Credit: Gabriel Widyna

Credit: DGAC/STAC

Runway Weather Information Systems

State of the art and main issues for standardization

ICAO/ACI Symposium – Implementation of the new GRF for runway surface condition – Montreal, March 28th 2019

Guilhem Blanchard, guilhem.blanchard@aviation-civile.gouv.fr – Zoltan Rado, zoltanr@avsafetech.com

1| Who we are

- **Guilhem BLANCHARD**
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- **Zoltan RADO**
  - Chief Scientist, Aviation Safety Technologies LLC, Dillon Kane Group
  - Chair of ASTM E-17 on Vehicle – Pavement Systems
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2| Runway surface condition assessments

- **Global Reporting Format: what do we need?**
  - Runway contamination type
  - Runway contamination depth
  - Aircraft braking action
  - Spatial coverage
  - Timely updates

and… **RELIABILITY !**

CREDIT: DGAC/STAC – R. METZGER

Assessment Criteria		Control/Braking Assessment Criteria	
Runway Condition Description	RwyCC	Deceleration or Directional Control Observation	Pilot Reported Braking Action
• Dry	6	---	---
• Frost • Wet (Includes damp and 1/8 inch depth or less of water) *1/8 inch (3mm) depth or less of:* • Slush • Dry Snow • Wet Snow	5	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	Good
-15°C and Colder outside air temperature: • Compacted Snow	4	Braking deceleration OR directional control is between Good and Medium.	Good to Medium
• Slippery When Wet (wet runway) • Dry Snow or Wet Snow (any depth) over Compacted Snow *Greater than 1/8 inch (3 mm) depth of:* • Dry Snow • Wet Snow *Warmer than -15°C outside air temperature:* • Compacted Snow	3	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	Medium
Greater than 1/8 inch(3 mm) depth of: • Water • Slush	2	Braking deceleration OR directional control is between Medium and Poor.	Medium to Poor
• Ice	1	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	Poor
• Wet Ice • Slush over Ice • Water over Compacted Snow • Dry Snow or Wet Snow over Ice	0	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	Nil

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3 | From human inspections to automated assessments

Today

visual inspections
ruler measurements

30’ runway closure
update frequency
reproducibility
coverage

Tomorrow?

mobile sensors
stationary sensors
aircraft sensors
data processing

reliability
predictions
optimizations

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4| Runway sensors: State of the art

- **Weather contamination sensors: STAC 2017 study**
  - In partnership with CEREMA and Groupe ADP (Paris Airports)
  - In-lab and on-site tests of 3 mobile sensors
  - In-lab tests of 2 stationary sensors (CSTB climate chamber)

Non-standard Assessment Procedures

Mobile Sensors – Lab tests on PVC platters

Credit: DGAC/STAC

Mobile Sensors – On-site tests on 1 runway (dry/wet) and several moutain road sections (dry/wet/snow)

Credit: CEREMA

Embedded Sensors – Lab tests in climate chamber

Credit: DGAC/STAC

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5| Runway sensors: State of the art

- **Main results – Systems limitations**

1. No system allows for the theoretical discrimination between ***all 8 contaminant types*** defined within ICAO's Global Reporting Format
2. No system can cover the ***full range of measurements*** related to aircraft operational limits (15mm of water / 130mm of dry snow)
3. Some of the ***contamination types*** could not be reliably detected – especially ice, layered contaminants and chemically-treated contaminants
4. Water depth can be reliably assessed, but results are strongly affected by the pavement ***surface characteristics and the chemical content*** of the water
5. Depth assessments do not appear reliable for ***non-liquid contaminants*** such as ice and snow
6. For stationary sensors (embedded into the pavement surface), the ***stabilization time*** for depth assessment may be way too long (about 40') for operational uses

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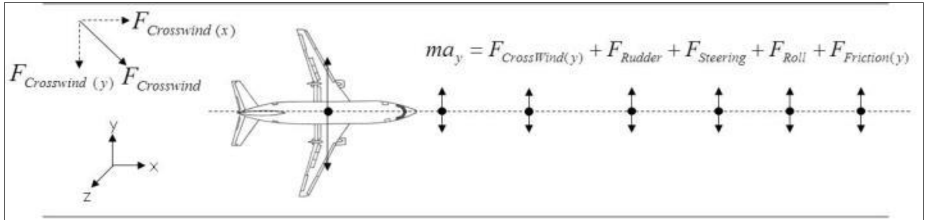
Runway sensors: State of the art

- **Several shortcomings are currently being corrected by sensor manufacturers and system integrators**
  - ***Discrimination between contaminant types:*** better measurements and algorithms
  - ***Detection of ice and chemically-treated contaminants:*** improved data-processing within the sensors and new, higher-powered sensors
  - ***Accuracy of depth values affected by local parameters:*** specific sensor calibrations and data processing for each geographical area within a runway mesh

