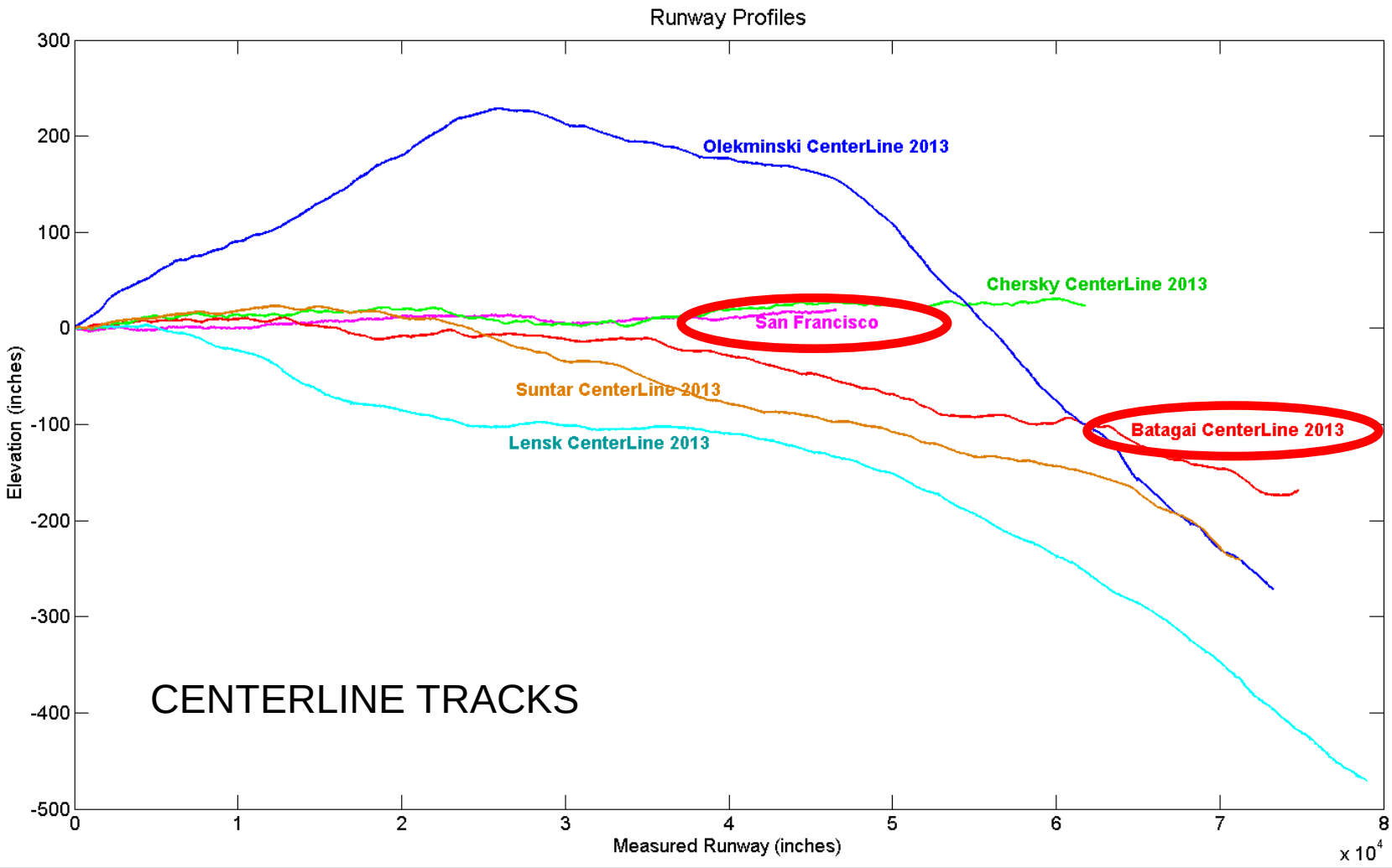


Runway Strengths

	Chersky	Lensk	Batagai	Olikminsk	Suntar
Boeing CBR					
Average	**44+**	**43**	**44+**	**42**	**20.7**
Minimum	**34**	**32**	**29**	**16**	**15.0**
Udarnik σ					
Average	**15+**	**15**	**15+**	**14.7**	**11.6**
Minimum	**15**	**13**	**15**	**10.8**	**8.6**

- Good correlation between Boeing CBR and Udarnik σ
- Strength of four of five runways was acceptable (met requirements of Q Series AFM Supplement of CBR =30)
- One problematic runway (Suntar)

