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Comparative Analyses of Operational Flights with AirFASE and The Morning Report Tools

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February 2009

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TABLE OF CONTENTS

LIST OF FIGURES

COMPARATIVE ANALYSES OF OPERATIONAL FLIGHTS WITH AIRFASE AND THE MORNING REPORT TOOLS

Nicolas P. Maille[1] and Irving C. Statler[2]

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ABSTRACT

This report describes a cooperative experiment conducted by ONERA and NASA, with the support of Airbus S.A.S. and easyJet Airline Company, Ltd. The study evaluated the benefits of two distinctly different methodologies for analyzing the same set of digital flight-recorded data. The experiment analyzed a set of easyJet commercial-flight data with both typical Flight Operational Quality Assur-ance (FOQA) software of an airline (in this case, AirFASE, developed by Airbus and Teledyne) and The Morning Report of Atypical Flights (developed by NASA). The study demonstrated the feasibility and potential value of using The Morning Report tool in conjunction with the FOQA airline tool and also showed the complementarities of the results produced by the two approaches.

1. INTRODUCTION

1.1 Scope of this Report

This report describes a cooperative experiment conducted by ONERA and NASA, with the support of Airbus S.A.S. and easyJet Airline Company, Ltd. This work was achieved under the NASA-ONERA "human factors" memorandum of agreement (ref. 1). The ONERA share of the work was partly funded by Airbus.

The aim of the study was to evaluate the benefits of two types of analyses of digital flight-recorded data based on distinctly different methodologies. The experiment was achieved by using a set of commercial-flight data provided by easyJet and two data-analysis tools developed by NASA and Airbus, respectively.

This work supports the emerging idea that a new step in the management of safety risks in air transportation can be achieved by the combined use of "classical" analysis employed by the Flight Operational Quality Assurance (FOQA) system (based on tracking exceedances predefined by subject-matter experts) and new clustering tools that allow the discovery of unexpected anomalous events.

Of course, this work is only one element in larger sets of research studies conducted by NASA and ONERA focused on the benefit of extracting and integrating information from various sources of data (digital and textual) (refs. 2 and 3).

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1.2 Applicative Background

Even though air transportation is the safest mode of travel, maintaining and improving the level of safety is a major concern of the aeronautical community. The airlines and the authorities would like to pursue proactive management of safety risks from a system-wide perspective. Such a process involves identifying hazards, evaluating causes, assessing risks, and implementing appropriate solutions. It is a nontrivial task that relies on the capability of continuously monitoring system performance and effectively analyzing very large databases with minimum human expertise.

Some airlines have developed quality-control strategies in which they routinely analyze their performance data. Their safety programs rely mainly on two types of data sources: (1) digital numerical data recorded during flight, and (2) textual data from incident-reporting systems. Other techniques such as in-flight audit are emerging but are not widely used yet.[3]

This report focuses on the analyses of digital flight-recorded data. Many airlines have implemented a FOQA system and routinely analyze all their flight data. The principle of the FOQA analyses relies on detection of prescribed deviations from standard operating procedures. These FOQA systems have contributed to the continuing improvement of the reliability of air transportation. Nevertheless, the analyses performed with these systems can reveal only the issues tracked by the prescribed deviations. The next challenge for proactive management of safety risk is to be able to discover the unknown events that could compromise safe operations.

NASA has developed a particularly promising tool, called "The Morning Report of Atypical Flights," to discover anomalous events in complex data systems (ref. 4). The Morning Report was one of the tools developed under the Aviation Performance Measurement System (APMS) Project (ref. 5).

1.3 Aim of the Study

Both the ONERA-NASA collaboration and the organizations' privileged links with leading actors of the air transportation community created the opportunity to analyze a significant set of commercial-flight data with both the FOQA airline software and The Morning Report tool. The purpose was to compare the results of analyses of the same set of data using both of these tools. The work performed during the study included:

- The selection and extraction of a significant set of flights from the airline's database;
- The development of a tool to format the digital flight data as required for use by The Morning Report tool (ref. 6);
- The analysis of the selected set of digital flight data with the airline's conventional FOQA software;
- The analysis of the same selected set of digital flight data with The Morning Report; and
- The comparison of the results produced by the two tools.

This report focuses on comparison of the results of the analyses performed with the two tools.

[3] At least when measured on the basis of the extent of the ongoing collection of data.

2. DESCRIPTION OF THE EXPERIMENT

2.1 Context

The experiment described in this report was designed to evaluate the potential added value offered by The Morning Report tool compared to the more classical techniques used in FOQA programs. Because The Morning Report was developed and evaluated mainly with data from U.S. airlines, one part of the challenge was to perform the study in a different operational context.

This study was conducted in cooperation with the European airline easyJet Airline Company, Ltd., with data recorded during flights conducted between a European city pair. These data along with the FOQA analysis tool, Aircraft Flight Analysis and Safety Explorer (AirFASE), were provided to ONERA for the study from easyJet through Airbus. NASA provided ONERA with The Morning Report tool and assisted ONERA in adapting it and the data for the experiment.

2.2 AirFASE: The FOQA Tool used by the Airline

AirFASE is a measurement, analysis, and reporting software tool developed jointly by Teledyne and Airbus that deals with in-flight operational performance of commercial aircraft. Routinely used by more than 100 airlines, including easyJet the past several years, this tool offers a stable definition of deviations (ref. 7). It is similar in its concepts and capabilities to the other FOQA analysis tools generally used by U.S. and European air carriers. Within easyJet, the safety department uses AirFASE to analyze all the flights, and the level-3 deviations (i.e., those considered of highest severity) are operationally validated.

2.3 The Morning Report of Atypical Flights

This software, developed through a NASA program, is not based on prescribed operational deviations, but rather relies on statistical algorithms that identify atypical flights from a multivariate analytical comparison with a baseline of typical flights. The Morning Report considers the comparison by phase of flight and identifies which flight parameters contributed to causing a flight phase to be designated as atypical. The tool also clusters the flights into a finite number of distinct patterns to aid in the interpretation of the identified atypical event.

This software is called "The Morning Report" because it was designed to run each night, producing a report in the morning of the flights during the previous day that were atypical relative to the baseline of data from past comparable flights. The Morning Report identifies only the atypical characteristics of the newly added flights from the previous day and uses past flight data (from an arbitrary number of previous comparable flights) to establish the baseline of typical flights. The data used for this experiment was limited to those from a single make of aircraft and a single city pair to enable the comparability analysis in The Morning Report.

The Morning Report is not used by easyJet. Not all the parameters from the flight-data recorder of an easyJet aircraft were used for the typicality analyses in this study. The selected parameters are defined by phase of flight, and the phases included in the analyses can be selected. For this study, ground phases (e.g., taxi in, taxi out, or ramp phases) were excluded. The relevant parameters and the definitions of the phases of flight that were used in this study were selected on the bases of NASA's prior experience with The Morning Report. The parameters used for this study are indicated in appendix A.

2.4 The Flights Selected

The experiment entailed a set of commercial flights selected to fit the requirements of The Morning Report; namely, all the flights came from a single city pair, with the same type of aircraft (Airbus A319). In order to show the airline how best to use the tool, all the flights (from the chosen city pair and the aircraft type) over approximately 6 months were selected, for a total of 289 flights. The data from the first 4 months of these flights (210 flights) were used to define the baseline and so were used only by The Morning Report, while the 79 remaining flights were the ones studied using both The Morning Report and AirFASE.

2.5 Summary of the Methodology Used

The 79 flights were analyzed independently with the two tools as indicated in figure 1. Each tool identified some flights that could be of interest for the airline safety department. Sections 3 and 4 summarize the results obtained with AirFASE and The Morning Report, respectively.

Then, in section 5, the results obtained by the two methodologies are compared. While both detected some safety-related events, special attention is given in section 5 to the flights detected by only one tool. These flights reveal the complementarities of the tools.