7 | Aircraft sensors: see specific presentation

- **Full information systems process braking action data from landing aircraft**
  - Hundreds of high-quality onboard sensors are already collecting real-time data from touchdown to the end of rollout
  - Actual aircraft tire friction can be calculated from sensor measurements and aircraft-specific parameters
  - The calculated friction and relevant runway information can be used to determine the runway conditions for the landing



ma_y = aircraft landing mass x y-axis acceleration

$F_{CrossWind\ (y)}$ = f(aircraft geometry, wind measurement, heading)

F_{Rudder} = f(aircraft geometry, rudder position, airspeed)

$F_{Steering}$ = f(aircraft geometry, nose gear position, groundspeed)

F_{Roll} = f(mass, roll angle)

$F_{Friction\ (y)} = F_N \times \mu_y$ $\quad F_N$ = From z-axis force balance

Red = Assumed
Blue = Measured or Calculated from Measurements
Green = Aircraft-Specific Database Information

$$\mu_y = \frac{ma_y + F_{CrossWind\ (y)} + F_{Rudder} + F_{Steering} + F_{Roll}}{F_N}$$

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Space & time coverage

- **What do we want?**
  - ***Reliable*** assessment of the ***current*** runway surface condition ***for each runway third***
  - From ***continuous, localized measurements*** (embedded pavement sensors)
    and/or ***one-time, track measurements*** (mobile sensors)
    and/or ***air-traffic related measurements*** (aircraft sensors)
  - Using all available knowledge on the local runway characteristics, weather conditions…

- **Best ways of assessing space & time coverage are still under research investigation**
  - Physical models for prediction of contamination flows?
  - Meteorological measurements and models?
  - Enhanced optical measurements from static/vehicle/UAV cameras ?
  - Data analytics with artificial intelligence?

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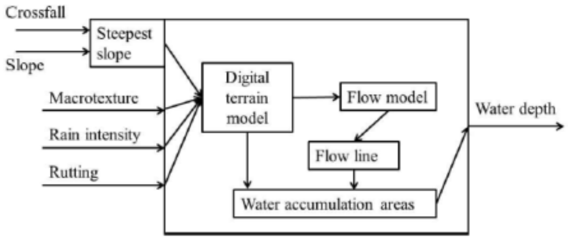
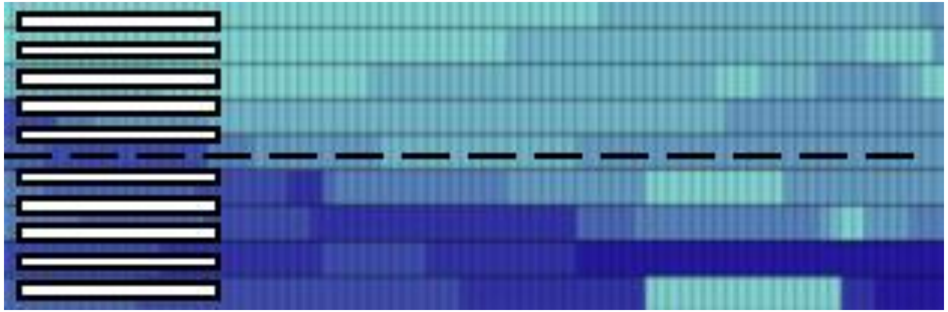
9| Space & time coverage

- **Example 1: OPHELIA concept and software** (STAC & CEREMA)

