“Big data Analytics” of braking distance at Paris-CDG airport

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at a glance

- Paris-CDG northern runways (27 and 09) traffic
- Merging relevant information in a « Big Table » from different sources
- Establishing how runway occupancy time (ROT) and braking distance (BD) could depend on MET or on traffic
- Predictability of braking capability in perspective
Braking Distance (to full stop) and ROT analysis

Main factors impacting Braking Distance

- Runway state → Friction Coefficient
- Auto-Brake: → High/Medium/Low → (BTV)
- Targeted Exit Taxiway → Coordinated with controller → Not coordinated with controller
- Clearance of Taxiway → Taxiway traffic
- Pilot Skills for Braking → Company dependent
- Braking process: → Aerodynamics → Reverse Engine
- Cross-Wind conditions → Pilot in the loop to compensate (differential braking)
- Aircraft Tire wear
- Runway Gumming

13 March, 2017
MAIN QUESTION

“Are BD or ROT parameters predictable?” at which level of accuracy? What do they depend on? (Inputs)

The steps are:
• collecting a larger set of relevant data: A/C movements and MET data
• establishing statistics on landings and sorting cases to be more explicated
• applying “Big Data algorithms” in order to find and establish finest correlations

INPUTs at CDG northern runways [27R, 09L] and [09R, 27L]
• ADSB, Lidar
• Météo-France data: local sensors and radars (scanning up to <250km)

OUTPUT Data
• ROT, deceleration for northern runways [27R, 09L] and [09R, 27L]
• List of cases out of mean statistics
COLLECTING and MERGING

Traffic on RWs
Taxiways Stop

Conditions on RWs

Table
one line per movement (landing, take-off, …)

CDG
RB
Lidar
Anenometers
Radar bd-X LEOPARD
Rainmeter
Radar bd-C « Lame d’eau » (Trappes)

A/C
ADSB
AIRPORT
WIND
RAIN

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CDG back-clipping plane for A/C path finding

CDG Northern RW / Exit Z1, Z2 - Z8

Radar LEOPARD bd-X
+ Lidar
+ ADSB antenna (P2)

Radar bd-C at 47km
Lame d'Eau

Techn. Center MF

09L to 27R
# INPUTs: two periods P1 and P2

<table>
<thead>
<tr>
<th>Data</th>
<th>Type</th>
<th>From</th>
<th>Machine</th>
<th>Rate</th>
<th>Raw data per month (approx.)</th>
<th>Merged in TABLE</th>
<th>Status A: analysed</th>
<th>C: Correlation ML: Machine Learning</th>
<th>Oct-15</th>
<th>Nov-15</th>
<th>Dec-16</th>
<th>Jan-17</th>
<th>Feb-17</th>
<th>Mar-17</th>
<th>Apr-17</th>
<th>May-17</th>
<th>Jun-17</th>
<th>Jul-17</th>
<th>Aug-17</th>
<th>Sep-17</th>
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<tbody>
<tr>
<td>ADSB</td>
<td>latitude longitude altitude</td>
<td>THALES</td>
<td>BaseStation CDG (r1)</td>
<td>about 1s</td>
<td>500Mo</td>
<td>yes</td>
<td>A,C</td>
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<td>P1</td>
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<td></td>
<td>BaseStation CDG (r2)</td>
<td>about 1s</td>
<td>8Go</td>
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<td>A,C</td>
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<td>P2</td>
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<td>LAME d’EAU</td>
<td>RR 1kmx1km grid</td>
<td>Météo France</td>
<td>Bd-C TRAPPES</td>
<td>5mn</td>
<td>&lt;200Mo</td>
<td>yes</td>
<td>A,C (Pluviometer)</td>
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<td>P1P2</td>
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<td>PLUVIO meter</td>
<td>RR 1kmx1km grid</td>
<td>Météo France</td>
<td>1 sensor Techn. Center</td>
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<td>&lt;150Ko</td>
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<td>A,C</td>
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<td>LEOPARD Bd-X CDG</td>
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<td>5 Go (HDF5)</td>
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<td>direction [*] speed [m/s]</td>
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<td>2 sensors 27L &amp; 9L CDG</td>
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<td>1 sensor Techn. Center</td>
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<td>&lt;100Ko</td>
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<td>C vs Lidar</td>
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<td>LEOSPHERE WLS7-550</td>
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</table>

