Runway Weather Information Systems

State of the art and main issues for standardization
Who we are

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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](image)

### Assessment Criteria

<table>
<thead>
<tr>
<th>Runway Condition Description</th>
<th>RayCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flot</td>
<td>6</td>
</tr>
<tr>
<td>Wet (includes damp and 1/8 inch depth or less of water)</td>
<td></td>
</tr>
<tr>
<td>1/8 inch (3mm) depth or less of:</td>
<td></td>
</tr>
<tr>
<td>- Slush</td>
<td></td>
</tr>
<tr>
<td>- Dry Snow</td>
<td></td>
</tr>
<tr>
<td>- Wet Snow</td>
<td></td>
</tr>
</tbody>
</table>

| +15°C and Colder outside air temperature:                          |       |
| - Compacted Snow                                                  |       |

| Greater than 1/8 inch (2 mm) depth of:                             |       |
| - Dry Snow                                                       |       |
| - Wet Snow                                                       |       |

| Warmer than +15°C outside air temperature:                         |       |
| - Compacted Snow                                                  |       |

| Greater than 1/8 inch (2 mm) depth of:                             |       |
| - Packed                                                          |       |
| - Slush                                                          |       |

| Ice                                                              |       |

| - Wet Ice                                                       |       |
| - Slush over Ice                                                 |       |
| - Water over Compacted Snow                                      |       |
| - Dry Snow or Wet Snow over Ice                                  |       |

### Control/Braking Assessment Criteria

<table>
<thead>
<tr>
<th>Deceleration or Directional Control Observation</th>
<th>Pilot Reported Braking Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braking deceleration is normal for the wheel braking effort applied AND directional control is normal.</td>
<td>Good</td>
</tr>
<tr>
<td>Braking deceleration is noticeably reduced for the wheel braking effort applied OR directional control is noticeably reduced.</td>
<td>Medium</td>
</tr>
<tr>
<td>Braking deceleration OR directional control is between Medium and Poor.</td>
<td>Medium to Poor</td>
</tr>
<tr>
<td>Braking deceleration OR directional control is significantly reduced.</td>
<td>Poor</td>
</tr>
<tr>
<td>Braking deceleration is minimal to non-existent for the wheel braking effort applied OR directional control is uncertain.</td>
<td>Nil</td>
</tr>
</tbody>
</table>

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@avsafe.com
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
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)

Mobile Sensors – Lab tests on PVC platters

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

Embedded Sensors – Lab tests in climate chamber

Non-standard Assessment Procedures
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
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
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

\[
ma_y = \text{aircraft landing mass xy-axis acceleration}
\]

\[
F_{\text{CrossWind}}(\gamma) = f(\text{aircraft geometry, wind measurement, heading})
\]

\[
F_{\text{Rudder}} = f(\text{aircraft geometry, rudder position, airspeed})
\]

\[
F_{\text{Steering}} = f(\text{aircraft geometry, nose gear position, groundspeed})
\]

\[
F_{\text{Roll}} = f(\text{mass roll angle})
\]

\[
F_{\text{Friction}}(\gamma) = F_N \times \mu_y
\]

\[
F_N = \text{from z-axis force balance}
\]

\[
\mu_y = \frac{ma_y + F_{\text{CrossWind}}(\gamma) + F_{\text{Rudder}} + F_{\text{Steering}} + F_{\text{Roll}}}{F_N}
\]
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?
Space & time coverage

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

Rainfall data/predictions + Terrain & Flow Models

= assessment of water accumulation areas
Space & time coverage

Example 2:

- Space & time coverage
- Example 2:

![Diagram showing space & time coverage example]
10 | Space & time coverage

- Example 2 (Cont.):

<table>
<thead>
<tr>
<th>Code</th>
<th>Contaminant Index 1/3</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Code</th>
<th>Contaminant Index 2/3</th>
<th>Coverage</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>78%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Contaminant Index 3/3</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>12%</td>
</tr>
</tbody>
</table>