Measured Runway Profiles



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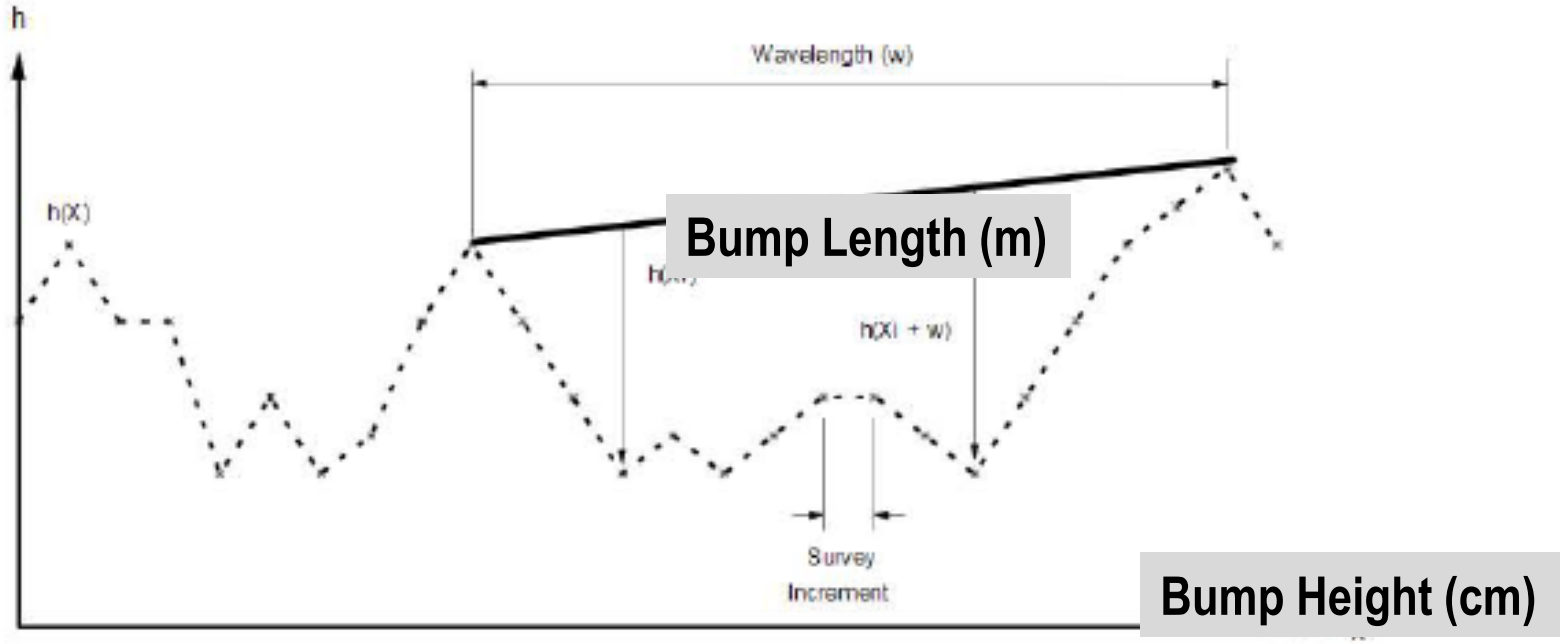
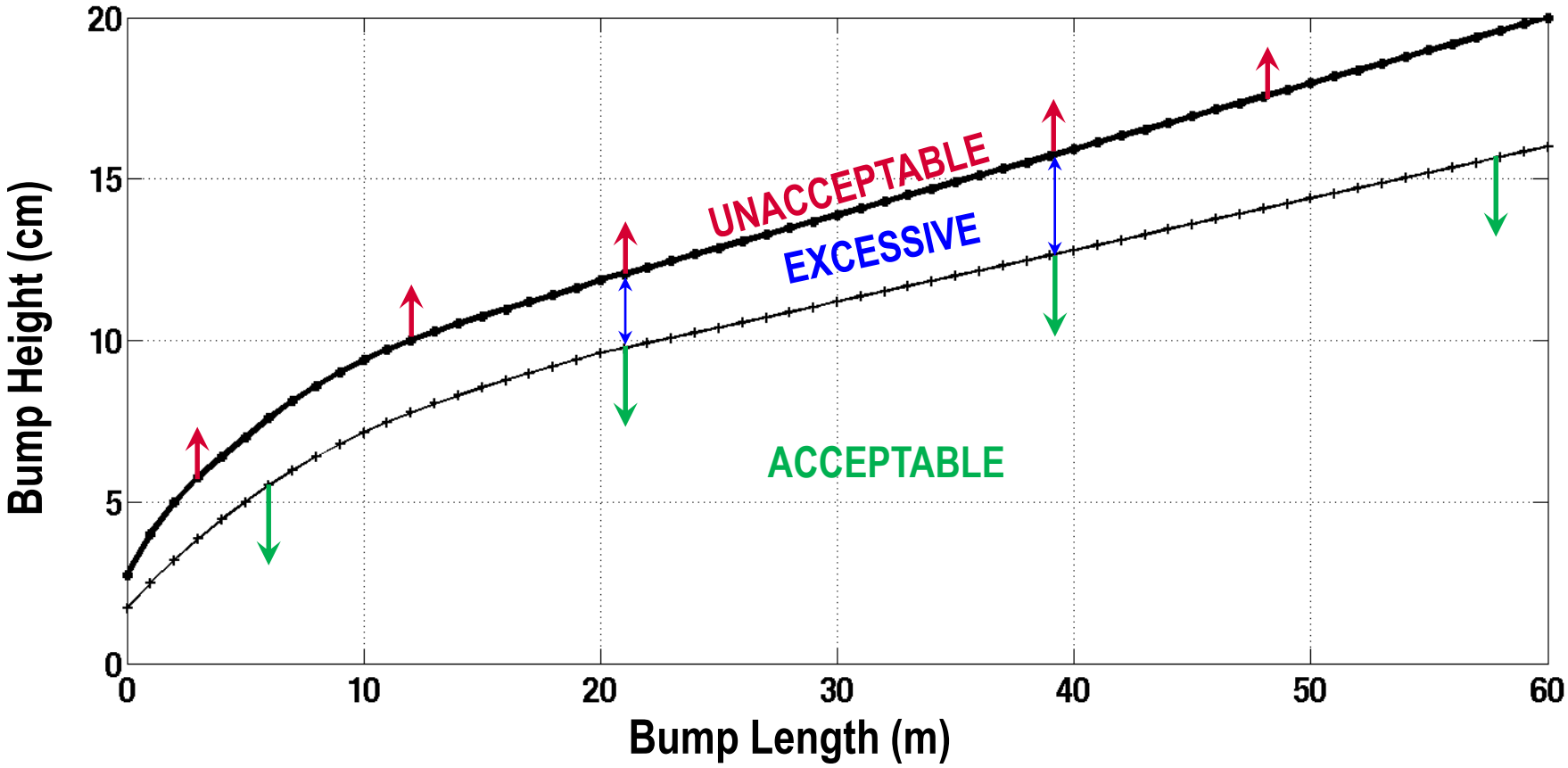
Boeing – Runway Bump Definition