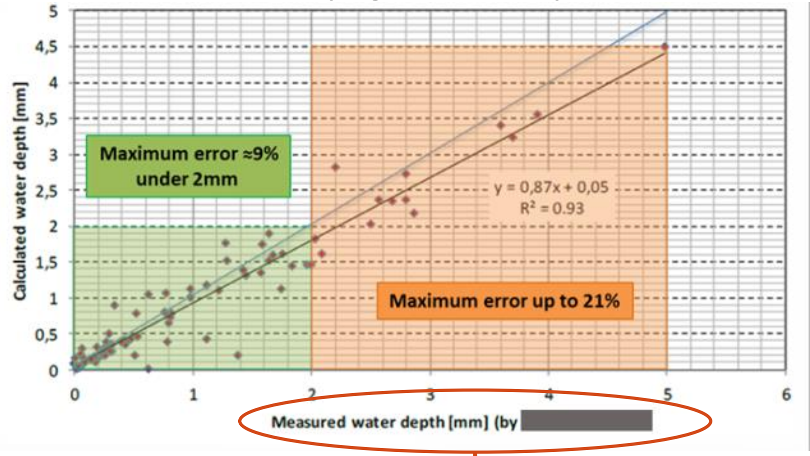


Rainfall data/predictions **+** **Terrain & Flow Models**

= assessment of water accumulation areas



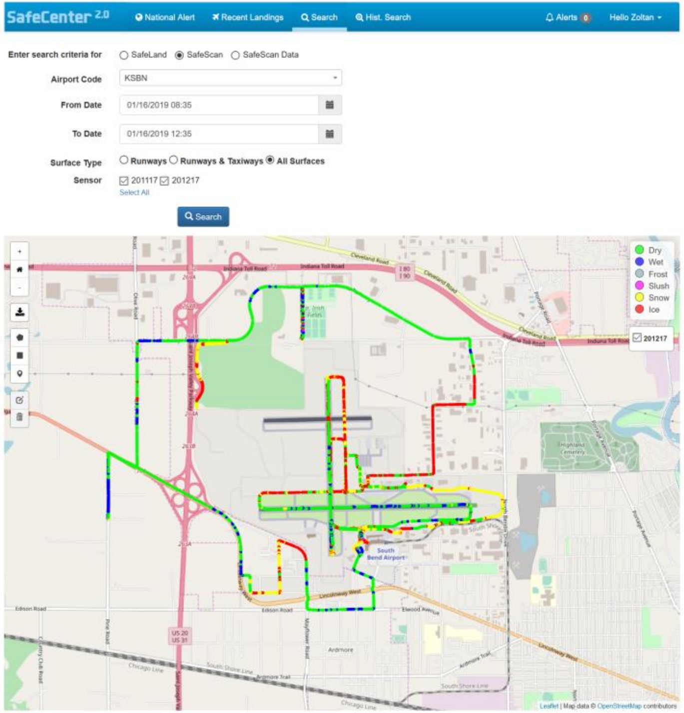
Test campaigns at LFLL airport

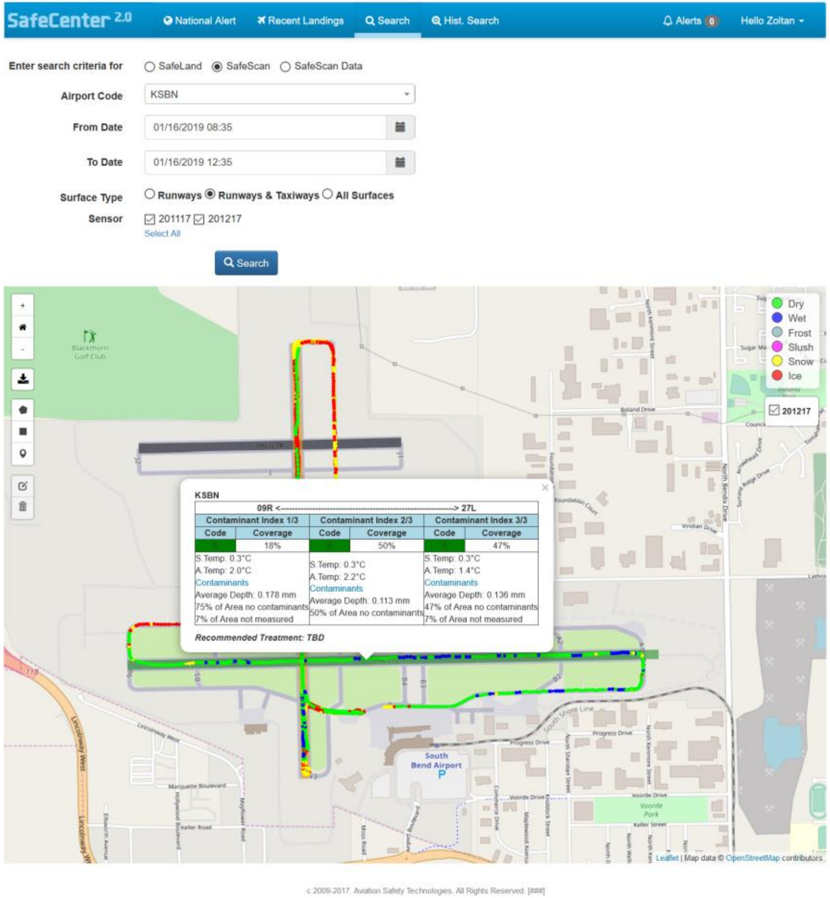


accuracy of reference value (mobile sensor) ?