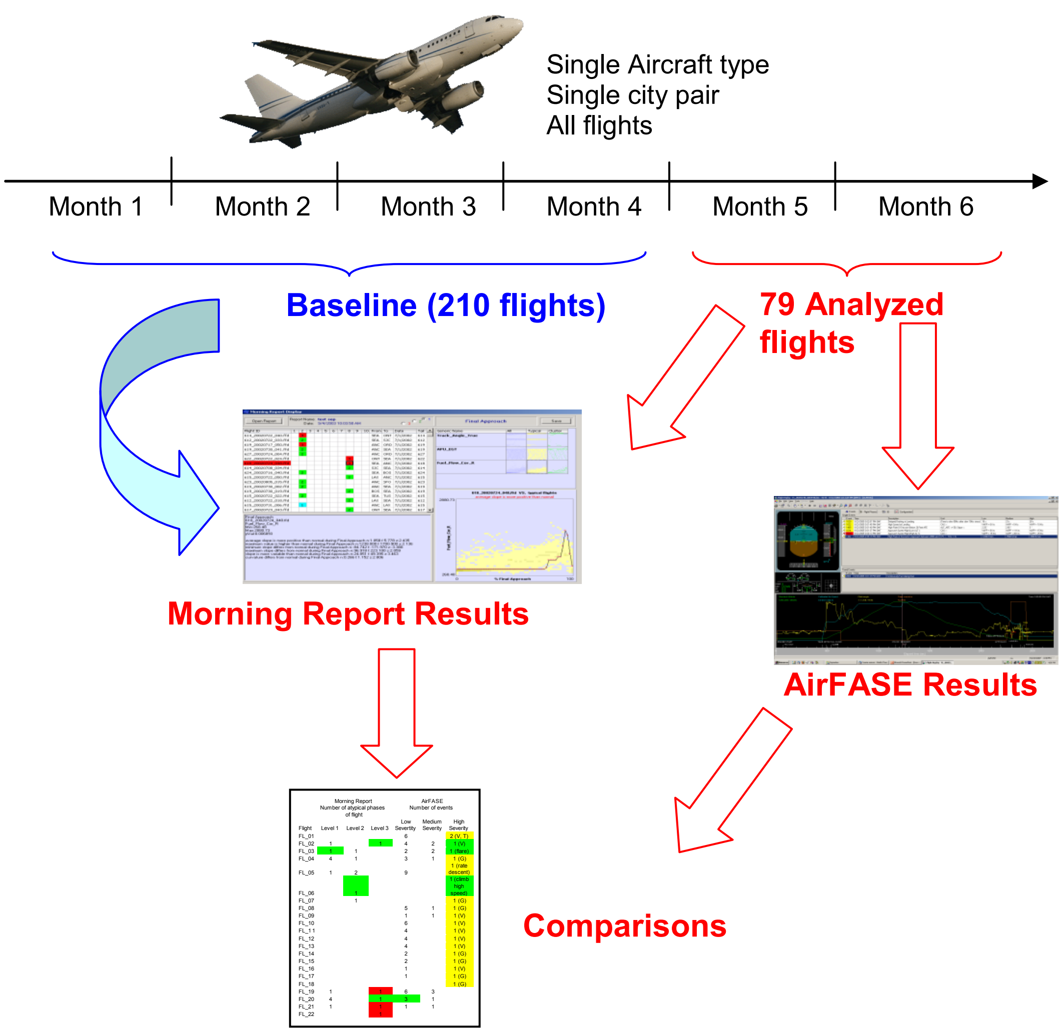


Figure 1. Methodology for the experiment.

3. OVERVIEW OF THE AIRFASE RESULTS

The set of 79 flights contains 258 AirFASE events distributed among the three severity classes, as shown in figure 2. Low-severity events are called level 1, medium-severity events are level 2, and high-severity events are level 3. Note that the absolute number of events (even by severity class) is not meaningful by itself as it greatly depends on the level of the threshold that has been assigned to the event description. A big challenge for the airline safety officer is to tune these event descriptions in order to obtain "all" the events that are operationally significant in the medium- and high-severity classes. For this experiment, the definitions of events as they were already prescribed in AirFASE for easyJet were used.

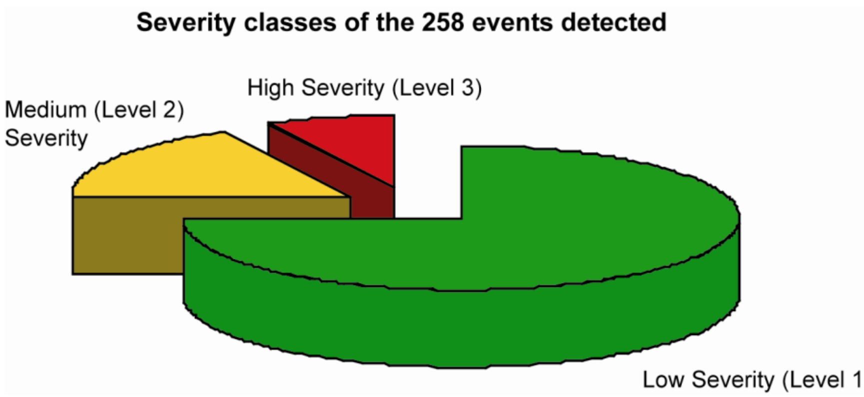


Figure 2. The three severity classes.

Very often, the airline safety officer closely reviews only those flights with high-severity events, while the low- and medium-severity classes are more useful for building a statistical view of the strengths and weaknesses of the operational practices. In this dataset, the 19 high-severity AirFASE events detected belong to 18 flights. Now consider the type of high-severity events detected.

Figure 3 indicates that the two main areas of concern were high-speed approaches (42% of the high-severity events) and taxi-speed exceedances (37% of these events). Such data give the airline an objective base for further analyses to manage safety, improve procedures and training, form aircrews, and so on.

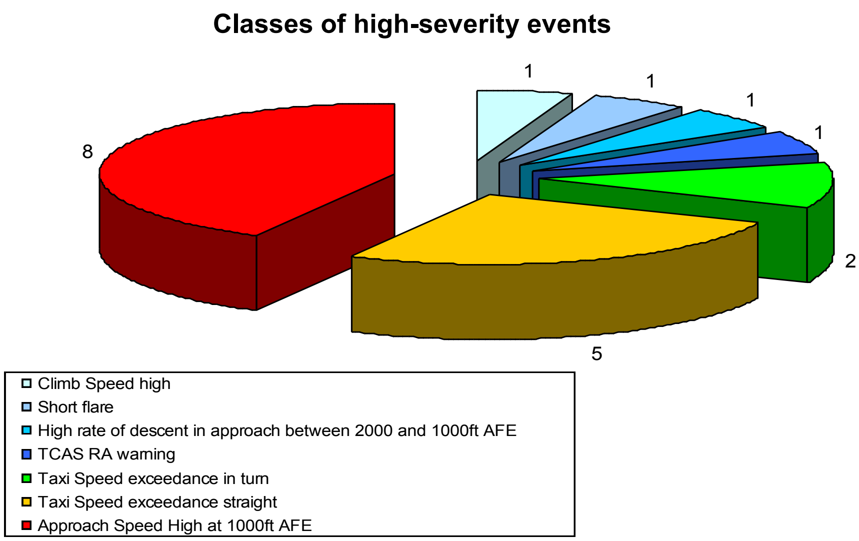


Figure 3. Classes of high-severity events.

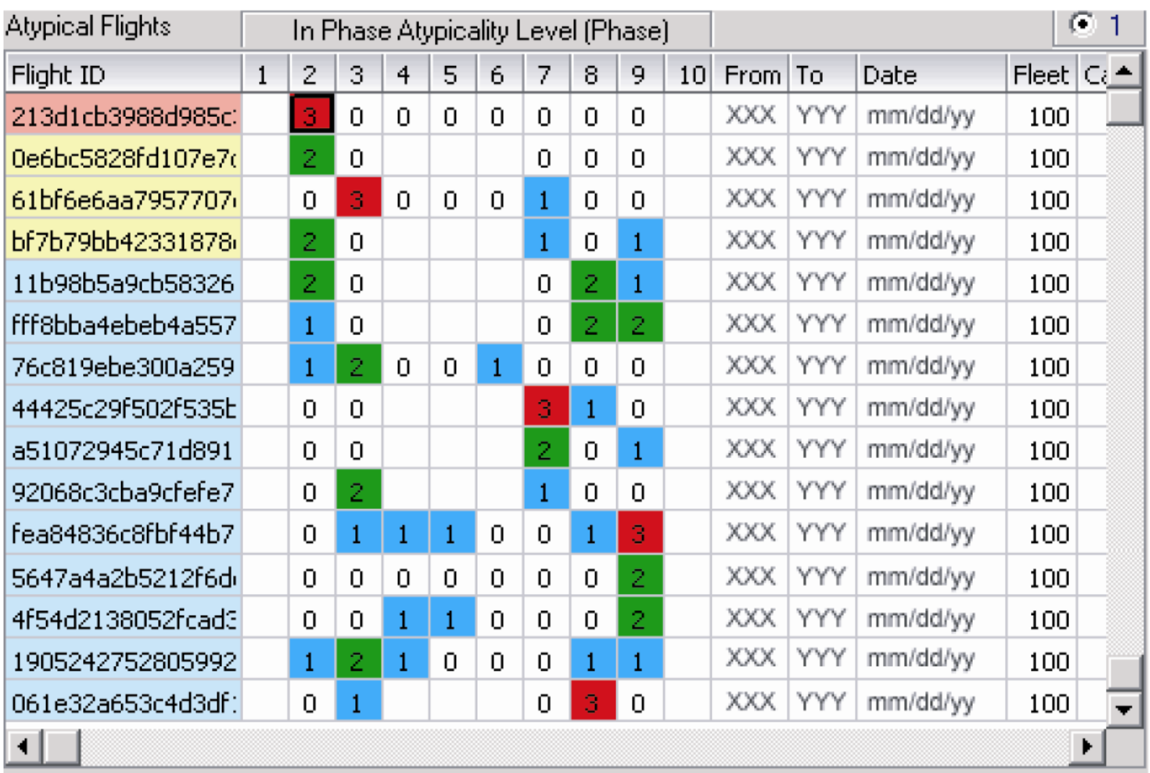
This study did not analyze these data any further, but rather focused on finding out how these level-3 AirFASE events (and, if necessary, level-2 events) correlate with events found by The Morning Report.