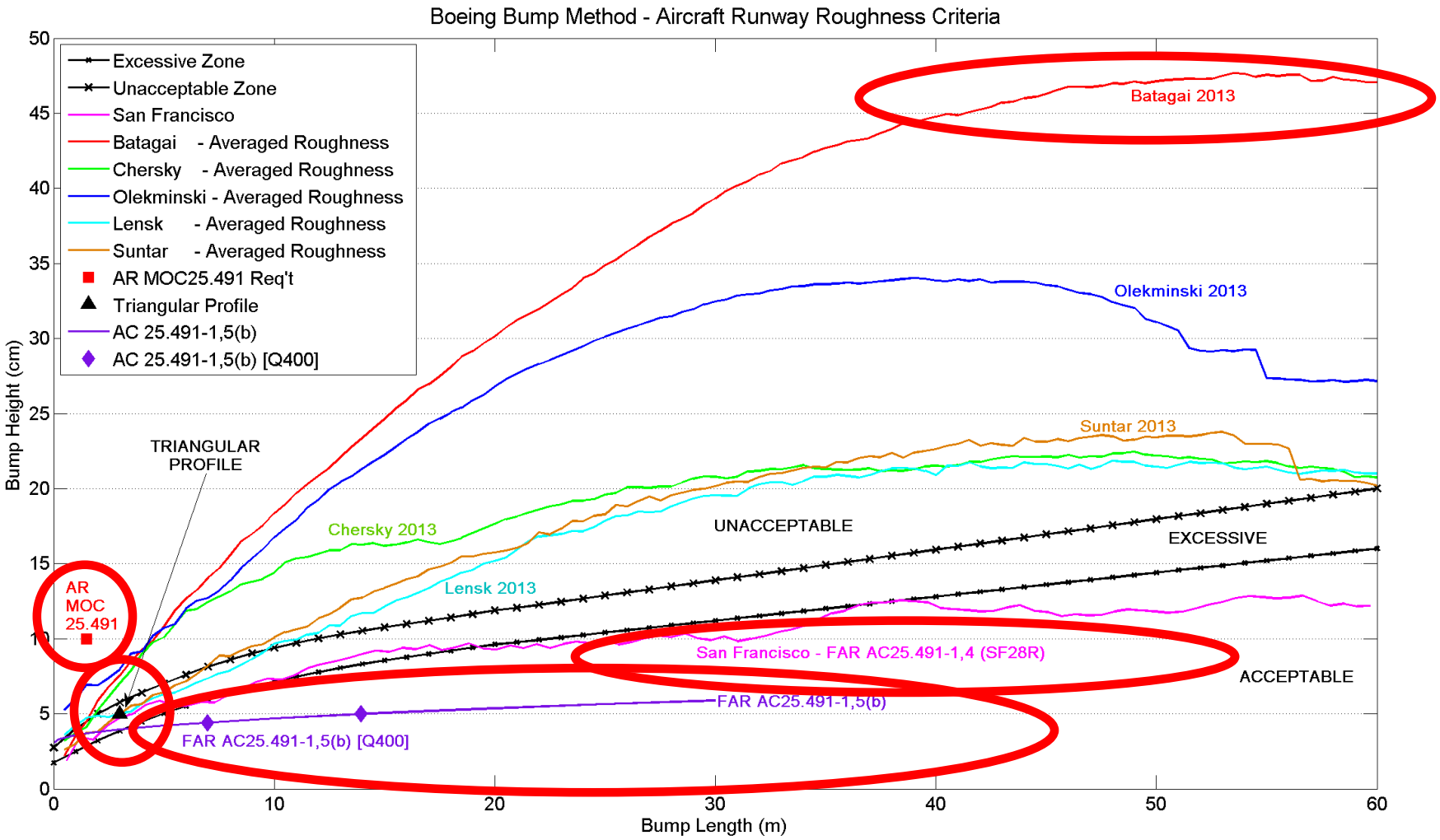


- The Max bump height – max +ve or –ve deviation from a straightedge whose end points lie on the profile
- Deviation is calculated as perpendicular distance from straightedge to profile surface

Boeing – Runway Bump Categorization



Runway Roughness Comparisons



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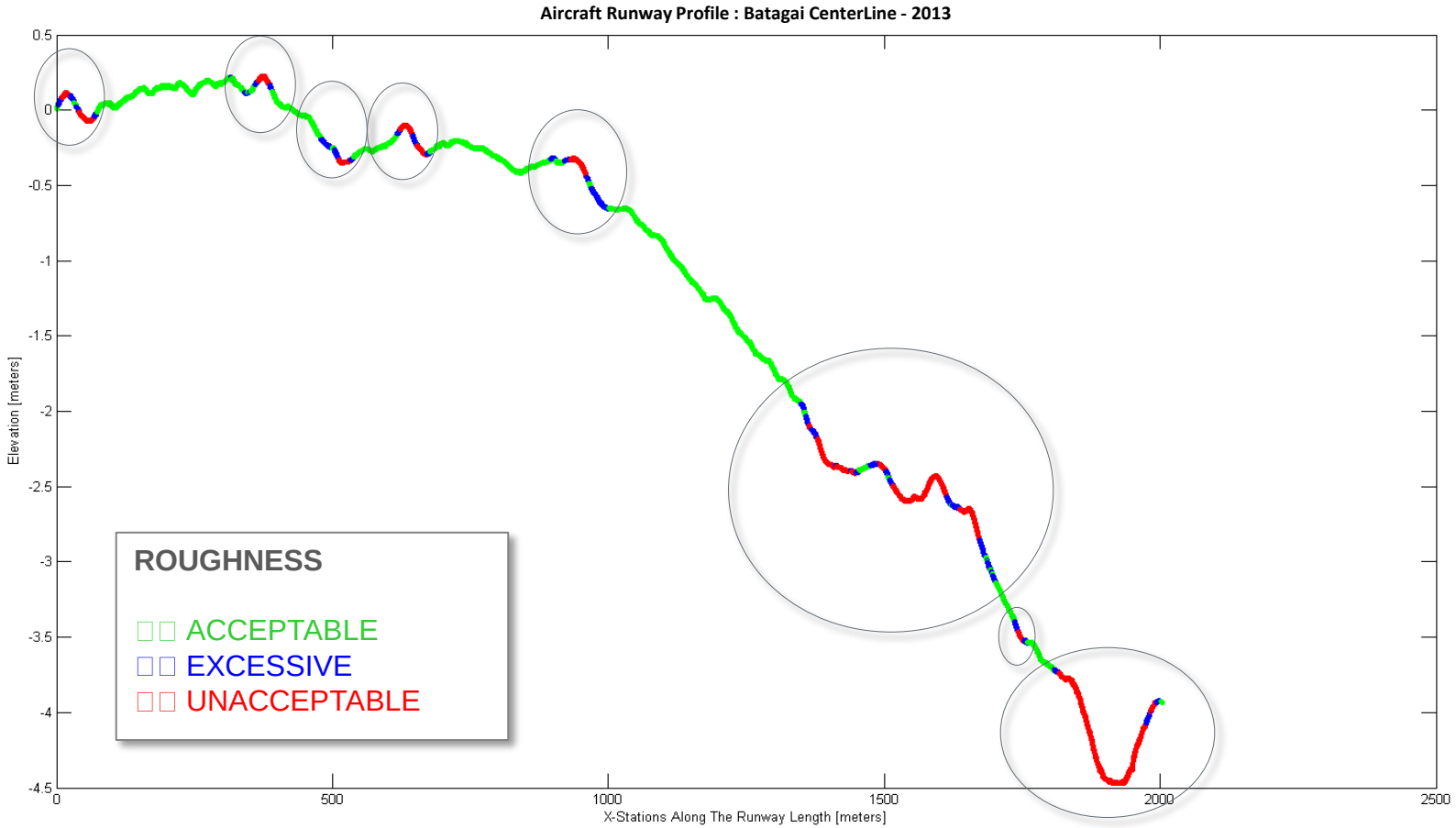
Batagay, Sakha Republic – Runway Condition