10 | Space & time coverage

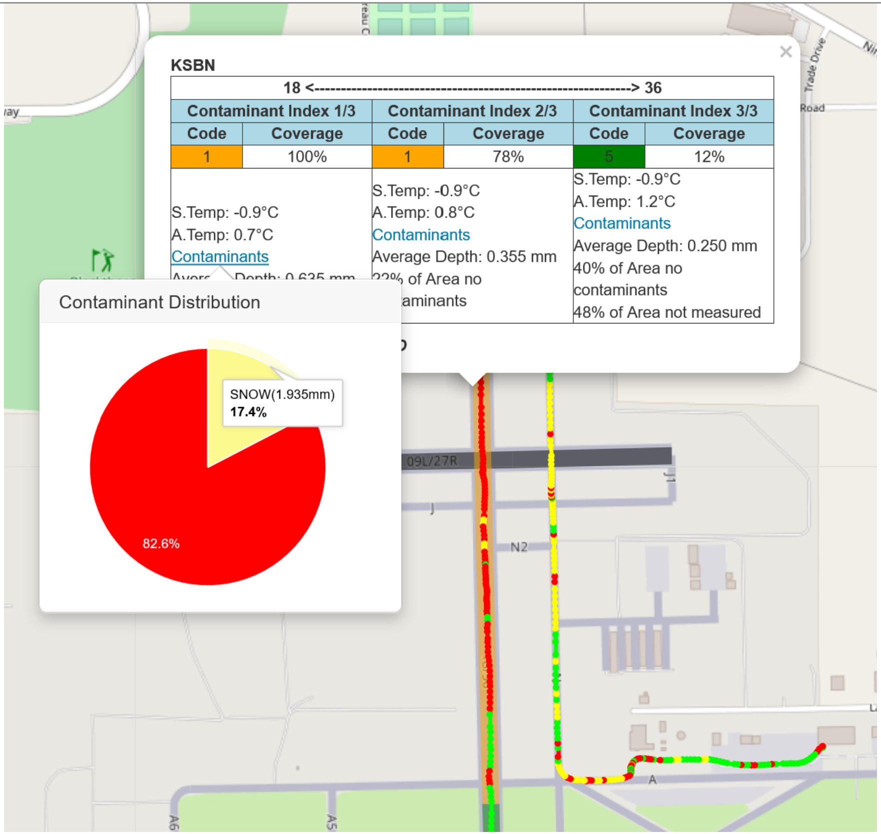
- **Example 2:**





10 | Space & time coverage

- **Example 2 (Cont.):**



10 | Space & time coverage

- **Example 2 (Cont.):**
  - **Full Assessments in filed NOTAM**
  - **Sensor based Automatic Assessment**
  - The study found that in **98% of the cases Automatic and Assessment GRF codes MATCHED perfectly**
  - **The 2% of the cases with mismatch was ALWAYS about DEPTH**

Time of NOTAM or Automatic Measurement

GRF codes from Assessment and Automatic Measurements

NOTAM	MSP	01/210	Aerodrome	01/10/2017 1318	!MSP 01/210 MSP RWY 12R FICON **5/5/5 100 PRCT 1/8IN WET SN DEICED LIQUID AND SANDED OBSERVED** AT 1701101318. 1701101318-1701111318
SafeScan	KMSP			01/10/17 12:48	KMSP RWY 12R-30L 01/10/17 12:48 **3/3/3** 90% covered with SLUSH+SNOW ave. depth: 4.6 mm; S.Temp: -3 C; A.Temp: -1 C; 10 % of Area not measured 91% covered with SNOW ave. depth: 4.64 mm; S.Temp: -3 C ; A.Temp: -1 C ; 9 % of Area not measured 86% covered with SNOW ave. depth: 4.89 mm; S.Temp: -3 C ; A.Temp: -1 C ; 14 % of Area not measured
SafeScan	KMSP			01/10/17 13:07	KMSP RWY 12R-30L 01/10/17 13:07 **5/5/5** 91% covered with SLUSH+SNOW+FROST ave. depth: 2.32 mm; S.Temp: -3 C; A.Temp: -1 C; 9 % of Area not measured 85% covered with SLUSH+SNOW+FROST ave. depth: 2.18 mm; S.Temp: -3 C ; A.Temp: -1 C ; 15 % of Area not measured 94% covered with WATER+SLUSH+SNOW+FROST ave. depth: 1.5 mm; S.Temp: -3 C ; A.Temp: -1 C ; 6 % of Area not measured
NOTAM	MSP	01/212	Aerodrome	01/10/2017 1359	!MSP 01/212 MSP RWY 12L FICON **5/5/5 100 PRCT WET DEICED LIQUID OBSERVED** AT 1701101359. 1701101359-1701111359
SafeScan	KMSP			01/10/17 13:44	KMSP RWY 12L-30R 01/10/17 13:44 **5/5/5** 81% covered with SLUSH+SNOW ave. depth: 2.61 mm; S.Temp: -3 C; A.Temp: 1 C; 19 % of Area not measured 83% covered with SLUSH+SNOW+FROST ave. depth: 1.92 mm; S.Temp: -3 C ; A.Temp: 1 C ; 17 % of Area not measured 81% covered with SLUSH ave. depth: 0.49 mm; S.Temp: -3 C ; A.Temp: 1 C ; 19 % of Area not measured
SafeScan	KMSP			01/10/17 13:56	KMSP RWY 12L-30R 01/10/17 13:56 **5/5/5** 78% covered with WATER+SNOW+FROST ave. depth: 0.7 mm; S.Temp: -3 C; A.Temp: 0 C; 22 % of Area not measured 80% covered with WATER+SLUSH+SNOW+FROST ave. depth: 0.34 mm; S.Temp: -3 C ; A.Temp: 0 C ; 20 % of Area not measured 87% covered with WATER+SLUSH ave. depth: 0.15 mm; S.Temp: -3 C ; A.Temp: 0 C ; 13 % of Area not measured
NOTAM	MSP	01/216	Aerodrome	01/10/2017 1430	!MSP 01/216 MSP RWY 12R FICON **5/5/5 100 PRCT 1/8IN WET SN DEICED LIQUID AND SANDED OBSERVED** AT 1701101430. 1701101430-1701111430
SafeScan	KMSP			01/10/17 14:14	KMSP RWY 12R-30L 01/10/17 14:14 **5/3/5** 93% covered with SLUSH+SNOW+FROST ave. depth: 2.57 mm; S.Temp: -2 C; A.Temp: -2 C; 7 % of Area not measured 87% covered with SNOW ave. depth: 5.33 mm; S.Temp: -2 C ; A.Temp: -2 C ; 13 % of Area not measured 87% covered with SNOW ave. depth: 2.87 mm; S.Temp: -3 C ; A.Temp: -1 C ; 13 % of Area not measured
SafeScan	KMSP			01/10/17 14:28	KMSP RWY 12R-30L 01/10/17 14:28 **3/3/3** 82% covered with SNOW+FROST ave. depth: 3.36 mm; S.Temp: -2 C; A.Temp: -1 C; 18 % of Area not measured 91% covered with SNOW ave. depth: 3.84 mm; S.Temp: -2 C ; A.Temp: -1 C ; 9 % of Area not measured 89% covered with SNOW+FROST ave. depth: 3.69 mm; S.Temp: -3 C ; A.Temp: -1 C ; 11 % of Area not measured

