INCIDENT ANALYSIS

Incident description:
On 20 August 2008, SpanAir Flight 5022 ("JK5022") lifted off from Runway 36L, briefly got airborne, rolled left and right, descended back to the grass strip at the right side of the runway, slid and bounced through uneven terrain between runways 36L and 36R, hit obstacles. It finally came to rest, disintegrated and caught fire. Most of the occupants were killed.
1 The Why-Because-Analysis

The reason for performing these analyses is to learn from accidents so that similar occurrences can be avoided in the future.

This cannot stop at a point where for example one human is found to have done something other than the optimal, or even the expected or the prescribed action. Instead, the question must be asked “Why did it make sense to the person at the time, to do what he/she did?” It is known that human beings occasionally make mistakes. Since that does not seem likely to change, it has to be seen that (a) the environment and training are such that as few mistakes as possible are made, and (b) mistakes that have been made can be recognised by the operator and their consequences mitigated or averted.

1.1 Sources

I have prepared this preliminary Why-Because-Analysis of the SpanAir-Accident, based on information from various posters on the well-known Internet forum PPRuNe, and the MD80 Flight Manual. The Official Preliminary report of the CIAIAC only mentions few things beyond a timeline and some known facts, such as that the flaps position was most likely at $0^\circ$.

1.2 Assumptions

Most of the nodes in the graph are not known with absolute certainty, however, many of them can be assumed with reasonable confidence. Those which concern actions of the deceased flight crew and some others, which are less certain, have been marked as "ASSUMPTION:"

1.3 Causes

The Why-Because-Analysis is based on a formal notion of causality, called the counterfactual interpretation: An event or a state A is a necessary causal factor of another event B, if, had A not happened, then B would not have happened either. Arrows in a Why-Because-Graph indicate this causal relationship.
There is a general trend in official investigation reports not to prioritise causes into one Primary Cause and several, ostensibly less important, contributing factors. It is our experience that there is no prioritisation criterion that will distinguish one causal factor over others that can be generally agreed upon. Instead, different involved parties may make their own prioritisation for their specific purposes.

Using only one out of many possible prioritisation criteria and focusing only on the priority cause may divert attention from contributing causes that were also present in many other incidents. This may slow down identifying common causes and delay the implementation of effective and much-needed countermeasures.

Some of the identified causes merit further attention, and I will comment on them below. Please note that this is a preliminary analysis without full knowledge of all the facts. Comments are highly encouraged.

2 Comments

Besides the obvious (if it is going to be confirmed) so-called “pilot error” of not setting the flaps and slats correctly, some other categories of causes can be identified.

I will comment on two of these: training issues and aircraft design issues.

2.1 Training Issues

Others (PJ2 being among the most eloquent in numerous posts on PPRuNe) have given detailed analyses of what aviation safety is about.

I will only highlight two points out of many. The following are not completed analyses and there is no clear-cut conclusion as to what should be done about it. The aim here is only to point towards areas of interest.

- The cause of the RAT probe heater turning on on the ground was apparently not investigated, and the MEL entry allowing dispatch with inoperative RAT probe heating was interpreted to also include a disabled heating, which was otherwise working. Reading and interpreting a Minimum Equipment List in its intended spirit does not
appear to come naturally. It has to be trained. According to the preliminary CIAIAC report, both the technician and the PIC agreed that dispatch was permissible.

- Possibly incomplete and hurried execution of checklists. Even the official report, which goes to great lengths not to talk about any shortcomings of crew actions admits that “some items” of appropriate checklists can be heard on the CVR. Although this may at least in part be due to the poor technical quality of the CVR recordings, it indicates that the reply to the “FLAPS”-challenge was not the prescribed ”X degrees, Takeoff“, but perhaps a simple ”OK“, likely without looking at either the handle or the indicator.

### 2.2 Aircraft Design Issues

As can be seen in the WB-Graph, at least the following design decisions were causal to the accident.

- Non-redundancy of ground-air sensing for the Takeoff Warning System (TOWS)

- Absence of a positive indication from the TOWS that the configuration is correct. Both TOWS failure and correct Takeoff configuration are indicated by silence.

- Autoslats stall-recovery system is only operative with slats extended to mid-seal position. It is inoperative with slats retracted.