4. OVERVIEW OF THE MORNING REPORT RESULTS

The Morning Report compared the 79 flights from the latest data batch to the baseline of the previous 210 flights, and calculated an atypicality score for each phase of each flight. Although The Morning Report attributes a global atypicality score for each flight in its display, the determination of atypical-ity is based on comparisons to the typical set by each of 10 phases of flight, a more meaningful method from an operational perspective. The results are summarized in figure 4, generated by The Morning Report. As mentioned previously, The Morning Report was not configured to consider ground phases (phases 1 and 10 on figure 4) in this study.

The Morning Report identified only 1 level-3 atypical flight (highlighted in red in the Flight ID column of figure 4), 3 level-2 atypical flights (the yellow ones) and 11 level-1 atypical flights. Among these 15 flights, 5 phases of flight had level-3 atypicality scores, 12 phases had level-2 atypicality scores, and 21 phases had level-1 atypicality scores. Notice that The Morning Report does not necessarily assign a high-severity level to the entire flight even though it had a level-3 atypical phase in that flight.

For each atypical phase, the tool identifies which parameters contribute the most to this atypicality. The Morning Report generates plots of these parameters, as indicated in figure 5. The characteristic of each atypical parameter is shown in the figure overlaid on the baseline of all the data (i.e., including both the baseline of 210 flights and the 79 flights being examined) in column 2 and overlaid on the baseline data alone in column 3. Column 4 indicates the cluster to which this flight belongs, and column 5 shows the recorded flight trace of the parameter.



Atypical Flights | In Phase Atypicality Level (Phase) | 1

Flight ID	1	2	3	4	5	6	7	8	9	10	From	To	Date	Fleet	Ca
213d1cb3988d985c:		3	0	0	0	0	0	0	0		XXX	YYY	mm/dd/yy	100	
0e6bc5828fd107e7(		2	0				0	0	0		XXX	YYY	mm/dd/yy	100	
61bf6e6aa7957707		0	3	0	0	0	1	0	0		XXX	YYY	mm/dd/yy	100	
bf7b79bb42331878		2	0				1	0	1		XXX	YYY	mm/dd/yy	100	
11b98b5a9cb58326		2	0				0	2	1		XXX	YYY	mm/dd/yy	100	
fff8bba4ebeb4a557		1	0				0	2	2		XXX	YYY	mm/dd/yy	100	
76c819ebe300a259		1	2	0	0	1	0	0	0		XXX	YYY	mm/dd/yy	100	
44425c29f502f535t		0	0				3	1	0		XXX	YYY	mm/dd/yy	100	
a51072945c71d891		0	0				2	0	1		XXX	YYY	mm/dd/yy	100	
92068c3cba9cfefe7		0	2				1	0	0		XXX	YYY	mm/dd/yy	100	
fea84836c8fbf44b7		0	1	1	1	0	0	1	3		XXX	YYY	mm/dd/yy	100	
5647a4a2b5212f6d		0	0	0	0	0	0	0	2		XXX	YYY	mm/dd/yy	100	
4f54d2138052fcad3		0	0	1	1	0	0	0	2		XXX	YYY	mm/dd/yy	100	
1905242752805992		1	2	1	0	0	0	1	1		XXX	YYY	mm/dd/yy	100	
061e32a653c4d3df:		0	1				0	3	0		XXX	YYY	mm/dd/yy	100	

Figure 4. Atypical flight and phases.

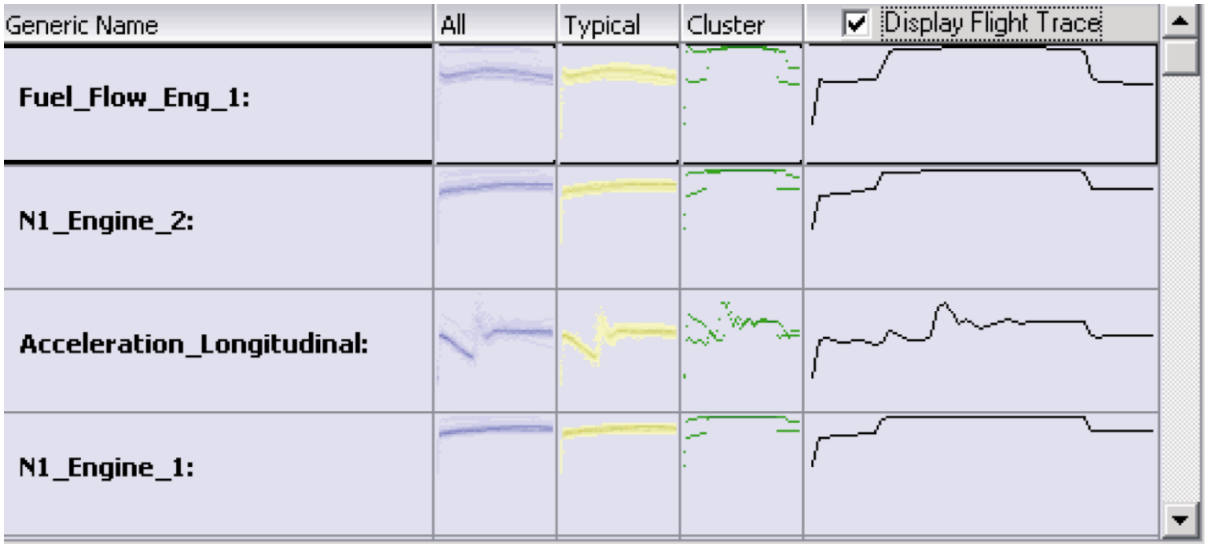


Figure 5. More atypical parameters for a given atypical phase of flight.

Of course, conversely to the analysis using AirFASE, the purpose of such a tool is not to generate statistics for a global view of operational performance, but rather to identify the few flights (or phases of flights) that reveal unexpected atypical situations. The analyses of these flights can allow the safety officer to discover new safety hazards, which may then become prescribed events to be tracked statistically with AirFASE.

The next section analyzes all the level-3 atypical flight phases discovered with The Morning Report and compares them with the events of that flight that were identified by AirFASE.

5. AIRFASE VS. THE MORNING REPORT

Both of the analysis tools highlighted events that might be of interest to the safety officer. This section compares the results of these two tools in order to identify events detected by both tools and evaluate the potential interest of events detected by only one tool. First, section 5.1 reviews the 19 high-severity events detected by AirFASE and discusses whether or not The Morning Report analysis identified them. Then section 5.2 reviews the level-3 atypical phases of flight The Morning Report found that do not map with an AirFASE event and discusses the operational significance of those situations. Finally, section 5.3 summarizes the mapping between the events detected by the two methodologies.

5.1 AirFASE High-Severity Events

This section examines whether or not The Morning Report detected the 19 high-severity events that AirFASE detected (fig. 3). Also, for each high-severity event identified with AirFASE, it discusses whether the phase of flight is classified as atypical (at whatever the level) with The Morning Report and whether the parameters that render it atypical correlate with the type of AirFASE event. This process allows us to determine which events were detected by AirFASE but not by The Morning Report.

The following analysis of the AirFASE events is conducted according to the classes of exceedances depicted in figure 3.

5.1.1 Taxi-speed exceedances (straight or in turn)

These two classes of exceedances contain seven events that The Morning Report could not detect because the tool was not configured to analyze ground phases for this study.