Batagay Runway

- **Areas of roughness are easy to see**



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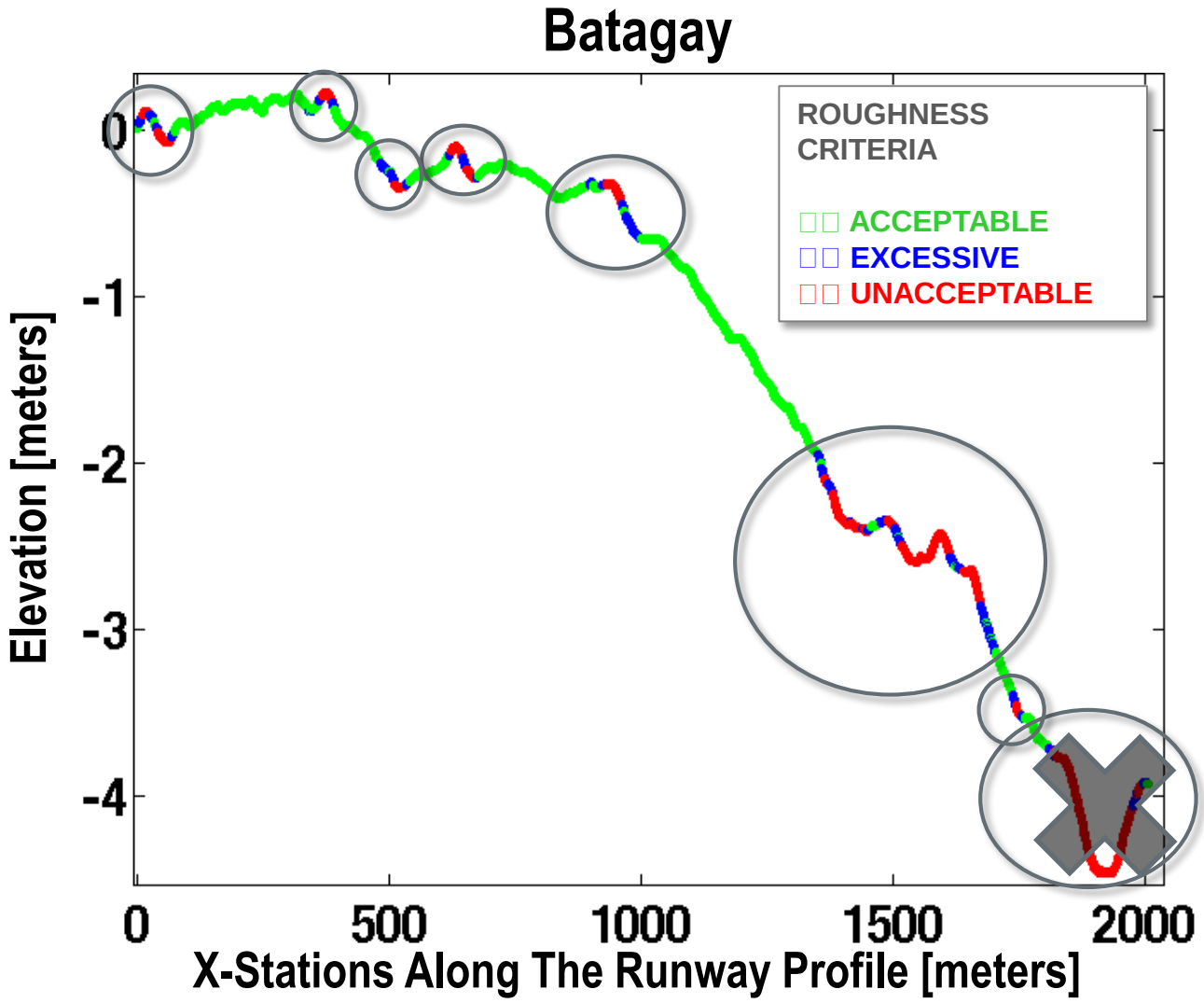
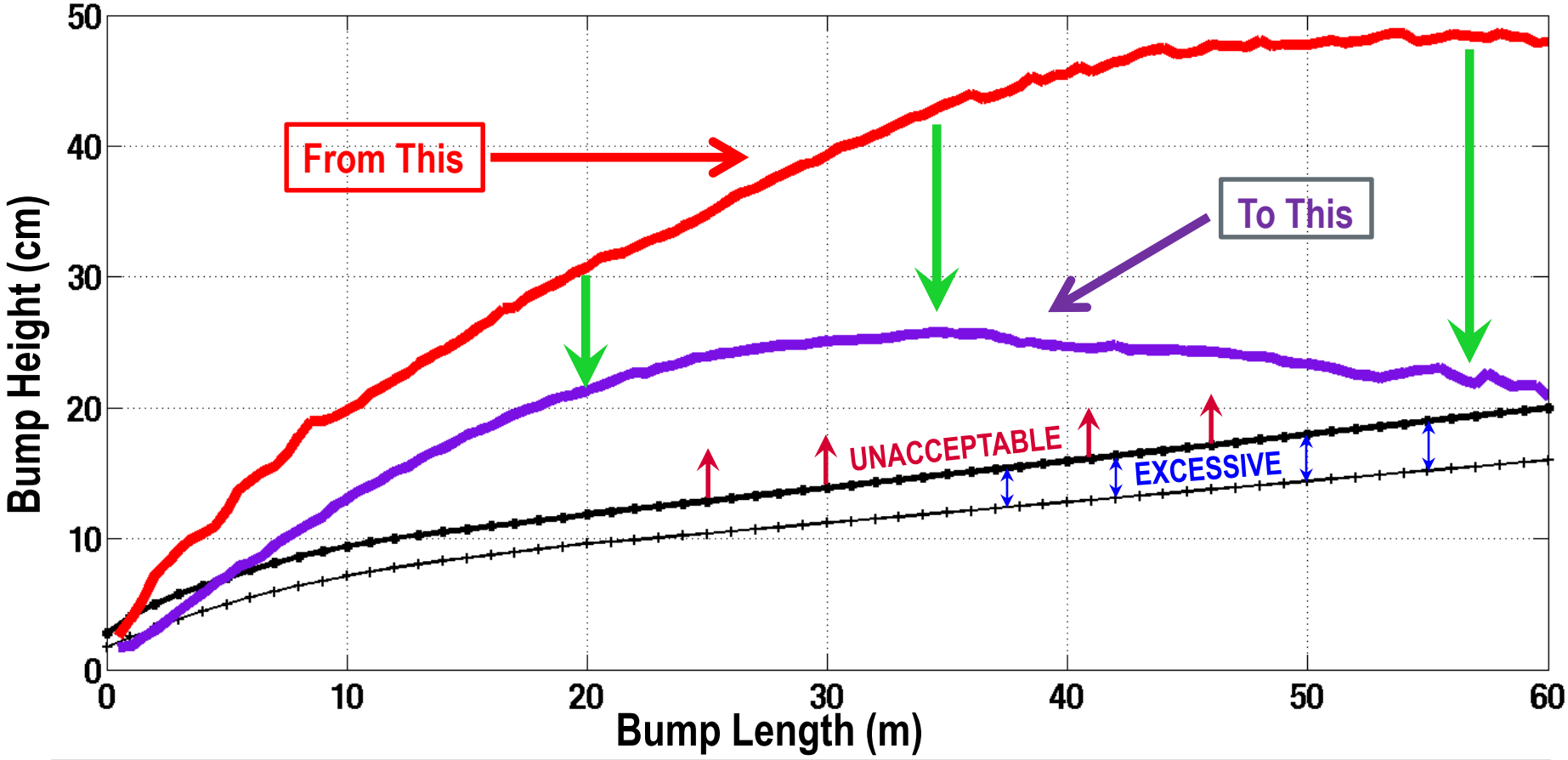
Batagay – Runway Condition



Batagay – Runway Roughness Envelope Improvement

- Batagay with last 250m removed from runway
- Improved dramatically!