- Stick-Pusher stall-recovery system is only operative with slats extended. It is inhibited with slats retracted.

Note that I merely wish to raise awareness to the fact that these points are causal factors in this accident. I recognise that introducing changes to existing systems is a large undertaking. I cannot say if and how any of these systems can or should be changed.
### Legend of Factorshapes

<table>
<thead>
<tr>
<th>Factortype</th>
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<tbody>
<tr>
<td>Unspecified Factortype</td>
<td><img src="image1" alt="Shape" /></td>
</tr>
<tr>
<td>Event</td>
<td><img src="image2" alt="Shape" /></td>
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<td>Un-Event</td>
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<td>State</td>
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<td>Assumption</td>
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<td>Countermeasure</td>
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<tr>
<td>Contraindication</td>
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Auto-slat system depends on slats being extended to "mid-seal" position. F/C retract slats/flaps (68) to the gate (45). Auto-slat stall recovery system is inoperative.


A/C is late for scheduled maintenance personnel. A/C is in "clean" configuration. F/C do not perform slats/flaps deactivate RAT probe and/or hurried because they did not check the TOWS thoroughly. ASSUMPTION: F/C do not set correct slat/flap configuration for second takeoff attempt. Flight.

Stick-pusher stall inoperative. Dispatch with inoperative RAT probe heating.

Uneven terrain is expected conditions are allowed when no icing runways 36L and 36R. RAT probe heating is.


A/C slides off even expected for the flight. A/C enters stalled condition. A/C banks heavily, alternating left and right. A/C is destroyed.

A/C airspeed is well below stall speed. A/C changes its trajectory. A/C hits obstacles. A/C catches fire. Uncontained Fuel is.

A/C enters stalled condition. A/C briefly becomes stick-pusher stall inoperative. A manufacturer recommendation to check the TOWS before crew absence from aircraft only call for TOWS check before second takeoff attempt. F/C are not aware of their A/C being configured correctly

Failure of Relay 2-5 continues to give "in-the-air" signal. Relay 2-5 controls TOWS.

There is no redundancy controlling the air/ground condition of the TOWS. TOWS is inhibited in the air. TOWS aural warning does not sound. TOWS is "stuck" in air-mode. ASSUMPTION: Relay 2-5 is "stuck" in air-mode.

Other abnormal symptoms are apparent. Maintenance personnel do not investigate. ASSUMPTION: Relay 2-5 remains undetected function is affected.
Auto-slat system depends on slats being extended to “mid-seal” position (68) while taxiing back to the gate (45). Auto-slat stall recovery system is inoperative.

HIGH TEMPERATURE INDICATION
A/C returns to gate F/C notice improbably after first taxiing (66) Improbably high temperature ASSUMPTION: F/C distracted A/C is late for scheduled maintenance personnel A/C is in “clean” configuration F/C do not perform slats/flaps deactivate RAT probe and/or hurried because checklist item thoroughly indication of the delay ASSUMPTION: F/C do heating (50) second takeoff attempt (44) configuration for (39) (48) (23) (51)indhing
depends on slats being (48) (13) (17) (18) (22) (24) (25) (27) (28) (31) (32) (33) (34) (35) (36) (37) (38) (40) (41) (42) (43) (46) (49) (52) (53) (54) (55) (56) (57) (58) (59) (60) (61) (62) (63) (65) (66) (67) (69) (70) (71) (72) (73) (74) (75) (76) (77) (78) (79) (80) (81) (82) (83) (84) (85) (86) (87) (88) (89) (90) (91) (92) (93) (94) (95) (96) (97) (98) (99) (100) (101) (102) (103) (104) (105) (106) (107) (108) (109) (110) (111) (112) (113) (114) (115) (116) (117) (118) (119) (120) (121) (122) (123) (124) (125) (126) (127) (128) (129) (130) (131) (132) (133) (134) (135) (136) (137) (138) (139) (140) (141) (142) (143) (144) (145) (146) (147) (148) (149) (150) (151) (152) People die Uncontained Fuel ignited over uneven terrain A/C reaches high pitch A/C maintains stalled condition F/C are not aware of the A/C is configured correctly F/C do not perform TOWS check before second takeoff attempt (59) ASSUMPTION: F/C believe A/C is late or not at all before first flight (60) are not aware that TOWS is affected failure of Relay 2-5 remains undetected function is affected no other systems with immediately apparent effects on the ground (70) There is no redundancy controlling the air/ground condition of the TOWS (64) Relay 2-5 controls TOWS TOWS gets “in-the-air” signal (63) Relay 2-5 continues to give “in-the-air” signal (62) There is no redundancy controlling the air/ground condition of the TOWS (61) Relay 2-5 controls RAT probe heating (60) Relay 2-5 controls RAT probe heating no other systems with immediately apparent effects on the ground (59) Design and layout of ground/air sensing and signalling system design and layout of ground/air sensing and signalling system
**Factor List**