5.1.2 Approach speed high at 1000 ft AFE

These eight AirFASE level-3 events are related to a high speed during the approach phase. In AirFASE, these events reflect the difference between the reference approach speed and the real speed of the aircraft. The reference approach speed is the output of a complex calculation performed on Airbus aircraft that considers the global mass of the aircraft.

Because the difference between the airspeed and the reference approach speed was not included among the parameters selected for The Morning Report as it was configured for this study, The Morning Report tool could not identify these specific types of AirFASE events. However, The Morning Report identified this event detected by AirFASE for flight FL_02 as a level-3 atypical approach phase for FL-02, while at the same time assigning the flight itself a level-2 severity. These results are compared in figure 6.

Figure 6 shows that The Morning Report found the airspeed of flight FL_02 during final approach (black line) to be higher than the baseline (blue regions) representing the previous 210 flights. During the same time, the altitude decreases more rapidly than the baseline data. The atypicality of this phase of flight identified by The Morning Report is related to the high-speed approach event detected by AirFASE.

In summary, among the eight level-3 high-speed approaches reported by AirFASE, The Morning Report detected only one. The discrepancy is largely due to the fact that the parameter used by AirFASE to define the event (i.e., the difference between airspeed and the reference approach speed) was not included in The Morning Report settings.

Figure 6 shows that The Morning Report used a very broad range of final approach speeds in the baseline data for its typical reference that may well have been indicative of the failure to account for the variation in the global mass of the aircraft as it is in the reference approach speed used by AirFASE. The broad range of speeds used as the typical reference by The Morning Report may indicate that the speed by itself is not a good indicator of this type of atypicality. A parameter to account for this typical range of approach speeds could be introduced into The Morning Report by way of a "derived parameter" using the recorded reference approach speed.

The difference in the results is an example of the difference in perspective between the two analyses. AirFASE identifies this event on the basis of just the single parameter, whereas the multivariate perspective of The Morning Report caused it to assign a high-severity level to only one final approach phase and lower levels to this phase for the other seven flights identified by AirFASE.

5.1.3 TCAS RA warning

The Morning Report did not detect this single level-3 AirFASE event (FL_01) because it did not include the Traffic Collision Avoidance System (TCAS) resolution advisory (RA) parameter for the atypicality calculations in this study.

AirFASE events of flight FL_02

Events | Flight Phases | 3D | Configuration

Single Events

Event	Description	Unit	Low	Medium	High
1030	Taxi Speed Exceedance in Straight path	GS	> 32 Kts	> = 35 Kts	> = 40 Kts
1102	Low Pitch Rate at TakeOff	PITCH_RATE (MAX) >:	2.5 °/s	2 °/s	1.5 °/s
1010	Approach Speed High (High ALT)	CAS >:	VAPP + 15 Kts	VAPP + 20 Kts	VAPP + 25 Kts
1601	Late Landing Flap Setting	ALTITUDE<:	1000 ft	750 ft	500 ft
1012	Approach Speed High (Med ALT)	CAS >:	VAPP + 10 Kts	VAPP + 15 Kts	VAPP + 20 Kts
1813	Height High at Threshold	High Height at THR	>=60 ft	>=70 ft	>=80 ft
1818	Long Touchdown	DIST_TO_THR (at TD)	750 m	900 m	1050 m

The Morning Report atypical phases of flight FL_02_

061e32a653c4d3df:	0	1			0	3	0		SGG	FPO	9/1/2005	100	Ea

Most atypical parameters in final approach

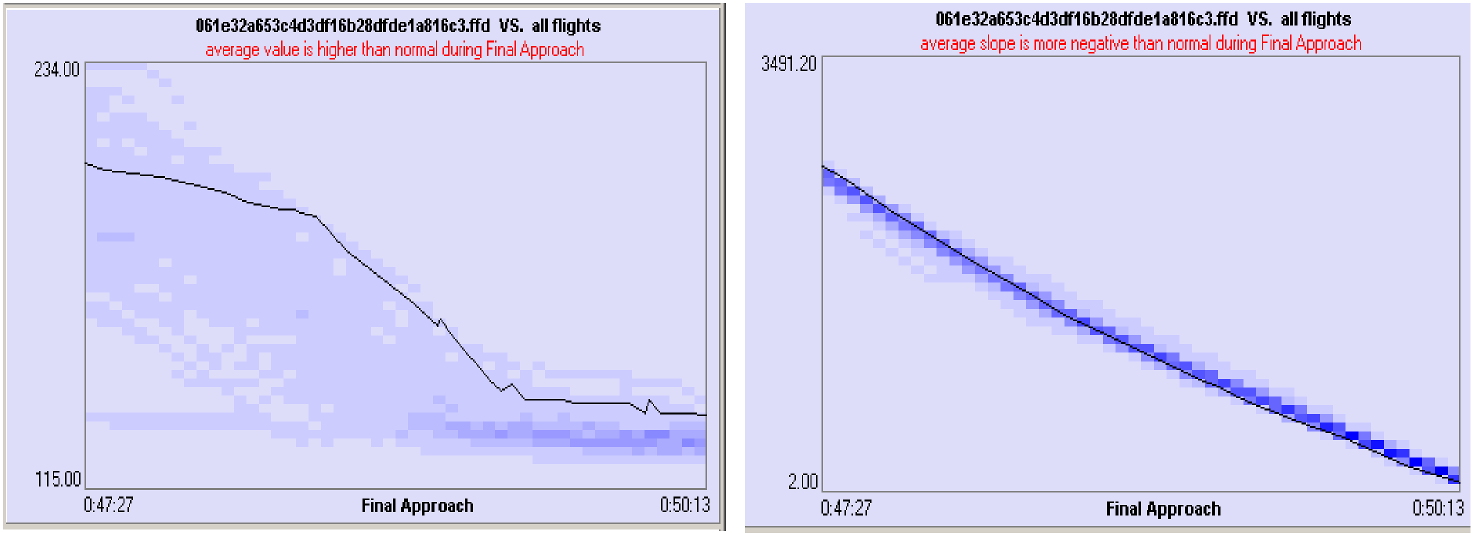


Figure 6. AirFASE and The Morning Report results for flight FL_02.

5.1.4 High rate of descent in approach

The Morning Report did not detect this single level-3 AirFASE event (FL_05) and, in fact, this phase of flight FL_05 had an atypicality score of 0 (i.e., a low level of atypicality). One possible explanation is that a high rate of descent during approach is a relatively frequent event in this set of 289 flights (including the baseline). In fact, according to AirFASE, 172 flights among the 289 flights selected have at least a low-severity AirFASE event of “High rate of descent in approach between 2000 and 1000 ft AFE” [Above Field Elevation].

Thus we can see from this case that The Morning Report is not adapted to tracking safety issues that occur frequently, while this tracking is clearly the strength of FOQA tools after the safety issue is defined as an exceedance event.

5.1.5 Short flare

The Morning Report identified this single level-3 AirFASE event (FL_03), shown in figure 7, as a level-1 atypical phase. Produced by The Morning Report, figure 7 shows that the pitch angle increases somewhat less than most of the baseline data and then decreases more quickly than the baseline data, while the elevator angle has a much more rapid movement than is seen in the baseline. The Morning Report deemed this comparison to be indicative of only a level-1 severity for the phase of flight.

Once again, such a level-3 AirFASE event is not well-detected by The Morning Report because the baseline contains other similar flights.

5.1.6 Climb speed high

In this experiment, The Morning Report identifies this single level-3 AirFASE event in FL_06 as a level-2 atypical takeoff phase of that flight. Figure 8 shows the AirFASE display of this event. The event called “climb speed high” is designated in AirFASE as 1032, its location on the figure indicates the time in the flight when the event was detected, and it appears in red because it has been identified as a level-3 event. Indeed, figure 8 shows that AirFASE detects this event during the initial climb, just after takeoff. The Morning Report tool did not use the same phase-of-flight decomposition in this study as AirFASE does, and this part of the flight was considered as part of The Morning Report’s takeoff phase of flight.