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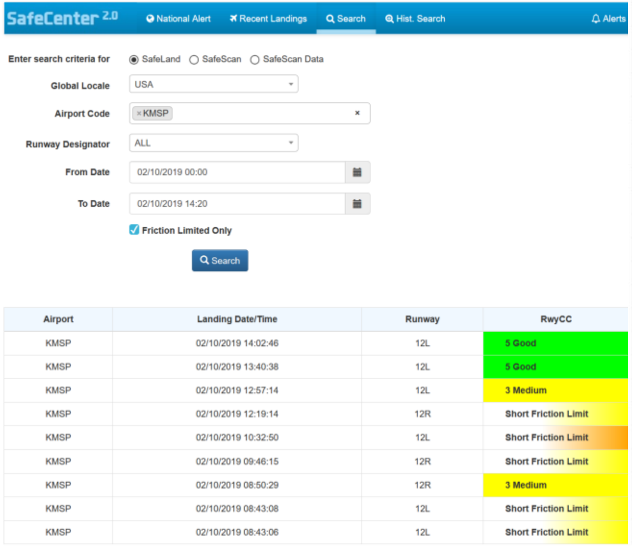
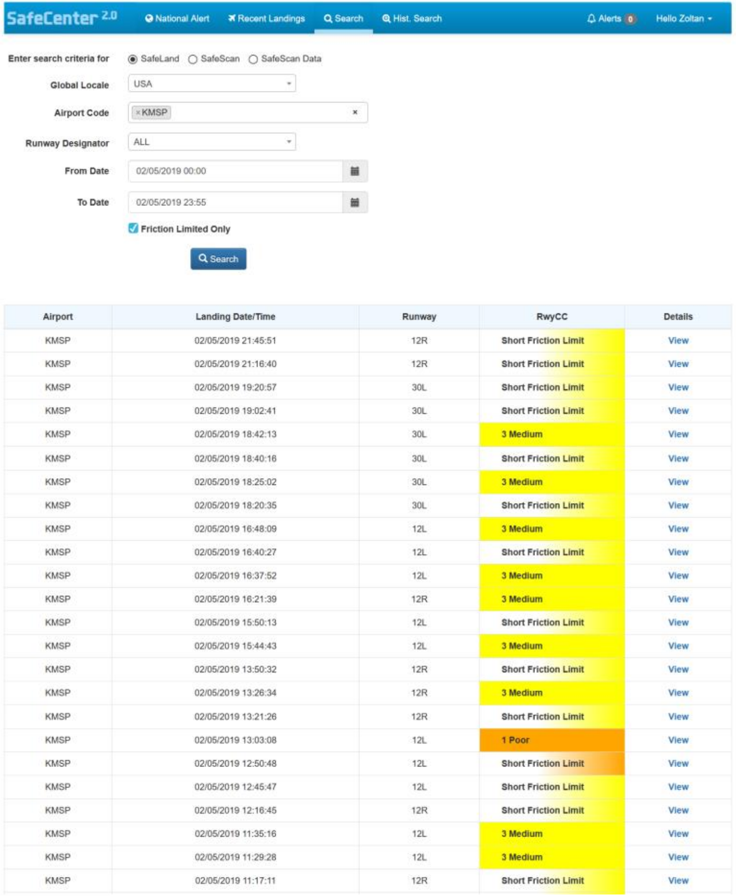
11 | Space & time coverage

- **Example 3:**
  - Winter Storm Event through Aircraft Braking Action:
    - <u>Calculated from Aircraft Data</u>
    - <u>MAPPED to GRF</u> Codes
    - <u>OBJECTIVE</u>
      Like PIREP/AIREP WITHOUT the SUBJECTIVENESS
    - <u>Near REAL-TIME (90s delay)</u>
      after touchdown
  - Mix of B737, A320
    <u>works with ALL aircraft types</u>
  - <u>Very low cost</u>
    (uses small very inexpensive software installed on aircraft)