1. A/C is destroyed
2. A/C catches fire
3. A/C hits obstacles
4. A/C slides and bounces over uneven terrain
5. Fuel tanks rupture
6. A/C slides off even grass strip at the runway side
7. A/C changes its trajectory to the right
8. A/C banks heavily, alternating left and right
9. Uneven terrain between runways 36L and 36R
10. A/C touches the ground at the side of the runway
11. A/C reaches high pitch angle
12. A/C enters stalled condition
13. A/C becomes uncontrollable
14. A/C starts to leave ground effect
15. A/C airspeed is well below stall speed
16. Stall speed is very high
17. A/C maintains stalled condition
18. A/C starts to descend again
19. F/C rotate A/C at calculated speed for FLAPS-11 configuration
20. A/C briefly becomes airborne
21. Ground effect increases lift close to the ground
22. A/C is in "clean" configuration
23. ASSUMPTION: F/C do not set correct slat/flap configuration for second takeoff attempt
24. "V"-speeds calculated for FLAPS-11 configuration
25. ASSUMPTION: F/C believe they have set correct slat/flap configuration
26. Recovery procedures (Maximum thrust, FLAPS 15) are initiated too late or not at all
27. 152 People die
28. Uncontained Fuel is ignited
29. TOWS aural warning does not sound
30. TOWS is inhibited
31. TOWS is inhibited in the air
32. TOWS gets "in-the-air" signal
33. ASSUMPTION: Relay 2-5 is "stuck" in air-mode
34. Relay 2-5 controls TOWS
35. RAT probe is heated on the ground
36. Relay 2-5 controls RAT probe heating
37. A/C returns to gate after first taxiing
38. Maintenance personnel deactivate RAT probe heating
39. Maintenance personnel do not investigate cause for RAT probe heating on the ground
40. A/C is dispatched for flight
41. Dispatch with inoperative RAT probe heating is allowed when no icing conditions are expected
42. No icing conditions expected for the flight
43. A/C is late for scheduled flight
44. F/C retract slats/flaps while taxiing back to the gate
45. A/C starts takeoff run
46. A/C taxies to second takeoff attempt
47. ASSUMPTION: F/C distracted and/or hurried because of the delay
48. F/C do not perform slats/flaps checklist item thoroughly
49. Improbably high temperature indication
50. F/C notice improbably high temperature indication
51. Failure of Relay 2-5 remains undetected
52. Relay 2-5 continues to give "in-the-air" signal
53. Relay 2-5 controls no other systems with immediately apparent effects on the ground
Relays 2-5 gives “in-the-air” signal

No other abnormal symptoms are apparent

F/C do not perform TOWS check before second takeoff attempt

F/C are not aware of non-functional TOWS

SpanAir procedures only call for TOWS check before first flight of day or after prolonged crew absence from aircraft

A manufacturer recommendation to check the TOWS before every flight was not made mandatory by the authorities

ASSUMPTION: F/C believe the A/C is configured correctly

Design and Layout of ground/air sensing and signalling system

Maintenance personnel are not aware that TOWS function is affected

F/C are not informed that TOWS is affected

Auto-slat stall recovery system is inoperative

Stick-pusher stall recovery system is inoperative

Auto-slat system depends on slats being extended to “mid-seal” position

Stick-pusher system depends on slats being extended

There is no redundancy controlling the air/ground condition of the TOWS

Handling characteristics of swept-wing T-tail aircraft
Factor List - Details

1  A/C is destroyed  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

2  A/C catches fire  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

3  A/C hits obstacles  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

4  A/C slides and bounces over uneven terrain  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

5  Fuel tanks rupture  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

6  A/C slides off even grass strip at the runway side  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

7  A/C changes its trajectory to the right  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation:  

8  A/C banks heavily, alternating left and right  
   Type of Factor: Process  
   Date/Time:  
   Actors involved:  
   Annotation:  