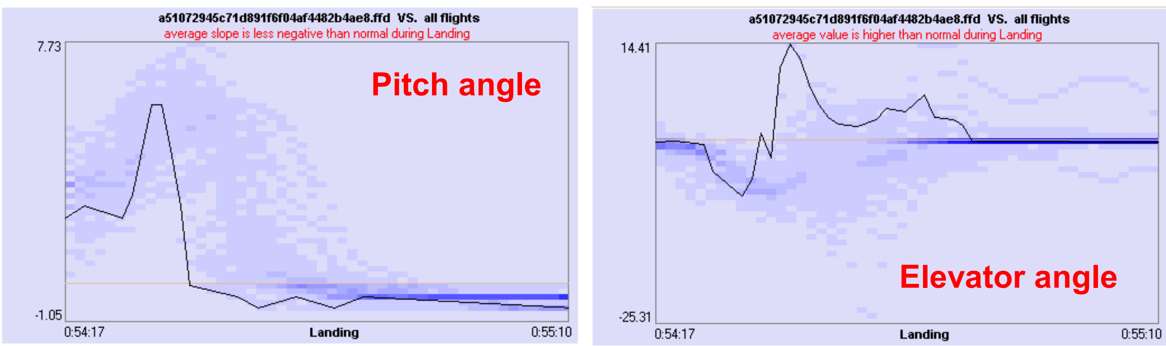


Figure 7. Most atypical parameters during landing for flight FL_03.

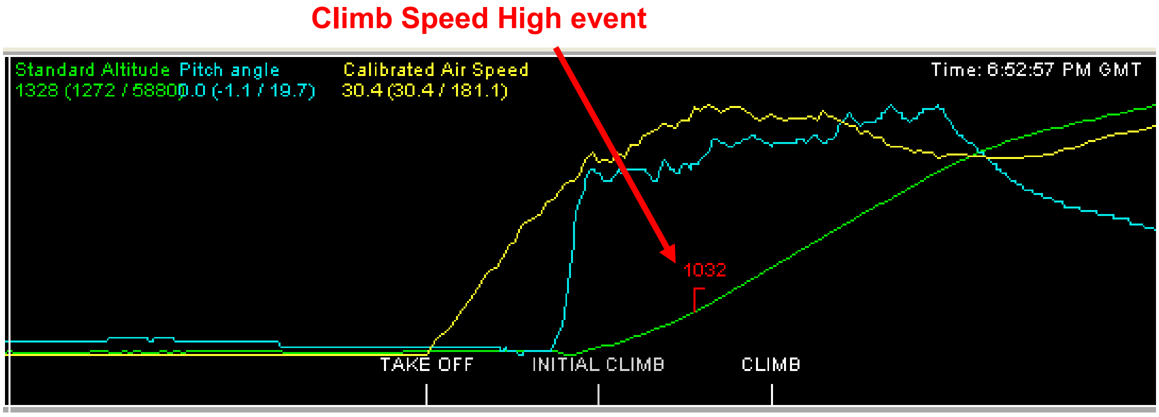


Figure 8. AirFASE climb speed high (1032) in flight FL_06.

Figure 9, from The Morning Report, shows that the parameters that contributed the most to the atypicality of this takeoff phase of flight were the altitude, the acceleration, the speed, and the fuel. The fuel parameter indicates that the crew applied a full-power takeoff procedure. Consequently, the acceleration is higher than the baseline and the airspeed also becomes higher than the baseline. The multi-variate comparison with baseline data provided by The Morning Report helps in the understanding of what happened.

This section has shown that The Morning Report tool as it was configured for this experiment detected only a few high-severity AirFASE events, and discussed explanations for each case. In fact, as has been noted, The Morning Report identified only one level-3 AirFASE event (approach speed high at 1000 ft AFE for flight FL_02) as a level-3 atypicality.

Now consider the level-3 atypical phases of flight that The Morning Report detected.

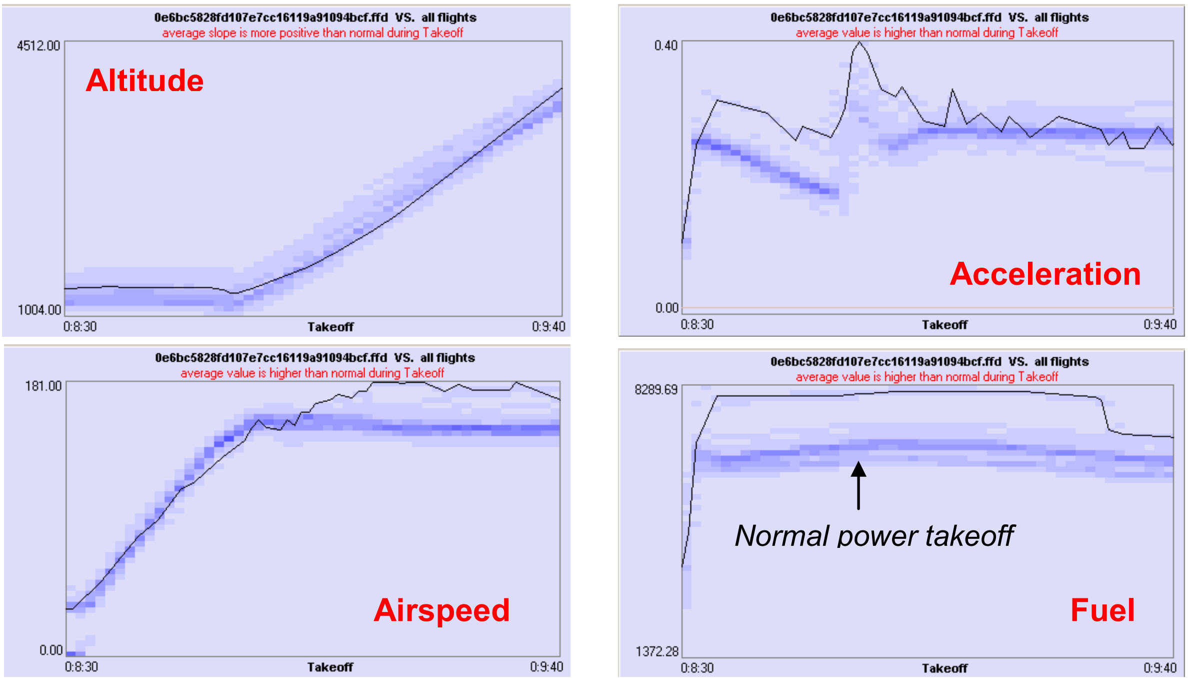


Figure 9. Atypical parameters of flight FL_06 for takeoff.

5.2 Morning Report Level-3 Atypical Phases

In this experiment, The Morning Report identified five flights with highly atypical phases of flight among the 79 flights from the last 2 months of the dataset in comparison with the previous 210 flights (see section 4). One of these five flights was also identified as having an AirFASE high-severity event in the same phase, as described in section 5.1. This section reviews the four remaining atypical flights identified by The Morning Report.

5.2.1 Flight FL_19: Fuel controller anomaly?

Flight FL_19 has a level-3 atypical low-speed climb phase of flight. As shown in figure 10, the parameters that were most responsible for making this phase atypical were the fuel flow (of both engines) and the longitudinal acceleration of the airplane.

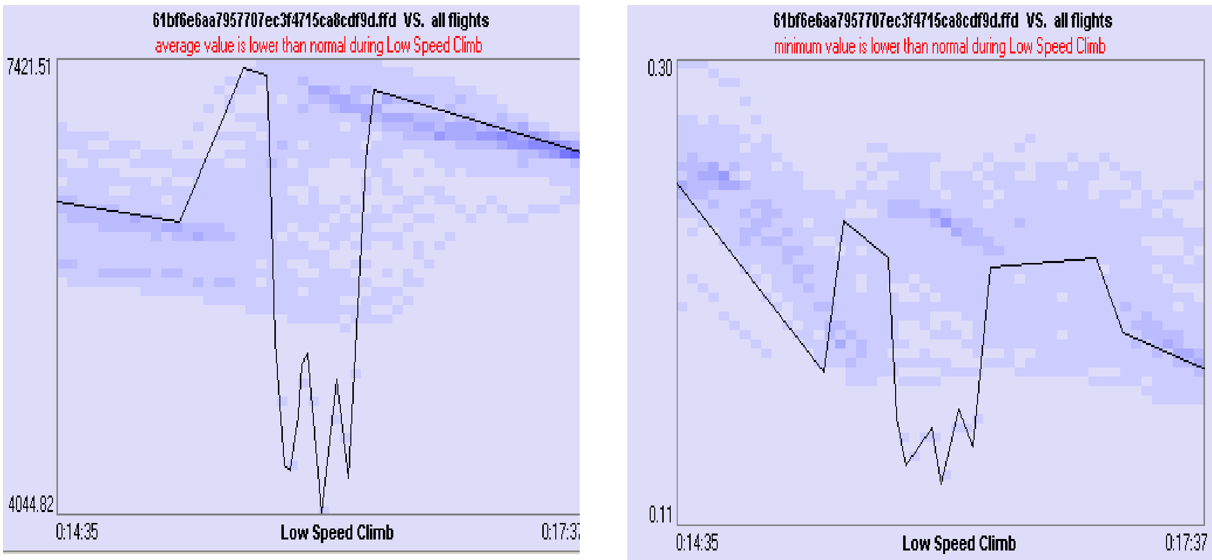
Notice the strange pattern for the fuel flow during about 30 seconds, and the longitudinal acceleration shows a similar pattern. Two explanations are possible: recording errors (bad data) or a fuel-controller anomaly. The first is very unlikely. If a recording error had occurred, the same pattern would be expected either on all the parameters (due to the recorder) or on only one parameter (due to the sensor). Here this anomaly appeared only on fuel-flow and related parameters (e.g., engine N1, acceleration,...) The possibility of a fuel-controller anomaly should be considered and an investigation should be made to search for similar patterns on a larger set of flights.