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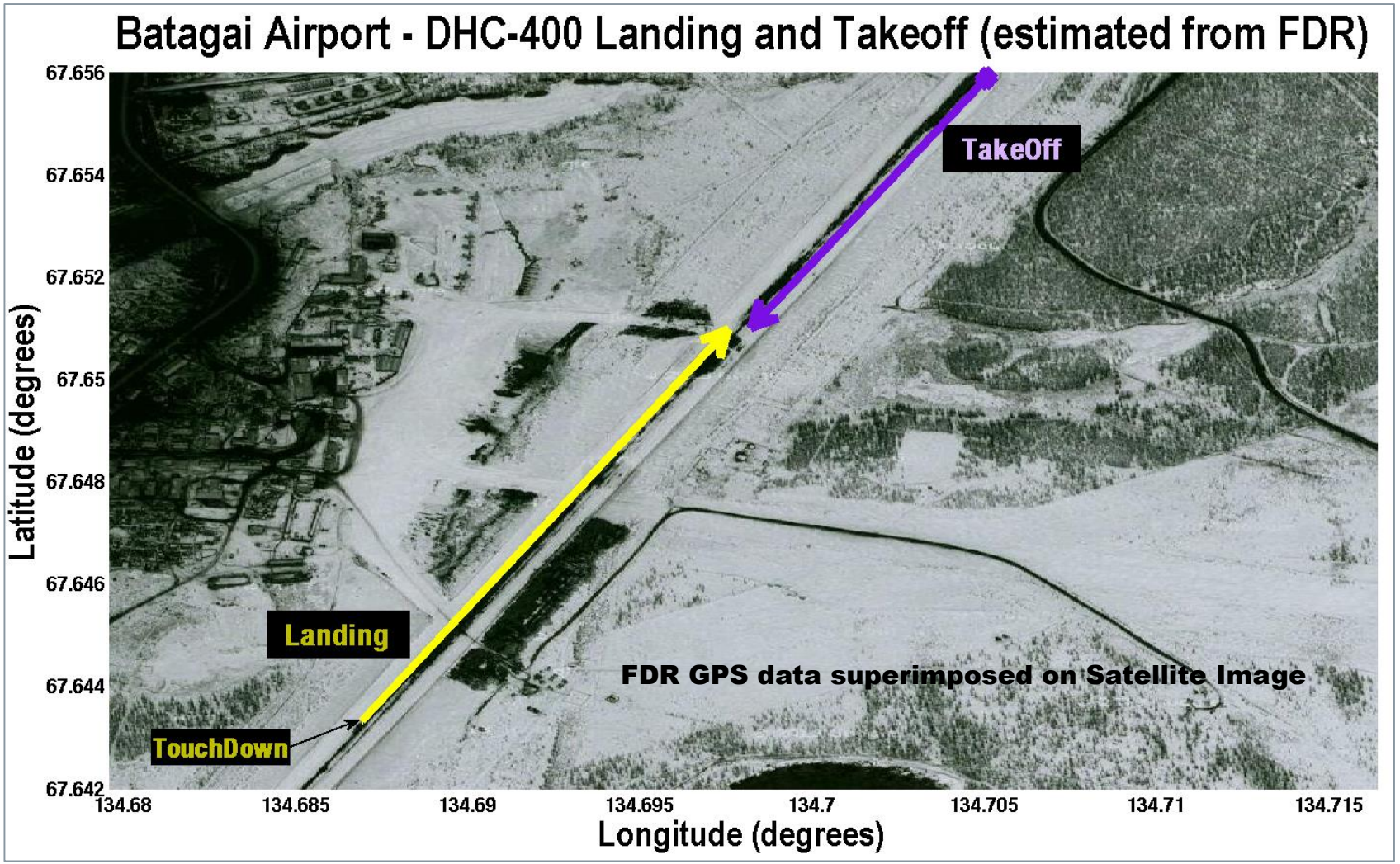
Batagay – Flight Test