9  Uneven terrain between runways 36L and 36R  
   Type of Factor: State  
   Date/Time:  
   Actors involved:  
   Annotation:  

10 A/C touches the ground at the side of the runway  
   Type of Factor: Event  
   Date/Time:  
   Actors involved:  
   Annotation: Marks in the grass strip from tail cone and main landing gear, possibly also from engine nacelles.
11 A/C reaches high pitch angle
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

12 A/C enters stalled condition
Type of Factor: Event
Date/Time:
Actors involved:
Annotation: Entering stalled condition incurs a significant loss of lift, often asymmetrically.

13 A/C becomes uncontrollable
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

14 A/C starts to leave ground effect
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

16 A/C airspeed is well below stall speed
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

17 Stall speed is very high
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

18 A/C maintains stalled condition
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

19 A/C starts to descend again
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

20 F/C rotate A/C at calculated speed for FLAPS-11 configuration
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

21 A/C briefly becomes airborne
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

22 Ground effect increases lift close to the ground
Type of Factor: State
Date/Time:
Actors involved:
Annotation:
A/C is in "clean" configuration  
Type of Factor: State  
Date/Time:  
Actors involved:  
Annotation: More important than the (firmly established) position of the flaps being at 0 degrees, is the position of the slats. The slats decrease the stall speed by some 30 knots, the flaps only by an additional 5-10 knots. Most likely a takeoff with slats deployed, but no flaps would have been uneventful, as V2 (liftoff speed) would have been above slats-only stall speed.

ASSUMPTION: F/C do not set correct slat/flap configuration for second takeoff attempt  
Type of Factor: UnEvent  
Date/Time:  
Actors involved:  
Annotation: A complete technical failure involving correct flap handle setting and correct flap/slat indications without actually deployed slats seems extremely remote.

"V"-speeds calculated for FLAPS-11 configuration  
Type of Factor: State  
Date/Time:  
Actors involved:  
Annotation:  

ASSUMPTION: F/C believe they have set correct slat/flap configuration  
Type of Factor: State  
Date/Time:  
Actors involved:  
Annotation:  

Recovery procedures (Maximum thrust, FLAPS 15) are initiated too late or not at all  
Type of Factor: UnEvent  
Date/Time:  
Actors involved:  
Annotation: Some Manual revision omit the "FLAPS 15" part.

152 People die  
Type of Factor: Event  
Date/Time:  
Actors involved:  
Annotation:  

Uncontained Fuel is ignited  
Type of Factor: Event  
Date/Time:  
Actors involved:  
Annotation: Possibly by sparks from ground contact, from electrical wiring, or at the hot engine exhaust pipes.

TOWS aural warning does not sound  
Type of Factor: UnEvent  
Date/Time:  
Actors involved:  
Annotation: The TOWS has no feedback for "Configuration OK." Absence of any indication can thus either mean "Ok", or a TOWS failure.

TOWS is inhibited  
Type of Factor: State  
Date/Time:  
Actors involved:  
Annotation:  

TOWS is inhibited in the air  
Type of Factor: State  
Date/Time:  
Actors involved:  
Annotation:
TOWS gets “in-the-air” signal
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

ASSUMPTION: Relay 2-5 is “stuck” in air-mode
Type of Factor: State
Date/Time:
Actors involved:
Annotation: R2-5 is the only relay to control TOWS. There is no redundancy.

Relay 2-5 controls TOWS
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

RAT probe is heated on the ground
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

Relay 2-5 controls RAT probe heating
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

A/C returns to gate after first taxiing
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

Maintenance personnel deactivate RAT probe heating
Type of Factor: Event
Date/Time:
Actors involved:
Annotation: Apparently by pulling the associated circuit breaker, “Z29”.

Maintenance personnel do not investigate cause for RAT probe heating on the ground
Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation:

A/C is dispatched for flight
Type of Factor: Event
Date/Time:
Actors involved:
Annotation: According to the preliminary report, both the captain and the maintenance technician agreed that the aircraft was fit to fly, and dispatch was allowed under MEL.