In AirFASE, no events were generated for this phase of flight.

This flight demonstrates that The Morning Report highlights unexpected atypical situations that can help the safety department discover latent or new concerns.

5.2.2 Flight FL_20: Questionable braking.

In the flight FL_20, The Morning Report identified a level-3 atypical landing phase of flight. This phase was designated as atypical mainly because the decrease of airspeed starts late and then occurs more rapidly than for the other flights. Figure 11 shows this decrease in airspeed and the associated longitudinal acceleration that reaches higher values of deceleration after landing than the flights of the baseline.



Fuel Flow **Longitudinal Acceleration**

Figure 10. Most atypical parameters for flight FL_19 during low-speed climb.

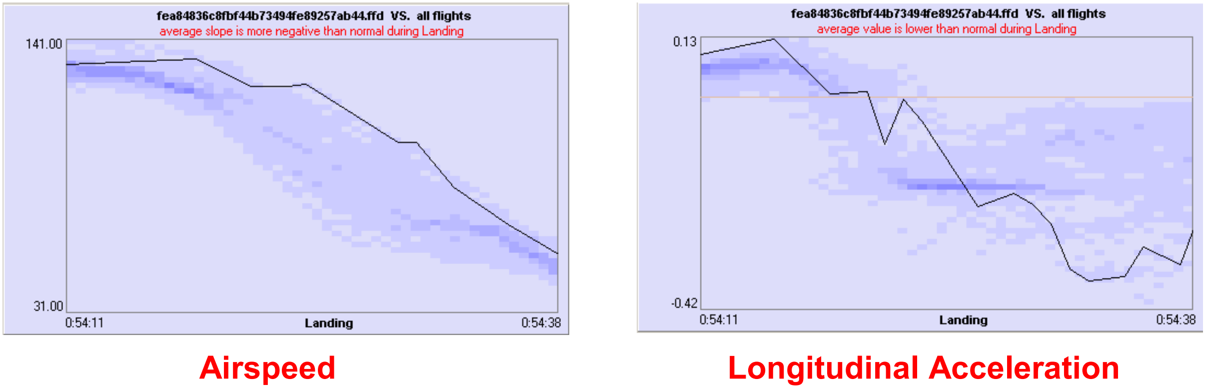


Figure 11. Most atypical parameters for flight FL_20 during landing.

For this flight, the AirFASE results indicated only a low-severity "questionable braking" event associated with the high negative value in longitudinal acceleration. The AirFASE display of this event (designated as 1035 in AirFASE) in figure 12 shows the time at which questionable braking was detected and appears in yellow on the display because it is identified as a low-severity (level-1) event.

So the atypicality detected by The Morning Report reflects a known issue already tracked by an AirFASE event, but The Morning Report identified it as a higher-severity event when compared with the baseline than did AirFASE based on comparison with its prescribed levels for this event.

5.2.3 *Flight FL_21*

In this flight, the level-3 atypical phase of flight detected by The Morning Report is the low-speed descent. The parameters that contribute to making this phase atypical are primarily: (1) values of N1[4] for both engines 1 and 2 that are lower than the baseline values; (2) the rudder position that has an average value more negative than the baseline; and (3) the vertical speed, which has a maximum value lower than the baseline. Figure 13 shows these parameters.

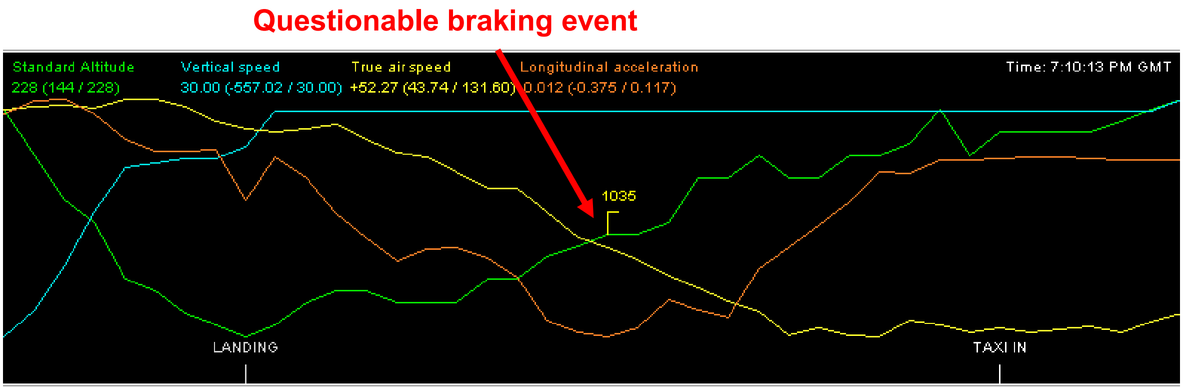


Figure 12. AirFASE event for flight FL_20 during landing.

[4] N1 is the rotational speed of the low pressure spool of the engine (in %).

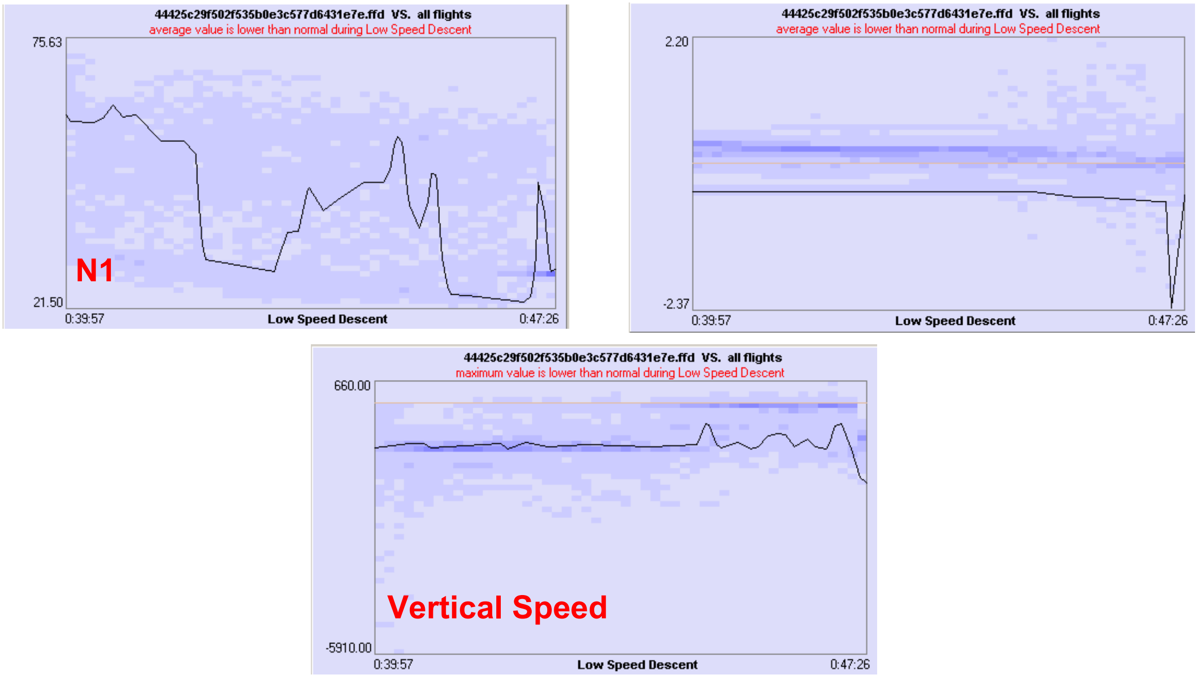


Figure 13. Most atypical parameters for flight FL_21 during low-speed descent.