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A/C movements in Table

1. **P1 (from 2015/10/01 to 2015/11/24)**
   - 55 ICAO types
   - 22575 movements
   - Landings (well identified trajectory / exit)
     - 09L : 3901
     - 27R : 4303
     - 27L : 312

2. **P2 (from 2016/12/22)**
   - 46 ICAO types
   - 33620 movements
   - Landings (well identified trajectory / exit)
     - 09L : 4322
     - 27R : 3949
     - 27L : 114
Stats: ROT on Landings A318-A319-A320-A321

A318 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

09L: 155 landings
27R: 144 landings

A319 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

09L: 549 landings
27R: 641 landings

A320 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

09L: 867 landings
27R: 953 landings

A321 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

09L: 463 landings
27R: 438 landings

27R
09L

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13 March, 2017 10
Stats: ROT on Landings A332-A333-A388

A332 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

A333 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

A388 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

27R
09L
Stats: ROT on Landings B737-B738-B77L-B77W

27R
09L
Stats : ROT on Landings B752-B763-B772

B752 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

- 09L: 112 landings
- 27R: 177 landings

B763 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

- 09L: 70 landings
- 27R: 103 landings

B772 on CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

- 09L: 142 landings
- 27R: 183 landings

CDG Northern Runways & landings with well identified taxiway exit
October & November 2015

- 09L
- 27R

27R

09L
Stats : Exit Taxiway per A/C type

- Z3 and Z6 are mostly used (70%), except for A388
- A388 prefers the next farer taxiway (Z2, Z7) (>60%)
Stats : ROT focus on the most frequent A/C

- ROT histogram depends on A/C type and on airport configurations (Westward or Eastward). It is little bit larger and staggered for Westward.
- Less than about 3s between successive exits (500m distant) shows that each landing has one targeted TWY exit.

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Stats : ROT vs Head and Cross Wind on the most frequent A/C

- Wind ranges are not the same for the two configurations: Eastward (red) < Westward (black)
- A trend appears on black diagrams: ROT is slightly increasing with the head wind speed.
Stats: Deceleration histograms for different phases

CDG Northeim RWY
P2 Period (Landings on 27R)

CDG Northeim RWY
P2 Period (Landings on 09L)

27R
RR30>0.4

09L
CONCLUSION
P1 and P2 (2016/12/22 ➔ 2017/01/31)

1. Each landing has one targeted TW exit
2. Exit Taxiway and ROT are closely related to A/C type
3. ROT increases slightly when head wind grows
4. Braking with full stop on RWY was not observed
5. Deceleration range is large enough within each phase (before and after TD, …).
6. Rain, as observed so far, does not reduce this observed range.

7. More input data are required in order to collect more rainy days
8. Further analysis is required to detail this deceleration range. The purpose is to find subsets of A/C, MET and runway parameters, each subset being associable with a deceleration level, and at a scale of a few minutes.
Ongoing:

1. **Period P2 (from 2016/12/22) still under analysis**
   - data from LEOPARD radar (dBZ and radial wind): with possible finer resolution
   - Further data will be merged (at least up to April)

2. **Isolating some « abnormal or extreme » cases**
   - rain or wind conditions
   - stronger braking ?, full stop on RWY ?
   - TW exit

3. **Modeling rain cumulative rule for giving an account of abnormal cases**
FUTURE SKY
SAFETY

Consortium
Stichting Nationaal Lucht- en Ruimtevaartlaboratorium
Deutsches Zentrum für Luft- und Raumfahrt
Office national d’études et de recherches aérospatiales
Centro para a Excelência e Inovação na Indústria Automóvel
Centro Italiano Ricerche Aerospaziali
Centre Suisse d’Électronique et Microtechnique SA
Institutul National de Cercetari Aerospatiale “Elie Carafoli”
Instituto Nacional de Cência Aeroespacial
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Cranfield University
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LIDAR Sensor:
Measure low altitude wind with high resolution

Transmission characteristics

→ **Vertical beams**:
  56 wide cone, 5 beams

→ **Low altitude**:
  [40m ; 200m],

→ **High resolution**:
  20m default altitude resolution
LEOPARD Radar of Météo-France (weather X-band Radar for CDG Airport)

Operational Product at CDG:
- Wind on 15 km-80 km at elevation 3°
- dBZ on 15 km-80 km at elevation 3°
- Windshear on runway at elevation 3°
- Vertical Profil of Wind along runway: (5 km long x 4 km Altitude)

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