Airport	Landing Date/Time	Runway	RwyCC
KMSP	02/10/2019 14:02:46	12L	5 Good
KMSP	02/10/2019 13:40:38	12L	5 Good
KMSP	02/10/2019 12:57:14	12L	3 Medium
KMSP	02/10/2019 12:19:14	12R	Short Friction Limit
KMSP	02/10/2019 10:32:50	12L	Short Friction Limit
KMSP	02/10/2019 09:46:15	12R	Short Friction Limit
KMSP	02/10/2019 08:50:29	12R	3 Medium
KMSP	02/10/2019 08:43:08	12L	Short Friction Limit
KMSP	02/10/2019 08:43:06	12L	Short Friction Limit



Airport	Landing Date/Time	Runway	RwyCC	Details
KMSP	02/05/2019 21:45:51	12R	Short Friction Limit	View
KMSP	02/05/2019 21:16:40	12R	Short Friction Limit	View
KMSP	02/05/2019 19:20:57	30L	Short Friction Limit	View
KMSP	02/05/2019 19:02:41	30L	Short Friction Limit	View
KMSP	02/05/2019 18:42:13	30L	3 Medium	View
KMSP	02/05/2019 18:40:16	30L	Short Friction Limit	View
KMSP	02/05/2019 18:25:02	30L	3 Medium	View
KMSP	02/05/2019 18:20:35	30L	Short Friction Limit	View
KMSP	02/05/2019 16:48:09	12L	3 Medium	View
KMSP	02/05/2019 16:40:27	12L	Short Friction Limit	View
KMSP	02/05/2019 16:37:52	12L	3 Medium	View
KMSP	02/05/2019 16:21:39	12R	3 Medium	View
KMSP	02/05/2019 15:50:13	12L	Short Friction Limit	View
KMSP	02/05/2019 15:44:43	12L	3 Medium	View
KMSP	02/05/2019 13:50:32	12R	Short Friction Limit	View
KMSP	02/05/2019 13:26:34	12R	3 Medium	View
KMSP	02/05/2019 13:21:26	12R	Short Friction Limit	View
KMSP	02/05/2019 13:03:08	12L	1 Poor	View
KMSP	02/05/2019 12:50:48	12L	Short Friction Limit	View
KMSP	02/05/2019 12:45:47	12L	Short Friction Limit	View
KMSP	02/05/2019 12:16:45	12R	Short Friction Limit	View
KMSP	02/05/2019 11:35:16	12L	3 Medium	View
KMSP	02/05/2019 11:29:28	12L	3 Medium	View
KMSP	02/05/2019 11:17:11	12R	Short Friction Limit	View

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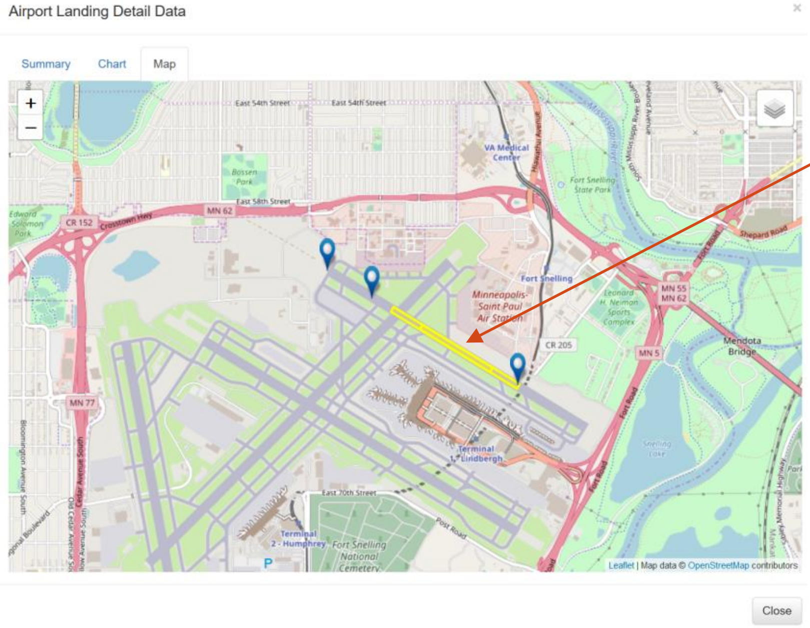
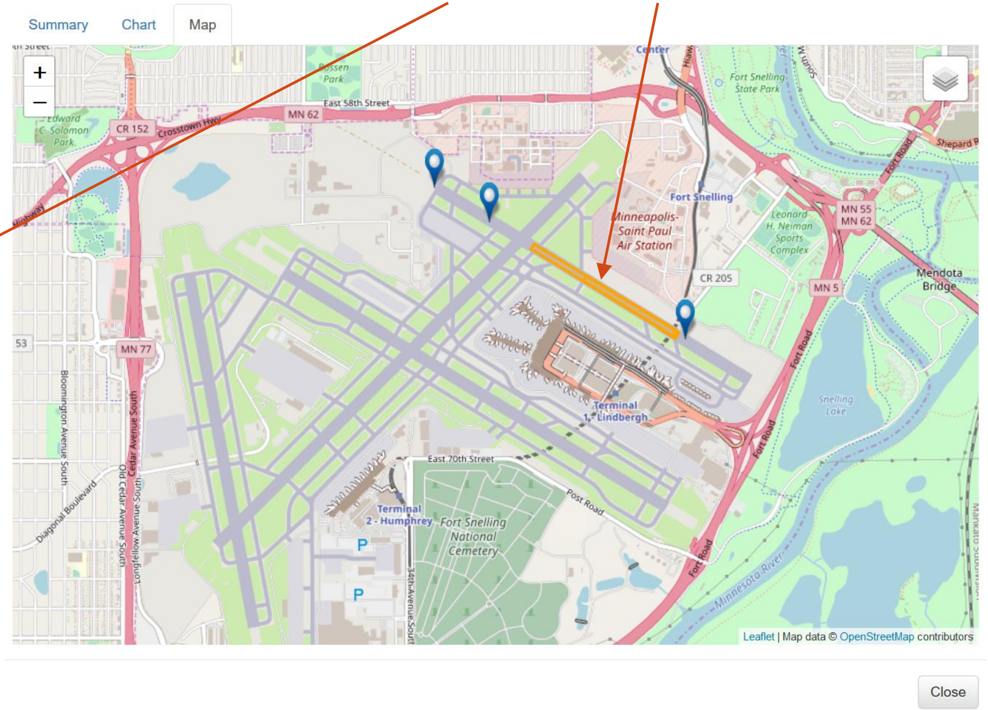
11 | Space & time coverage