This event was identified statistically as a level-3 phase of flight, but the operational significance of this event is not obvious. The rudder position is quite likely associated with a crosswind. Low-speed descent ends and landing phase begins about five seconds prior to touchdown. As shown in figure 13, the vertical speed in the baseline data increases at the end of the low-speed descent (and then returns to 0), while flight FL_21 still had negative vertical speed at the end of the low-speed descent phase of flight. So the average value of the vertical speed during low-speed descent is more negative for FL_21 than for the baseline. FL_21 was descending at idle power for a couple of minutes just before landing. Just before the end of low-speed descent, it seems that FL_21 slowed down and the pilot apparently added power while pushing the nose down to avoid a stall. This theory is, of course, speculation without the display of air-speed during both the low-speed descent and landing phases for confirmation, but, given what we have, the safety analyst would be most interested in this speculation as a starting point for understanding.

In the AirFASE analysis, there is no event for this phase of flight.

5.2.4 Flight FL_22: Possible wind shear

In this flight, the level-3 atypical phase of flight is the takeoff. The atypicality is mainly related to a step change in the fuel flow of both engines, as shown in figure 14. The other contributing parameters are the N1 of both engines and the longitudinal acceleration.

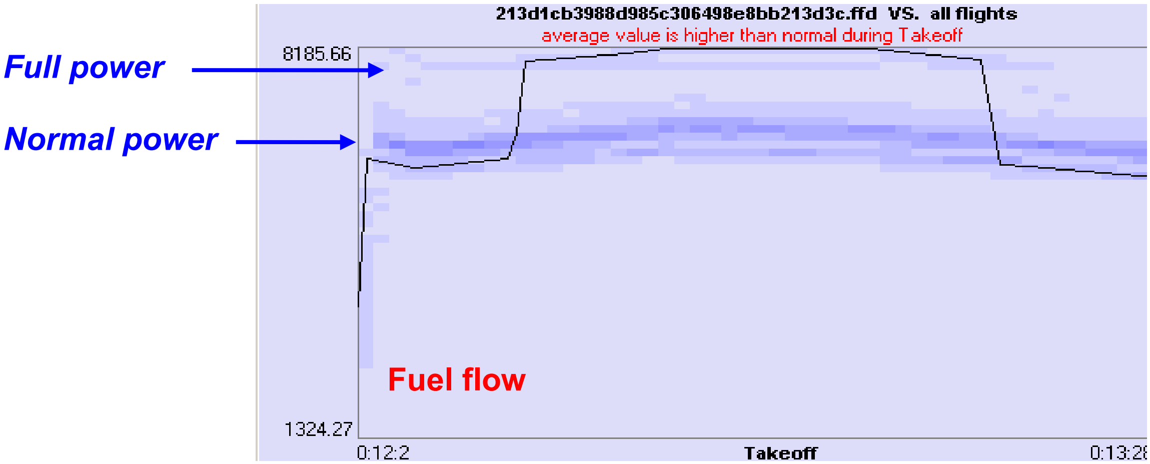


Figure 14. Fuel flow of engine 1 for flight FL_22 during takeoff.

From an operational point of view, the baseline (in blue) depicts principally the normal power for takeoff, which is used by nearly all the flights. But takeoff can be also realized with full power, as was already seen in section 5.1.6. The light blue part of the baseline at the top of the figure indicates that a few flights used this procedure.

In the case of flight FL-22, the crew started the takeoff with the normal power and 15 seconds later decided to change to a full-power takeoff. It is this change that made the flight highly atypical. From an operational point of view, it is interesting to understand why the crew made such a decision. To aid in this understanding, consider a few of the other parameters during the takeoff of flight FL_22 (see figure 15, from The Morning Report).

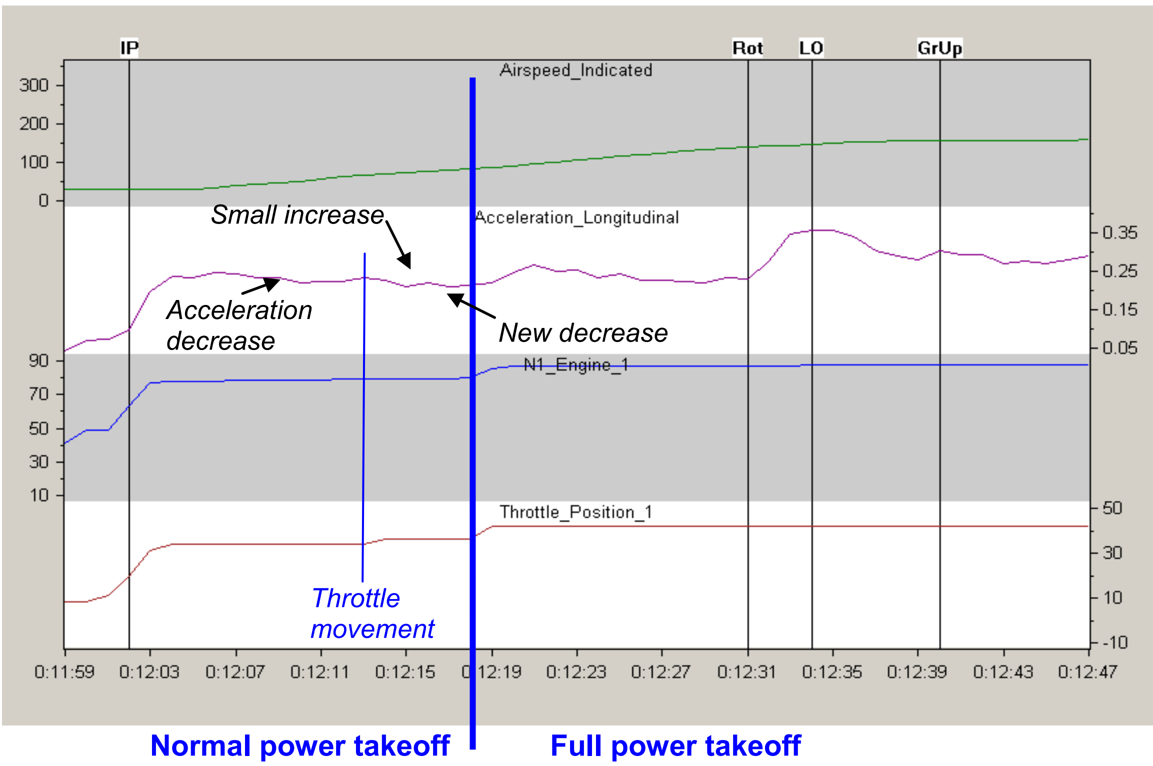


Figure 15. Takeoff parameters for flight FL_22.

Notice a gradual decrease of the acceleration after the start of the takeoff and the crew moved the position of the throttle slightly. Initially, the acceleration increased, but then it started to decrease again. So the crew put the throttle to full-power position. Such a decrease of acceleration during takeoff could be associated with a change of wind conditions, possibly a wind shear. It is evident that the crew detected the unusual performance of the aircraft quickly and reacted appropriately.

In AirFASE, no event was associated with this phase of flight.

5.3 Summary of the Results

Flight FL_02 relates to a high-speed approach identified as a high-severity event in AirFASE and a level-3 atypical approach phase of flight in The Morning Report. Both tools detected this situation, albeit from two different perspectives.

Two other high-severity events as defined by AirFASE (namely, short flare on FL_03 and high-speed climb on FL_06) are also identified in The Morning Report, but they were designated as level-1 or -2 atypical phases in those flights compared with the baseline.

The Morning Report did not detect atypical (at any level) phases of flight that were relevant to 16 events identified by AirFASE as high severity, either because the settings of The Morning Report as configured for this study did not account for the relevant parameters or because the situation was not unusual in the baseline flights.

One level-3 atypical situation (questionable braking) identified with The Morning Report as an atypical landing phase was detected by AirFASE as a low-severity event based on the deceleration parameter.

The three remaining level-3 atypical phases of flight identified with The Morning Report highlighted situations that could not be detected by AirFASE. At least two of them have an operational interest: one dealing with a possible fuel-flow anomaly, which should be further investigated, and one dealing with possible wind shear.

6. AIRFASE AND MORNING REPORT COMPLEMENTARITIES

This study, using only a small set of flight data, demonstrated fundamental differences between the two tools used for analyses.

AirFASE relies on a priori definitions of safety events and the ability to systematically and reliably detect them. Such events having been defined by subject-matter experts have a clear operational meaning, and coherent statistics on the frequencies of their occurrences can be gathered over time, allowing the airline to manage known safety issues. The inherent weakness of the conventional FOQA tools, such as AirFASE, is the need to predefine the events to be tracked. This methodology offers no help in discovering unexpected anomalies to reveal new operational events that could compromise safety. Of course, airlines also have other experience feedback channels, such as crew reports, which can give some idea of new events to search for in the digital data.