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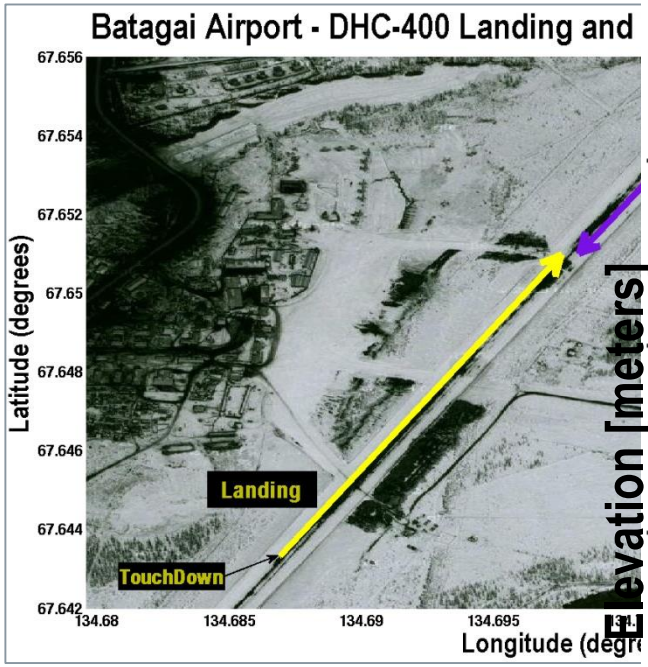
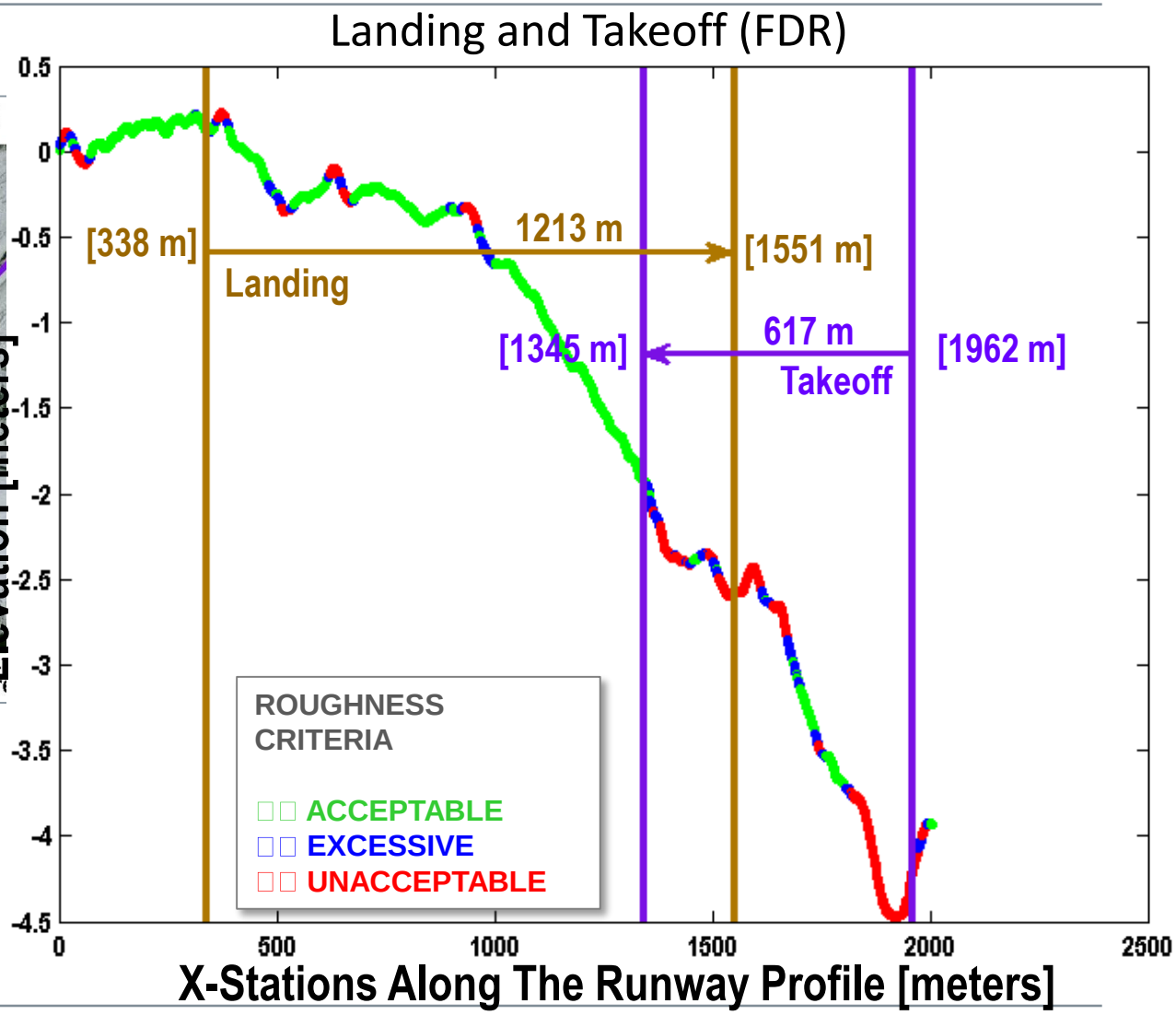
Batagay – Flight Test





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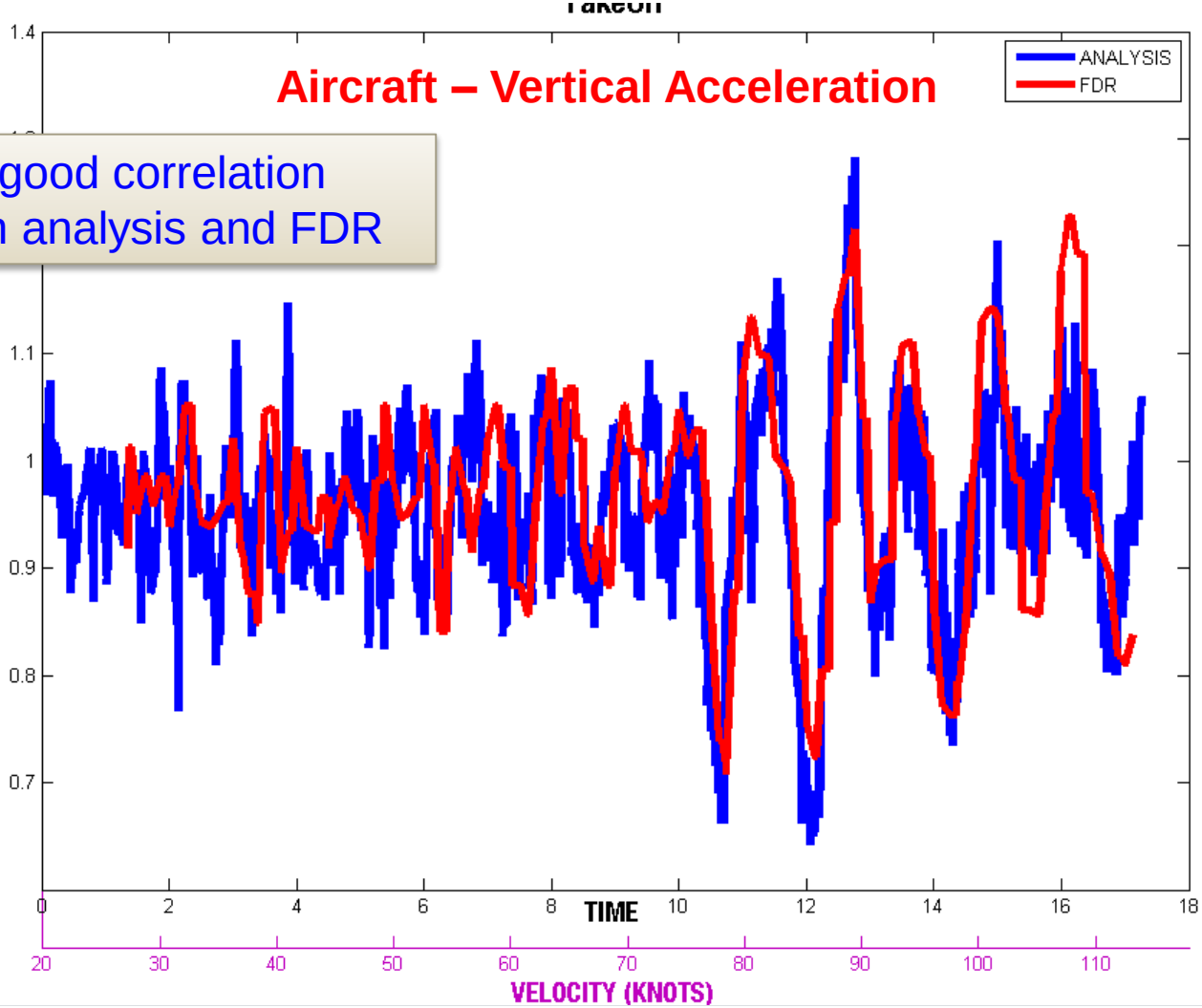
Batagay – Flight Test Data v Aircraft Loads Analysis