Two landings within15 minutes in snowing condition show trending of runway from MEDIUM to POOR

- **Example 3 (Cont.):**
  - **Color coded geographic location of GRF coded surfaces according to aircraft braking action**





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12 | Standardization

- **Objectives**
  - Better understand the precise needs related to aviation applications and the main technical limitations of current technologies, so as to ask for **reasonable levels of performance (accuracy & reliability)**
  - Make sure that the systems **actually reach minimal levels** of performance before they can be considered compliant with safety regulations

- **Standardization efforts for aviation** *(convergence with road sector still to be done)*

WG-109 Runway Weather Information Systems ⟷ ***E-17 Vehicle/Pavement Systems***

EUROCAE

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Standardization

- **EUROCAE WG-109 Runway Weather Information Systems**
  - ED-XXX Minimum Aviation System Performance Standards (MASPS) for Runway Weather Information Systems

- **Standardization process within EUROCAE**
  - Transparent and open process
  - Consensus driven development approach
  - Standards validation through open consultation (not only within EUROCAE)
  - Worldwide recognition and application
  - Open for worldwide participation
  - By the industry – for the industry

Document development approved
↓
Drafting of document by WG
↓
EUROCAE Open Consultation
↓
Comment resolution & Finalisation of draft
↓
EUROCAE Council approval
↓
Publication of EUROCAE Document

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14 | Standardization

- **ASTM E-17 Vehicle/Pavement Systems**
  - WK62735 Minimum Equipment Requirements for Mobile Surface Contaminant Classification and Measurement Equipment
  - E3188-19 Standard Terminology for Aircraft Braking Performance
  - WK63444 Aircraft Braking Performance
  - WK64909 Friction Limited Aircraft Braking Measurements and Reporting

- **Standardization process within ASTM**
  - 7 principles governing the procedures for the development and adoption of voluntary consensus standards

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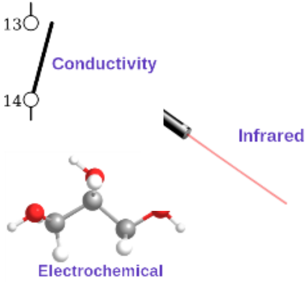
15 | Standardization

- **Main issues to be tackled**

  - ***Common terminology***, compatible with both human experience and physical properties

  - ***Use cases and performance requirements***, depending on
    (i) airport operations to be substituted or accelerated
    (ii) air traffic
    (iii) climate conditions

  - ***Performance assessments procedures*** for
    (i) the production of stable reference contaminations
    (ii) the determination of reference depth values
    (iii) the reproduction of operational conditions



