Trajectory APproach AnalysiS: a post-operational aircraft approach analysis tool

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2. Software

3. Study

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Safety Context

- Traffic Growth (7.8 billion in 2036)
- Approach and landing accidents (47% of the total number of accident)
- Identify, detect, and manage safety event precursors
Non Stabilized Approaches (NSA)

Figure: Stabilized vs Non Stabilized Approach
Non Compliant Approaches (NCA)

Figure: Compliance Criteria
Operational Context

French Safety State Programme (SSP):

- NCA identified as undesirable events.
- Approach path management.

Accidents Study - DGAC 2015:

- 57% NSA with 74% of them in NCA
- While stabilized 84% compliant
- 74% bad weather condition, 15% final approach tailwind
Glide Interception From Above detection tool at CDG Airport

**Figure**: GIFA detection tool using the APW at CDG Airport
Ideas

- No or few speed monitoring from ground side
- Airline safety offices focus on the last 5NM
- Approach path management, atypical total energy detection
Our Methodology

- Functional Principal Component Analysis
  \[ \gamma(t) = \sum_{0}^{K} \alpha_k \cdot \phi_k(t), \text{ (K min)} \]
- Sliding Window
- Total Specific Energy (from radar equivalent parameters):
  \[ E_t = E_c + E_p = \frac{1}{2} \cdot V^2 + g \cdot h \text{ (J/kg)} \]
- Localization of atypical energy behaviors, categorization with threshold (typical, atypical)
Algorithm

Figure: Atypical Scoring Algorithm
Objectives

- Trajectory APproach AnalysiS (TAPAS) a post-operational approach analysis software
- Validation with FDM data and safety office analysis
- Providing non-monitored flights, potential safety precursors, can help enhancing safety
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Data Section

TAPAS - Trajectory APproach AnalySiS

Aircraft Types

- A330: 2.7 (387)
- A320: 11.4 (1651)

Airports

- DAAE: 4.3 (628)
- DAON: 3.2 (457)
- LFPO: 52.4 (7590)
- DAAG: 28.8 (4170)
- LFLL: 11.4 (1651)

Runways

- DAAE-RW26: 4.3 (628)
- DAON-RW25: 3.2 (457)
- LFPO-RW08: 2.8 (400)
- LFPO-RW26: 31.8 (4605)
- DAAG-RW27: 12.4 (1798)
- DAAG-RW23: 7.5 (1093)
- DAAG-RW09: 8.8 (1279)
- LFLL-RW17R: 1.7 (250)
- LFLL-RW17L: 2.4 (349)
- LFLL-RW35R: 4.0 (583)
- LFLL-RW35L: 3.2 (469)
TAPAS - Trajectory APproach Analysis

Data

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Events</th>
<th>Flight Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Compliant</td>
<td>Non Compliant</td>
</tr>
</tbody>
</table>

Phase: 25NM-THR

Airport: All

Runway: All

Aircraft: All

Compliance Criteria

- Too Low: 15.7 (2270)
- Lateral Deviation: 36.0 (5218)
- Glide Deviation: 23.2 (3360)
- Too High: 22.6 (3273)
- Compliant: 48.5 (7025)

Operational Limits

- Critical: 9.3 (1351)
- Warning: 39.0 (5649)
- Nominal: 51.7 (7496)

Energy Results

- Atypical: 2.1 (308)
- Typical: 56.0 (8849)

Event Phase

- Go Around: 9 (57)
- Descent: 7.6 (1098)
- Approach: 32.2 (4671)
- Final Approach: 50.6 (7338)
- Landing: 55.0 (7966)

Event Number

- More than three: 8.7 (973)
- Three Events: 10.3 (1488)
- Two Events: 24.0 (3473)
- One Event: 34.5 (5004)
- No Events: 24.5 (3558)

Event Level

- Inf: 1.9 (277)
- High: 20.4 (2963)
- Medium: 54.4 (7884)
# Event Section

## TAPAS - Trajectory APproach Analysis

### Event List

<table>
<thead>
<tr>
<th>Event</th>
<th>Number of occurrences per 100 flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed below 0500</td>
<td>26.4 (3827)</td>
</tr>
<tr>
<td>Height High THR</td>
<td>24.2 (3504)</td>
</tr>
<tr>
<td>Long Touchdown</td>
<td>20.1 (2907)</td>
</tr>
<tr>
<td>Short Flare</td>
<td>19.6 (2839)</td>
</tr>
<tr>
<td>Late Setting Landing Conf</td>
<td>8.3 (1205)</td>
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<tr>
<td>High ACC LDG</td>
<td>8.2 (1184)</td>
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<tr>
<td>Low Thrust below 0500</td>
<td>4.3 (622)</td>
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<tr>
<td>High ACC Flight</td>
<td>3.6 (519)</td>
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<tr>
<td>Significant Tail Wind LDG</td>
<td>2.6 (412)</td>
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<tr>
<td>DSI Dual Stick Input</td>
<td>2.8 (399)</td>
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<tr>
<td>High Rate Dec 3000 1000</td>
<td>1.7 (250)</td>
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<tr>
<td>Late Flare</td>
<td>1.6 (232)</td>
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<tr>
<td>Late Thrust Reduction LDG</td>
<td>1.5 (215)</td>
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<tr>
<td>Degraded Flight</td>
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<tr>
<td>High Speed 0500</td>
<td>1.3 (192)</td>
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<tr>
<td>TCAS</td>
<td>1.3 (185)</td>
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<tr>
<td>Level Bust Suspicion</td>
<td>1.3 (185)</td>
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<tr>
<td>High Speed below 8000 Descent</td>
<td>1.2 (178)</td>
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<tr>
<td>Height Low THR</td>
<td>1.1 (165)</td>
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</tbody>
</table>