- S. Temp: -0.9°C
- A. Temp: 0.7°C
- Contaminants: Snow
- Average Depth: 0.355 mm
- 40% of Area no contaminants
- 48% of Area not measured

Contaminant Distribution:
- Snow (1.056 mm): 17.4%
- Rain: 92.6%
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

<table>
<thead>
<tr>
<th>NOTAM</th>
<th>MSP</th>
<th>Aerodrome</th>
<th>01/10/2017 13:18</th>
</tr>
</thead>
<tbody>
<tr>
<td>SafeScan</td>
<td>KMSP</td>
<td>01/10/17 12:48</td>
<td></td>
</tr>
<tr>
<td>KMSW Rwy 12L-30L 01/10/17 17:13 5/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90% covered with SLUSH+SNOW area: depth: 4.6 mm; S.Temp: -3 C; A.Temp: -1 C; 10 % of Area not measured</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>91% covered with SNOW area: depth: 4.64 mm; S.Temp: -3 C; A.Temp: -1 C; 9 % of Area not measured</td>
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<td></td>
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</tr>
<tr>
<td>86% covered with SNOW area: depth: 4.89 mm; S.Temp: -3 C; A.Temp: -1 C; 14 % of Area not measured</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
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<td>KMSW Rwy 12L-30L 01/10/17 17:13 5/5</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>81% covered with SLUSH+SNOW area: depth: 2.61 mm; S.Temp: -3 C; A.Temp: 1 C; 19 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>83% covered with SLUSH+SNOW+FROST area: depth: 1.92 mm; S.Temp: -3 C; A.Temp: 1 C; 17 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>81% covered with SLUSH area: depth: 0.49 mm; S.Temp: -3 C; A.Temp: 1 C; 19 % of Area not measured</td>
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</table>

<table>
<thead>
<tr>
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</tr>
<tr>
<td>KMSW Rwy 12L-30L 01/10/17 17:13 5/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>78% covered with WATER+SLUSH+FROST area: depth: 0.7 mm; S.Temp: -3 C; A.Temp: 0 C; 22 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80% covered with WATER+SLUSH+FROST+FROST area: depth: 0.34 mm; S.Temp: -3 C; A.Temp: 0 C; 20 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87% covered with WATER+FROST area: depth: 0.15 mm; S.Temp: -3 C; A.Temp: 0 C; 13 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>01/10/2017 14:30</th>
</tr>
</thead>
<tbody>
<tr>
<td>SafeScan</td>
<td>KMSP</td>
<td>01/10/17 14:14</td>
<td></td>
</tr>
<tr>
<td>KMSW Rwy 12L-30L 01/10/17 17:13 5/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>93% covered with SLUSH+FROST area: depth: 2.57 mm; S.Temp: -2 C; A.Temp: -2 C; 7 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87% covered with SNOW area: depth: 5.33 mm; S.Temp: -2 C; A.Temp: -2 C; 13 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87% covered with SNOW area: depth: 2.87 mm; S.Temp: -3 C; A.Temp: -1 C; 13 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOTAM</th>
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<th>Aerodrome</th>
<th>01/10/2017 14:28</th>
</tr>
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<tbody>
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<td>KMSP</td>
<td>01/10/17 14:28</td>
<td></td>
</tr>
<tr>
<td>KMSW Rwy 12L-30L 01/10/17 17:13 5/5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>82% covered with SNOW+FROST area: depth: 3.36 mm; S.Temp: -2 C; A.Temp: -1 C; 18 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91% covered with SNOW area: depth: 3.84 mm; S.Temp: -2 C; A.Temp: -1 C; 9 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>89% covered with SNOW+FROST area: depth: 3.68 mm; S.Temp: -3 C; A.Temp: -1 C; 11 % of Area not measured</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example 3:

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

Example 3 (Cont.):

- Color coded geographic location of GRF coded surfaces according to aircraft braking action

Two landings within 15 minutes in snowing condition show trending of runway from MEDIUM to POOR
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*
13 | 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
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
### 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
The ultimate goal of ALL use cases is the safe operation of aircrafts!
Standardization

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

Feel free to join!
Thank you for your attention