Very good correlation between analysis and FDR



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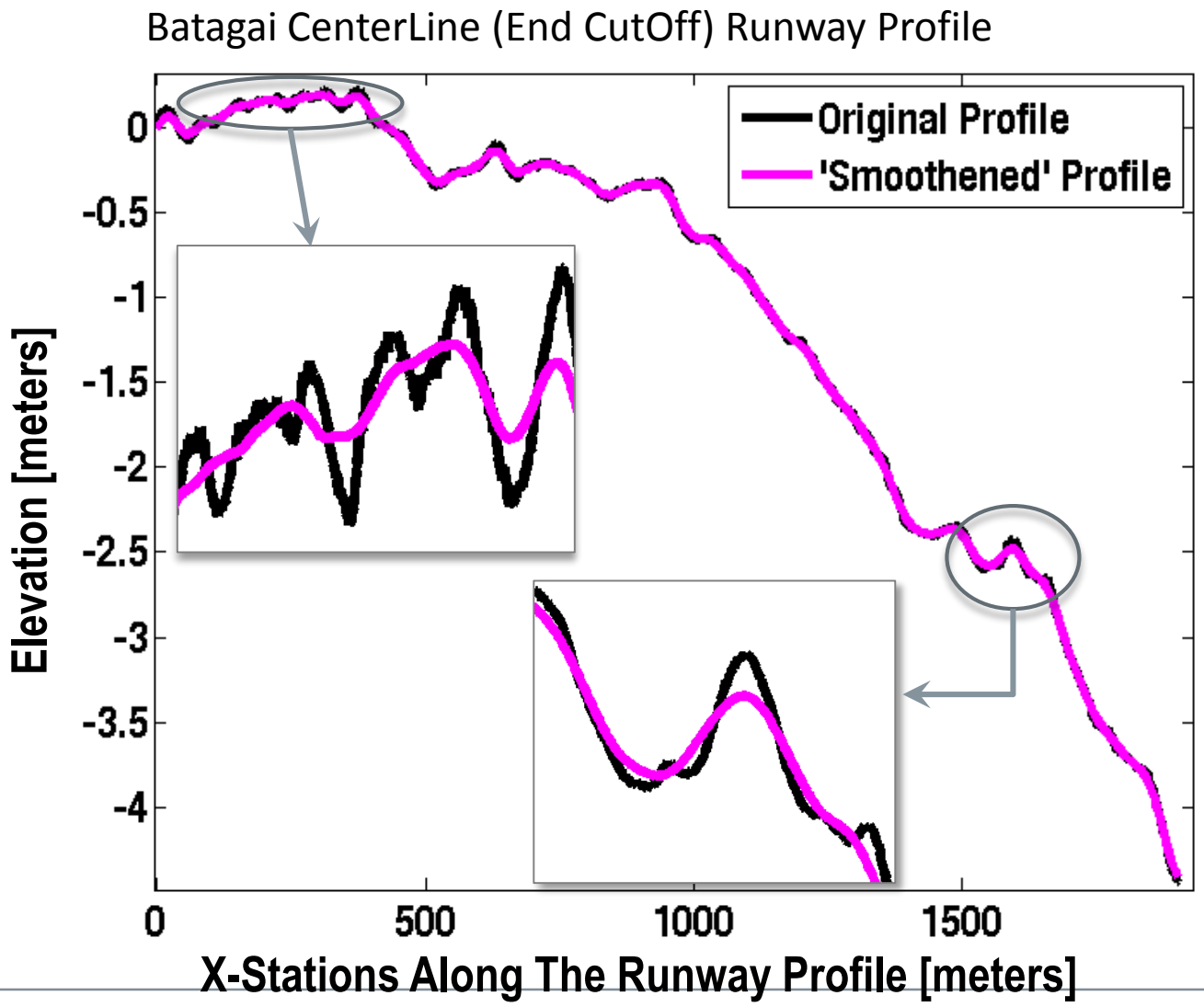
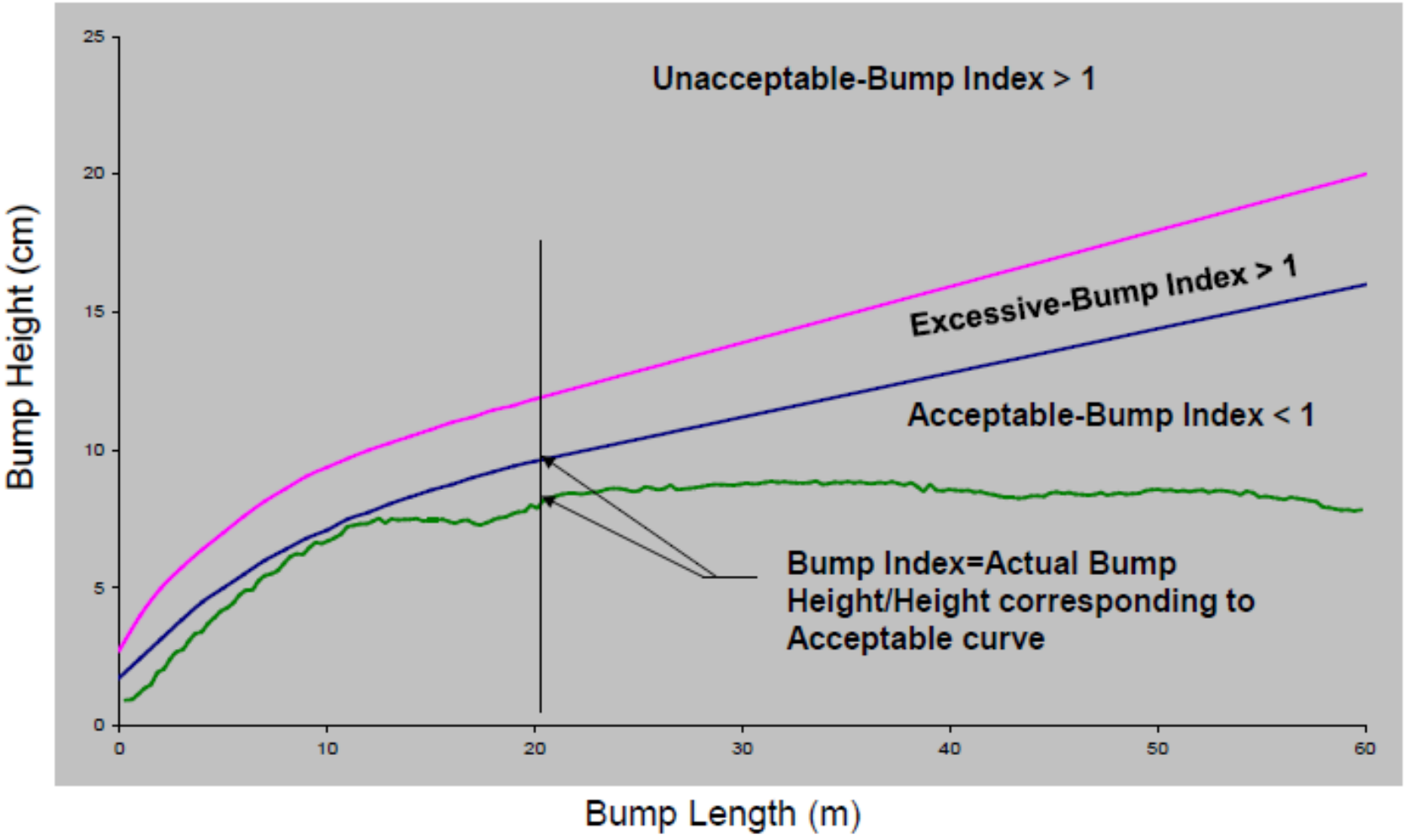
Batagay – Potential Improvements