The strength of The Morning Report is in filling this gap between tracking known events and discovering unexpected events with a statistical process that requires no a priori information about safety hazards. The Morning Report identifies those parameters that contribute the most to making atypical each atypical situation it finds, representing an extremely valuable aid to understanding the operational situation and to helping safety officers describe it if they want to perform a retrospective search of the database for similar events or to define a new event for the classical FOQA program of the airline.

Clustering by phase of flight produced by The Morning Report reveals conveniently the most atypical situations found in the flight-recorded data that are analyzed and is very useful for understanding each atypical situation. For example, the landing phase of FL_20 (questionable braking in section 5.2.2) is in a small cluster of five flights. All three flights found by AirFASE with a questionable braking event (whether of low, medium, or high severity) belong to this cluster (fig. 16). Such a cluster with a few atypical flights can characterize a type of operational event, and the display of the commonality of their relevant parameters gives clues to the possible irregularities that could compromise safety.

Also, the analysis of the parameters that distinguish the flights of this cluster from the other flights can help safety officers detect and characterize a new type of safety event to be tracked in FOQA.

It must be emphasized that The Morning Report tool is not designed to systematically pick up prescribed events, but rather it relies on comparisons to the content of the baseline. Such a baseline is normally constituted by a set of the most recent similar flights (a fixed number of flights). So, the baseline evolves with time as it is updated. A situation identified as atypical with respect to one baseline can be typical with respect to another baseline. The Morning Report does not give a stable and systematic view of events, but pinpoints particular flights that can help to detect specific risky situations before they become more current or are reported by another channel of information (incident or accident report, for example).

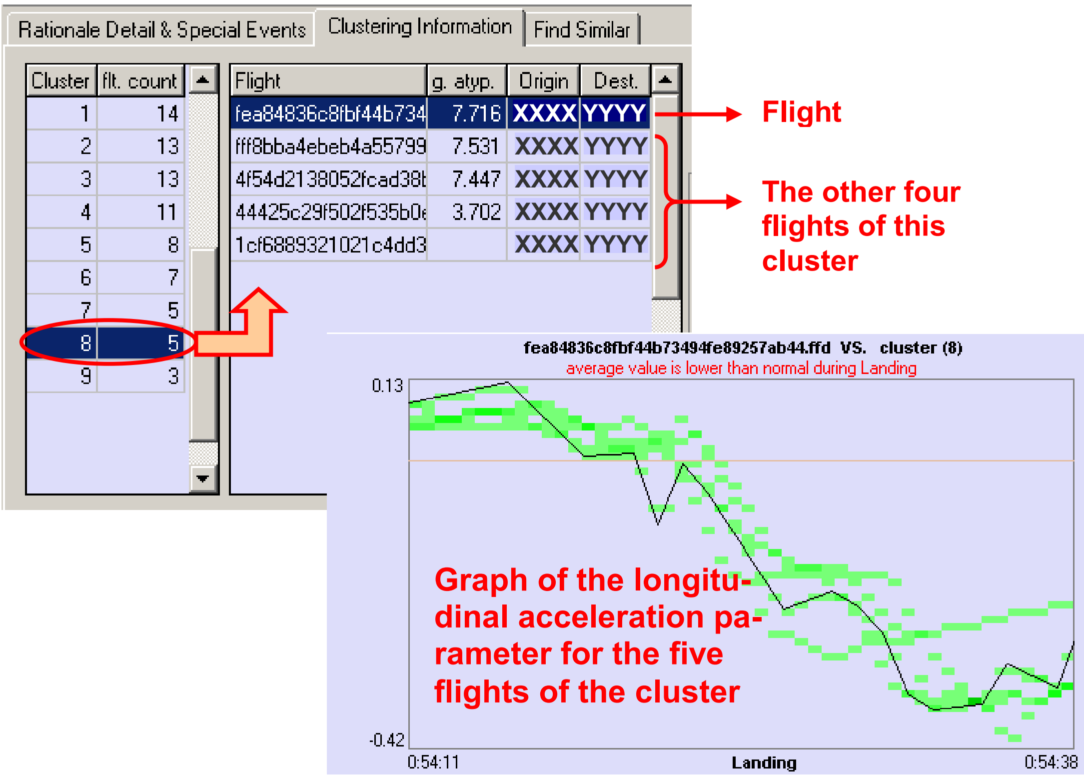


Figure 16. Example of flights of one atypical cluster.

7. CONCLUSION

This study demonstrated the feasibility and the potential value of using The Morning Report tool in conjunction with the FOQA tool of the airline (AirFASE in our experiment) and showed the complementarities of the results given by the two approaches.

While AirFASE allows safety officers to manage and systematically detect known safety events, The Morning Report is designed to discover unexpected atypical situations that may or may not relate to an operational-safety issue. The evaluation conducted by this study was sufficient to demonstrate the value of this new methodology to the airline, even though it was based on only a six-month period:

- The number of similar flights (single city pair, same type of aircraft) allowed the generation of a reliable baseline for The Morning Report (although a larger number of flights for the baseline is preferred).
- The number of atypical situations identified by The Morning Report in the analyzed flights is small enough that it is practical for a safety officer to analyze them further to establish their operational significance. (The Morning Report tries to minimize the false negatives and provides information to aid in understanding the situation.)
- Some of the atypical phases of flights found by The Morning Report revealed interesting operational situations (even in a small set of only 79 flights) that could not be identified by the regular FOQA program.
- The fact that The Morning Report did not detect atypical phases of flight relevant to events identified by AirFASE as high severity because the situation was not unusual in the baseline flights is both a limitation and an advantage of The Morning Report, and shows how it complements the usual FOQA exceedances-based analyses. If the FOQA analysis finds a problematic flight that The Morning Report does not find, further analyses may reveal a systemic problem.

The results reported here establish that such a statistical unsupervised search tool is a pertinent complementary element in support of the goal of better proactive management of safety within an airline.

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APPENDIX A

Parameters used in this study for analyses with The Morning Report: (takeoff to landing only).

Parameter Name	Unit	Type	Used in The Morning Report
Acc_Normal_Load_Factor	g	FLOAT	Yes
Acceleration_Lateral	g	FLOAT	Yes
Acceleration_Longitudinal	g	FLOAT	Yes
Airspeed_Indicated	knots	SHORT	Yes
Airspeed_True	knots	SHORT	Yes
Altitude_MSL_GPS	feet	FLOAT	Yes
Altitude_QNE	feet	FLOAT	Yes
Angle_of_attack_L_U	deg	FLOAT	Yes
Elevator_Pos_L_U	deg	FLOAT	Yes
Flap_Position_Inbd_Only_L	deg	FLOAT	Yes
Fuel_Flow_Eng_1	lb/h	FLOAT	Yes
Fuel_Flow_Eng_2	lb/h	FLOAT	Yes
N1_Engine_1	% rpm	FLOAT	Yes
N1_Engine_2	% rpm	FLOAT	Yes
Pitch_Angle	deg	FLOAT	Yes
Rudder_Position_Lwr_Only	deg	FLOAT	Yes
Vertical_Speed_Inertial	ft/min	FLOAT	Yes
Glide_Slope_Dev_Dots_L	dot	FLOAT	Yes (final landing only)
GPWS_Glide_Slope	-,TRUE	BOOLEAN	Yes (final landing only)
GPWS_Warning	-,TRUE	BOOLEAN	Yes (final landing only)
Localizer_Deviation_Dots_L	dot	FLOAT	Yes (final landing only)
Windshear_Warning	-,ALERT	BOOLEAN	Yes (final landing only)
Air_Gnd_Sw_Pos_Main	AIR,GROUND	BOOLEAN	Yes (takeoff and landing)

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14. ABSTRACT
This report describes a cooperative experiment conducted by ONERA and NASA, with the support of Airbus S.A.S. and easyJet Airline Company, Ltd. The study evaluated the benefits of two distinctly different methodologies for analyzing the same set of digital flight-recorded data. The experiment analyzed a set of easyJet commercial-flight data with both typical Flight Operational Quality Assurance (FOQA) software of an airline (in this case, AirFASE, developed by Airbus and Teledyne) and The Morning Report of Atypical Flights (developed by NASA). The study demonstrated the feasibility and potential value of using The Morning Report tool in conjunction with the FOQA airline tool and also showed the complementarities of the results produced by the two approaches.

15. SUBJECT TERMS
Data mining, Operational analyses, Flight recorded data

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