### Filter Options

- **Phase**: 25NM-THR
- **Airport**: All
- **Runway**: All
- **Aircraft**: All
Flight Study Section

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<table>
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<tr>
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<td></td>
</tr>
<tr>
<td></td>
<td>Typical</td>
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<td></td>
</tr>
</tbody>
</table>

### Phase
- Z3NM-THR

### Airport
- LFPO

### Runway
- All

### Aircraft
- All

### Flight Study

#### Trajectory Information
- Traj Id: 128681

#### Compliance
<table>
<thead>
<tr>
<th>Compliance</th>
<th>Atypical</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>2NM - 10NM</th>
<th>15NM - 30NM</th>
<th>35NM - THR</th>
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<tbody>
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<td>Operational</td>
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<td>2</td>
<td>2</td>
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<td>2</td>
</tr>
<tr>
<td>CAS</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>All</td>
<td>0</td>
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Case Study

- 16471 flights approach at LFPO, LFFF, LFML, DAON, DAAE and DAAG
- A320
- 25NM to runway threshold (25NM-15NM-5NM-THR)
- FDM events (low, medium, high)
Safety Event Analysis

Strong correlation between atypical flights and safety events number/intensity

- No safety event ratio: 27.8% -> 9.7%
- More than 3 safety events ratio: 5.4% -> 30.6%
- high-intensity events per 100 flights: 18.5 -> 92.7
- Long Touchdown ratio: 4.3% -> 7.5%
- Unstabilized Approach Low: 2.9% -> 18.6%
- Unstabilized Approach High: 0.3% -> 2.7%
Atypicality Appearance Phase Analysis

![Diagram showing atypicality appearance phase analysis with counts and percentages for different phases: 25NM to 15NM (138, 100.0%), 15NM to 5NM (117, 48.3%), 5NM to THR (85, 55.2%), and 5NM to THR (57, 37.0%).]
Inappropriate Control Inputs

A320 - Flaps Configuration Time Distribution and Atypical Ratio (16471 flights)

- Atypical Ratio

Time (s)

Number of trajectories

0 60 120 180 240 300 360 420 480

Atypical Ratio (%)

3.7 % 1.8 % 1.3 % 1.3 % 2.2 % 1.4 % 0.9 % 15.2 %
Inappropriate Control Inputs

A320 - Gear Down Configuration and Atypical Ratio (16471 flights)

- 28.6 %
- 9.1 %
- 1.2 %
- 0.9 %
- 0.0 %

Number of trajectories

Flaps Configuration

Atypical Ratio (%)
Example 1

TAPAS - Trajectory Approach Analysis

Data | Statistics | Events | Flight Study
--- | --- | --- | ---

Phase: 25NM-THR | Airport: All | Runway: All | Aircraft: All

Limits: Operational 16670 | Traj Id: 16670 | Traj # (over 13409): 5444

Origin Airport | Destination Airport | Destination Runway | Registration | Type | Compliance | Atypical | Operational | Too High | Glide Deviation | Too Low | Lateral Deviation | 0 | 1 | 2 | 1 | 1 | 0 | 1

Latitude | Longitude
2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5

Altitude | Distance to Threshold (NM)
0 | 25 | 50 | 75 | 100

Atypical | Operational | GS | CAS | Ait | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 2 | 2 | 0

Parameters | 25NM - 15NM | 15NM - 5NM | 5NM - THR
--- | --- | --- | ---

Ground Speed | Computed Air Speed
0 | 100 | 200 | 300

Left Engine | Right Engine | Speed Brakes
Gears | FULL | 2 | 3 | FULL | Gears

Engage

Founding Members
Example 2

TAPAS - Trajectory APpraoch Analysis

Data  Statistics  Events  Flight Study

- Phase: 25NM-THR
- Airport: All
- Runway: All
- Aircraft: All

Limits:
- Operational: 28358
- Traj Id: 28356
- Traj Id: 13409: 12427

Compliance  Atypical  Operational
- Too High: 0
- Glide Deviation: 0
- Too Low: 0
- Lateral Deviation: 0

Parameters
- 25NM - 10NM: 0
- 10NM - 5NM: 2
- 5NM - THR: 2

- Atypical
- Operational
- GS: 0
- CAS: 0
- Alt: 0

Engage

founding members
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Conclusions

▶ Relevant atypical energy behaviours detection based on ground data available parameters and confirmed by FDM data

▶ Pedagogical tool highlighting non monitored behaviors and potential threats

▶ Off-line analysis software, complementary to FDM monitoring analysis
Perspectives and future works

- Other aircraft types (B737)
- Real time extension to ground and on-board tools (research)
- Aircraft landing configuration detection
- Discussions with FDM analysis software providers
Questions

Thank you for your attention, any questions?