Dispatch with inoperative RAT probe heating is allowed when no icing conditions are expected
Type of Factor: State
Date/Time:
Actors involved:
Annotation: This may be a misinterpretation of the Minimum Equipment List (MEL). The MEL states that dispatch with inoperative RAT probe heating is allowed. This covers a failed heater, but its applicability to a heater turning on on the ground, and subsequently disabled by pulling a circuit breaker, is dubious.
43  No icing conditions expected for the flight
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

44  A/C is late for scheduled flight
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

45  F/C retract slats/flaps while taxiing back to the gate
Type of Factor: Event
Date/Time:
Actors involved:
Annotation: Standard procedure when returning to the gate.

46  A/C starts takeoff run
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

47  A/C taxies to second takeoff attempt
Type of Factor: Process
Date/Time:
Actors involved:
Annotation:

48  ASSUMPTION: F/C distracted and/or hurried because of the delay
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

49  F/C do not perform slats/flaps checklist item thoroughly
Type of Factor: Event
Date/Time:
Actors involved:
Annotation: The official preliminary report states that "some items" of the appropriate checklists could be heard on the CVR. Other sources suggest that the "flaps" challenge was made, but the response was only "Ok", instead of the required "11 degrees, Takeoff".

50  Improbably high temperature indication
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

51  F/C notice impossibly high temperature indication
Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

52  Failure of Relay 2-5 remains undetected
Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation:
53 **Relay 2-5 continues to give "in-the-air" signal**
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

54 **Relay 2-5 controls no other systems with immediately apparent effects on the ground**
Type of Factor: State
Date/Time:
Actors involved:
Annotation: The two other systems controlled by R2-5 are AC crosstie and radio rack venting.

55 **Relays 2-5 gives "in-the-air" signal**
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

57 **No other abnormal symptoms are apparent**
Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation:

58 **F/C do not perform TOWS check before second takeoff attempt**
Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation: It is unclear whether or not the crew was absent from the cockpit for a "prolonged" period of time. It is thus uncertain if they should have performed a second TOWS check, according to SpanAir procedure.

59 **F/C are not aware of non-functional TOWS**
Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation:

60 **SpanAir procedures only call for TOWS check before first flight of day or after prolonged crew absence from aircraft**
Type of Factor: State
Date/Time:
Actors involved:
Annotation: EASA has released an airworthiness directive mandating that procedures be changed (and the AFM be updated accordingly to include):

61 **A manufacturer recommendation to check the TOWS before every flight was not made mandatory by the authorities**
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

62 **ASSUMPTION: F/C believe the A/C is configured correctly**
Type of Factor: State
Date/Time:
Actors involved:
Annotation:

63 **Design and Layout of ground/air sensing and signalling system**
Type of Factor: State
Date/Time:
Actors involved:
Annotation:
64  Maintenance personnel are not aware that TOWS function is affected
Type of Factor:  UnEvent
Date/Time:  
Actors involved:  
Annotation:  

65  F/C are not informed that TOWS is affected
Type of Factor:  UnEvent
Date/Time:  
Actors involved:  
Annotation:  

66  Auto-slat stall recovery system is inoperative
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  

67  Stick-pusher stall recovery system is inoperative
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  

68  Auto-slat system depends on slats being extended to "mid-seal" position
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  The auto-slat system extends the slats from "mid-seal" to the fully extended position in case of a stall condition. It does not extend slats from the retracted position.  

69  Stick-pusher system depends on slats being extended
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  The stick-pusher system pushes the steering column forwards if a stall condition is detected. It is inhibited if the slats are retracted. 

The independent stick shaker system, and the aural stall warning, are available in all flight phases.  

70  There is no redundancy controlling the air/ground condition of the TOWS
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  

71  Handling characteristics of swept-wing T-tail aircraft
Type of Factor:  State
Date/Time:  
Actors involved:  
Annotation:  Swept-wing t-tail aircraft have a natural pitch-up tendency in case of a stall condition. This can be mitigated to some extent by constructional details of the wing controlling flow separation at high angles of attack. However, with increasing AoA, e.g. when the pilot keeps the column pulled back, leading to complete flow separation, the pitch-up tendency returns, exacerbating the stall condition.  

cf. David P. Davies: "Handling the Big Jets", pp. 109ff