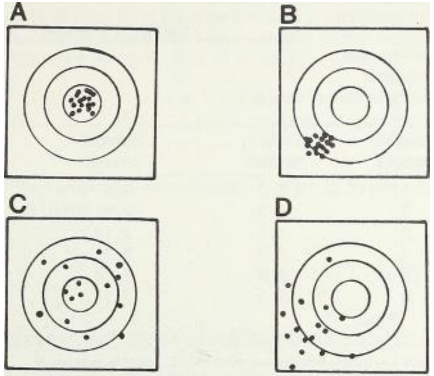
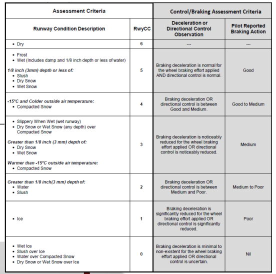
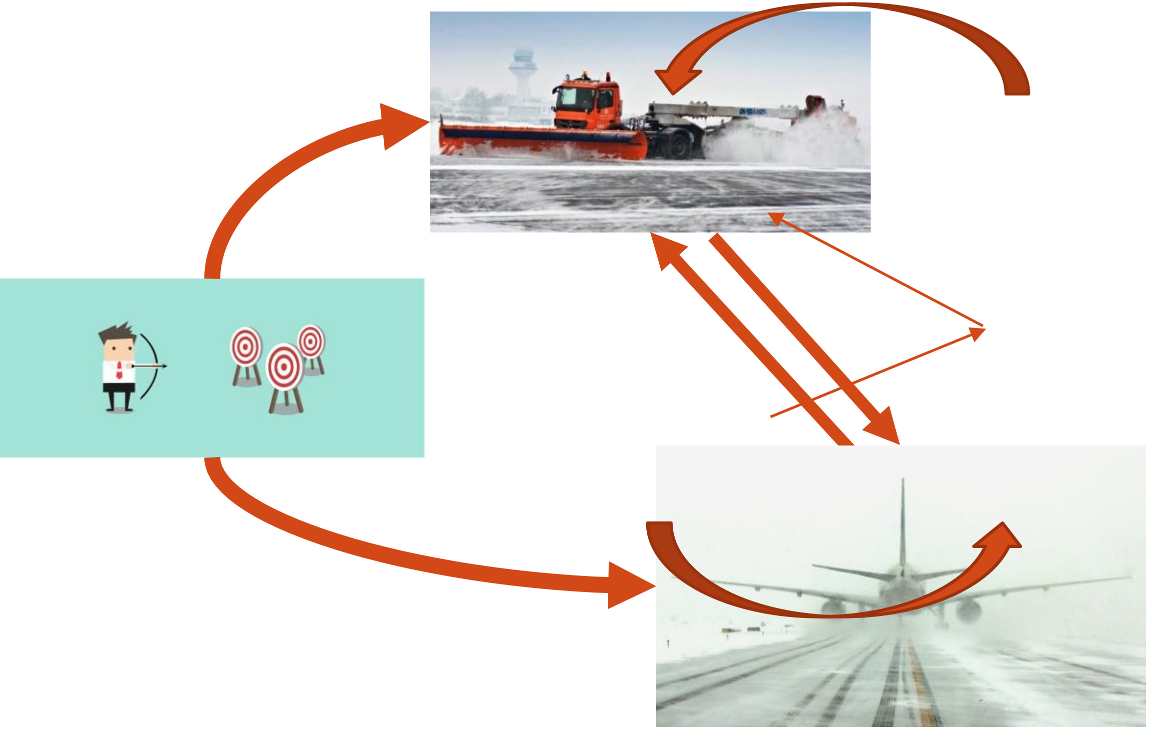


Figure 1.—The bullseye analogy. Various patterns of darts at a target: **(A)** high precision, low bias, high accuracy; **(B)** high precision, high bias, medium accuracy; **(C)** low precision, low bias, low accuracy; and **(D)** low precision, high bias, lowest accuracy.

16 | Standardization



Assessment Criteria		Control/Braking Assessment Criteria	
Runway Condition Description	RwyCC	Deceleration or Directional Control Observation	Pilot Reported Braking Action
• Dry	6	---	---
• Frost • Wet (Includes damp and 1/8 inch depth or less of water) *1/8 inch (3mm) depth or less of:* • Slush • Dry Snow • Wet Snow	5	Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.	Good
-15°C and Colder outside air temperature: • Compacted Snow	4	Braking deceleration OR directional control is between Good and Medium.	Good to Medium
• Slippery When Wet (wet runway) • Dry Snow or Wet Snow (any depth) over Compacted Snow *Greater than 1/8 inch (3 mm) depth of:* • Dry Snow • Wet Snow *Warmer than -15°C outside air temperature:* • Compacted Snow	3	Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.	Medium
Greater than 1/8 inch(3 mm) depth of: • Water • Slush	2	Braking deceleration OR directional control is between Medium and Poor.	Medium to Poor
• Ice	1	Braking deceleration is significantly reduced for the wheel braking effort applied OR directional control is significantly reduced.	Poor
• Wet Ice • Slush over Ice • Water over Compacted Snow • Dry Snow or Wet Snow over Ice	0	Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.	Nil



The ultimate goal of ALL use cases is the safe operation of aircrafts!

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17 | Standardization

- **Strong involvement of key stakeholders**
  - Airport operators
  - Airlines
  - Aircraft manufacturers
  - Pilots
  - Sensors manufacturers
  - Systems integrators
  - Civil aviation authorities

➢ **Feel free to join!**

ASTM INTERNATIONAL Standards Worldwide

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Thank you for your attention