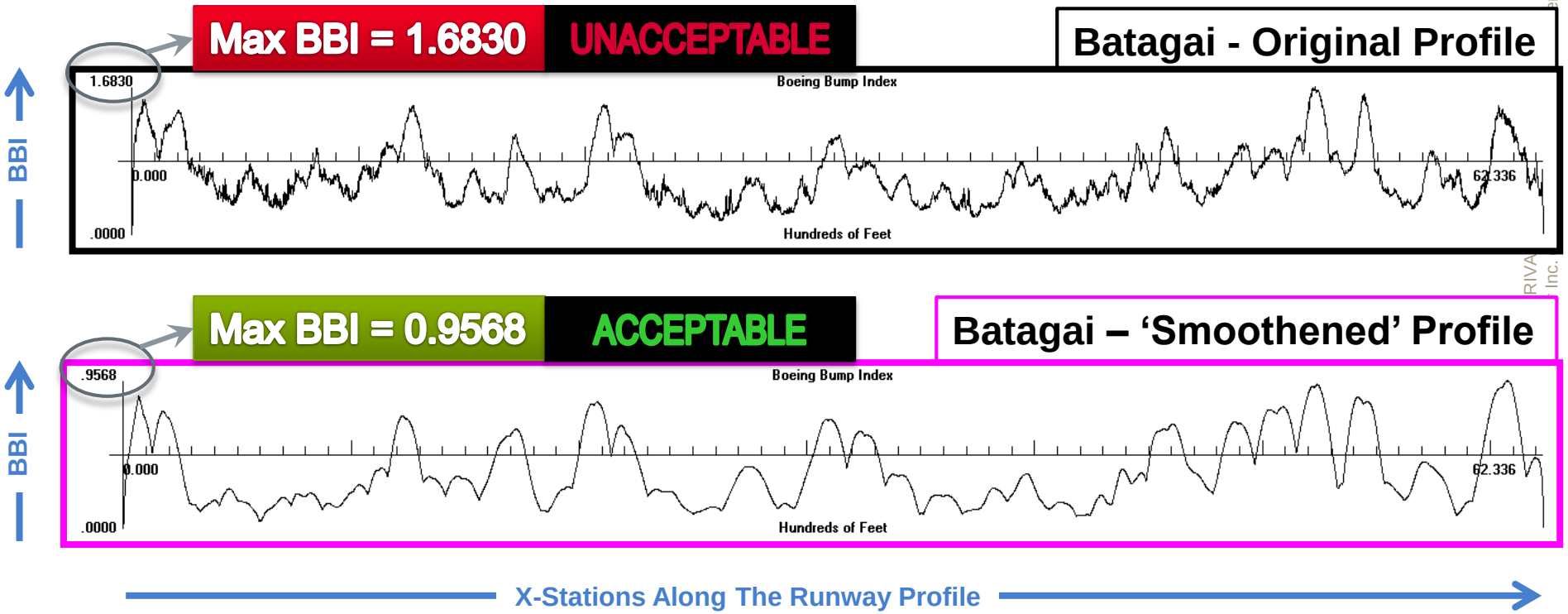
Batagay – Potential Improvements



Batagay – Potential Improvements

Significant improvement of the Boeing Bump Index (BBI) evaluated by the ProFAA Software, developed by FAA for runway roughness evaluation

- **BBI > 1 ➔ Excessive/Unacceptable**
- **BB < 1 ➔ Acceptable**



AFM Development for AR

D.O.T. Approved

AIRPLANE FLIGHT MANUAL

PSM 1–84–1A

TEMPORARY AMENDMENT NO. 33

FOR AIRCRAFT CERTIFIED BY INTERSTATE AVIATION COMMITTEE – AVIATION REGISTER (IAC AR) OR OPERATING IN THE COMMONWEALTH OF INDEPENDENT STATES (CIS)
OPERATION FROM UNPAVED/GRAVEL RUNWAYS (CR853SO90252, CR811CH00688)

b. Surface bearing material must not be less than 12 inches in depth and well compacted. The surface bearing material must demonstrate a minimum average California Bearing Ratio (CBR) of 30 with the lowest measured CBR points of not less than 20, as determined by a Boeing High Load Penetrometer.

NOTE

For sandy / sandy-loam soil types, measured σ values of 14 kg/cm^2 correlate with a CBR of 30, and measured σ values of 12 kg/cm^2 correlate with a CBR of 20, where σ is measured using a Udarnik strike penetrometer per REGA RF–94, Appendix 12.

AFM Development for AR

f. The runway shall be maintained with a roughness not exceeding 4.5 cm (H) over a 3 m length (L).

g. The assessed and accepted runway is:
– Batagai Rwy 05/23, runway roughness characteristics specified in Figure 6–26–1.

WARNING

Operation on the first 200 m of Batagai Runway 23 is prohibited.

h. Runway smoothness must conform to the above, respective profiles in item 1. g., in addition to the roughness criteria stated in item 1. f.

i. For fatigue and load evaluation, the Flight Data Recorder data must be retrieved and forwarded to Bombardier Aerospace for all taxi, landings, landing roll-outs and take-offs from unpaved runways.

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Q&A

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