SpanAir Flight 5022 Accident at Madrid on 20 August 2008

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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 $0°$.

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

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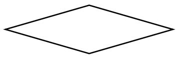
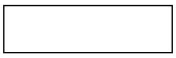
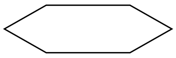
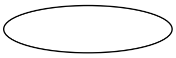
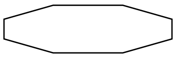
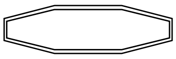
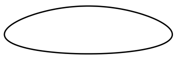
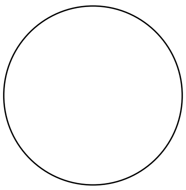
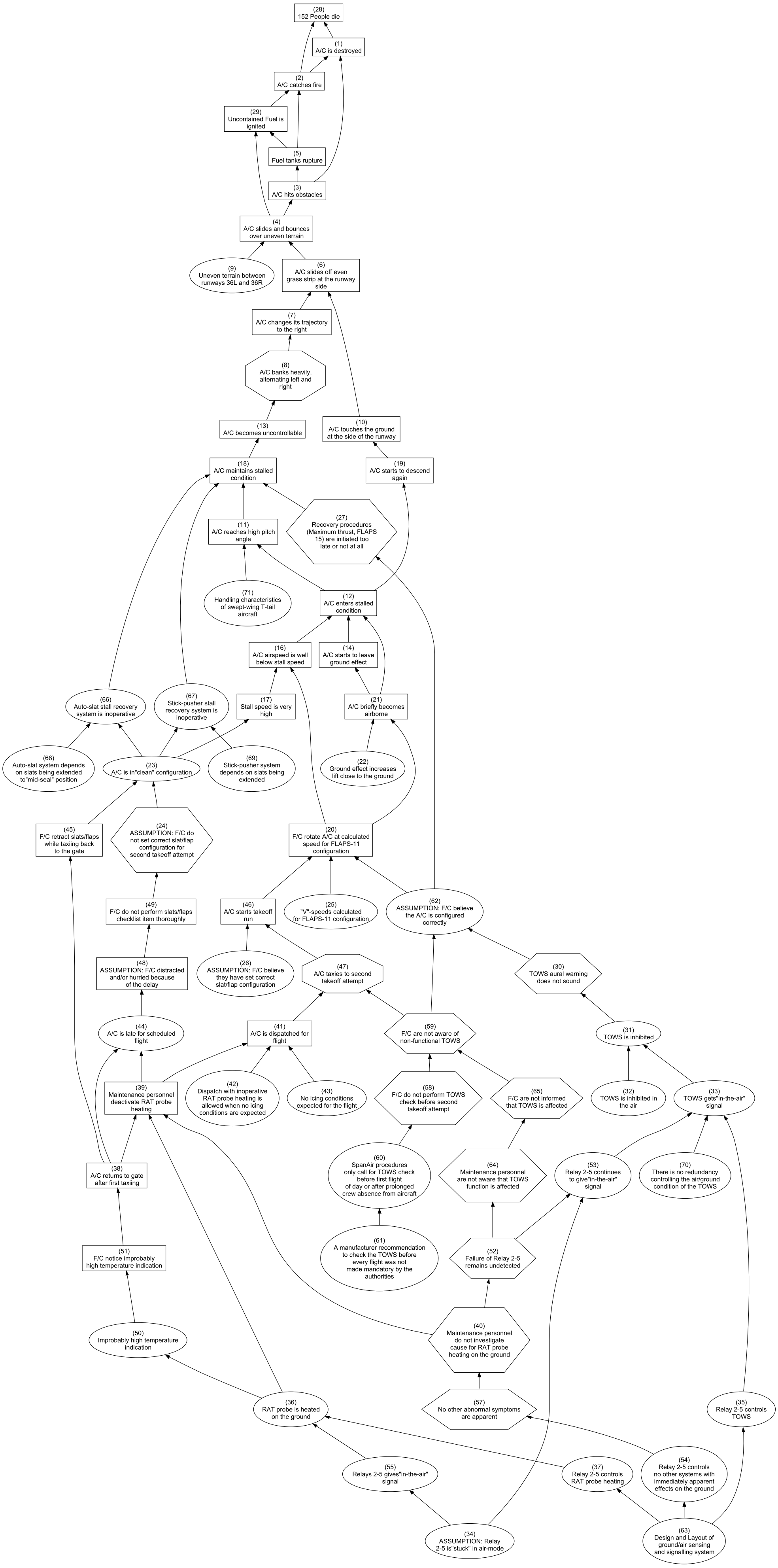
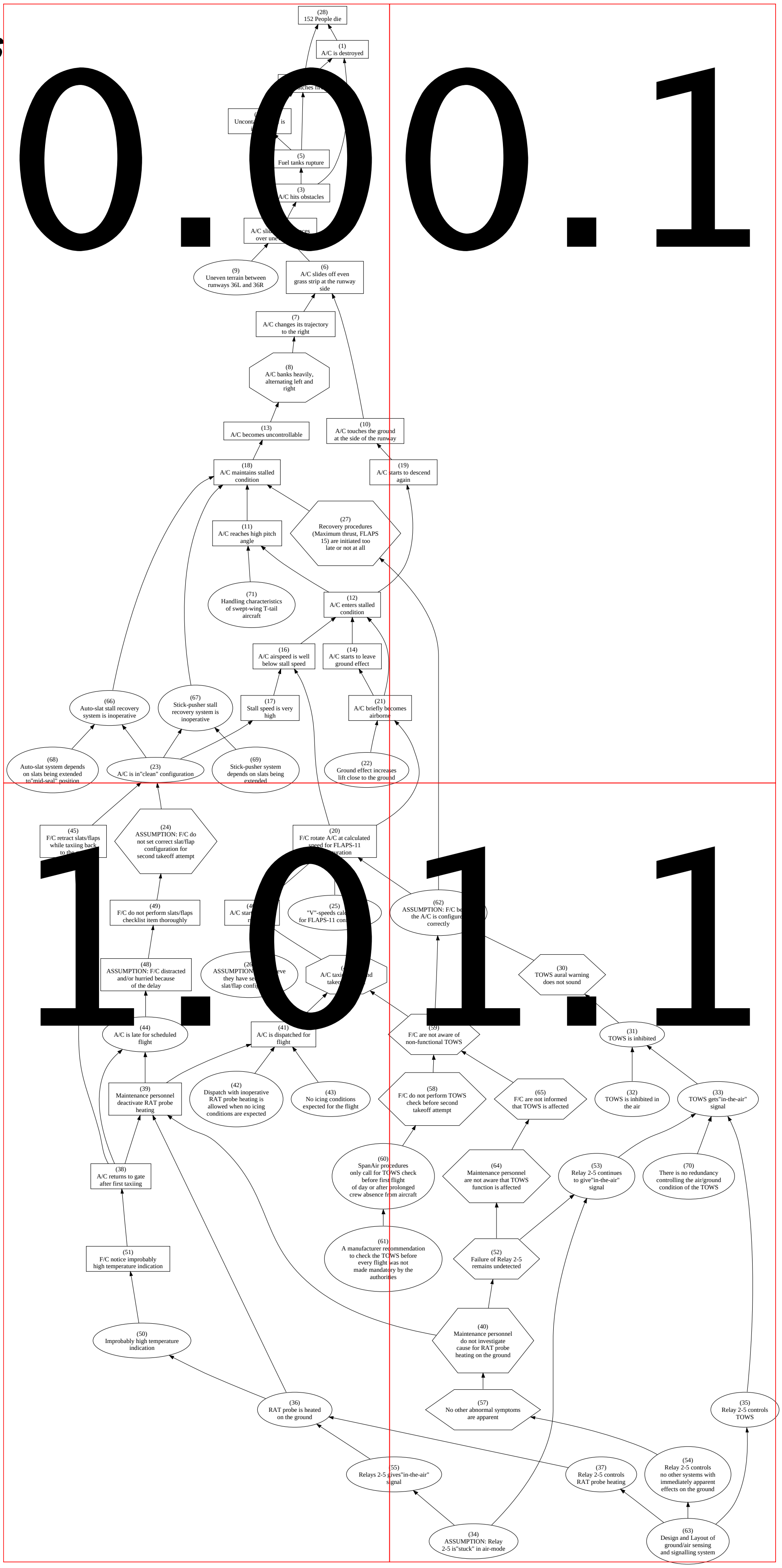
Unspecified Factortype	
Event	
Un-Event	
State	
Process	
Assumption	
Countermeasure	
Contraindication	

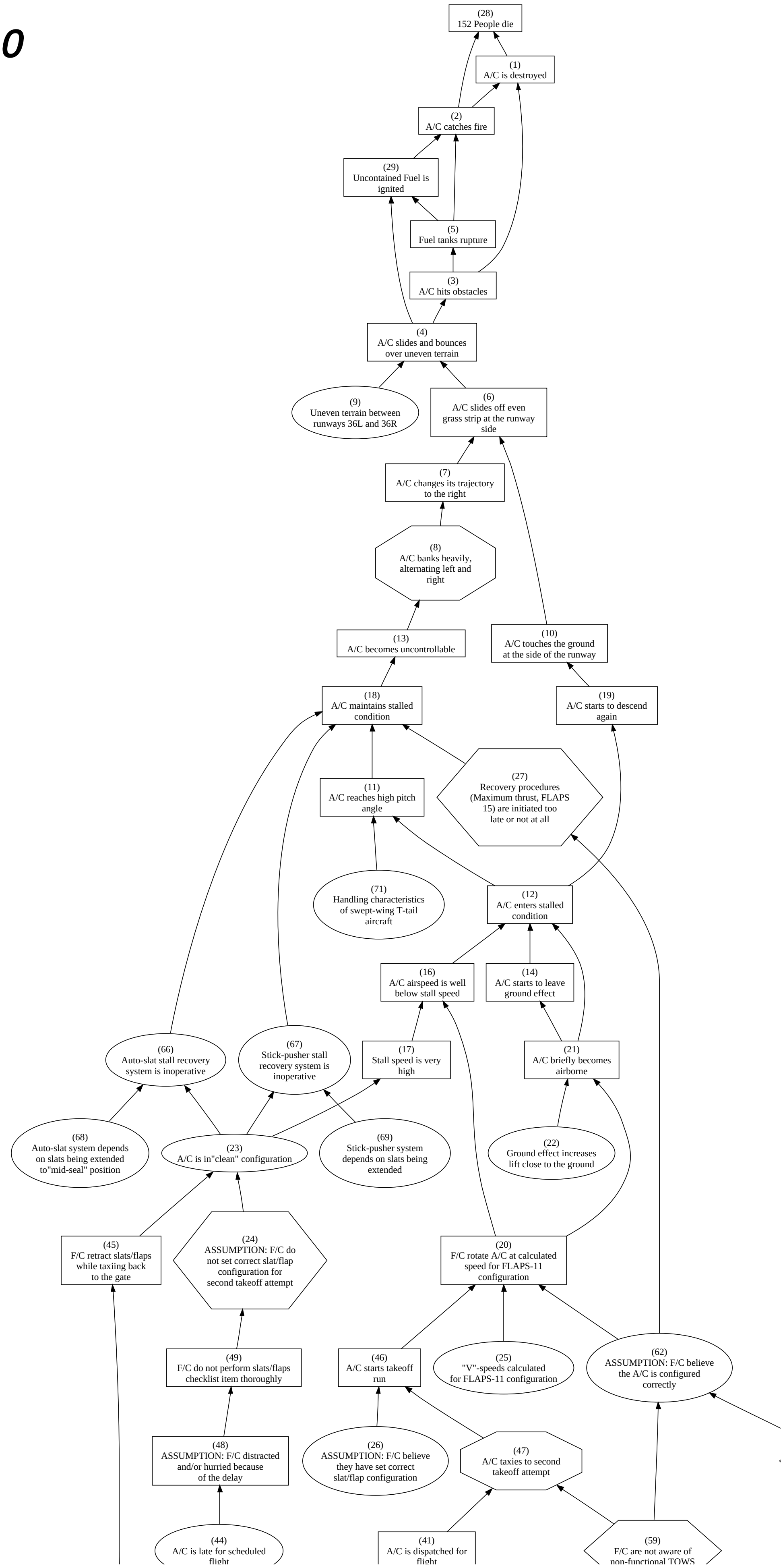
Why-Because Graph



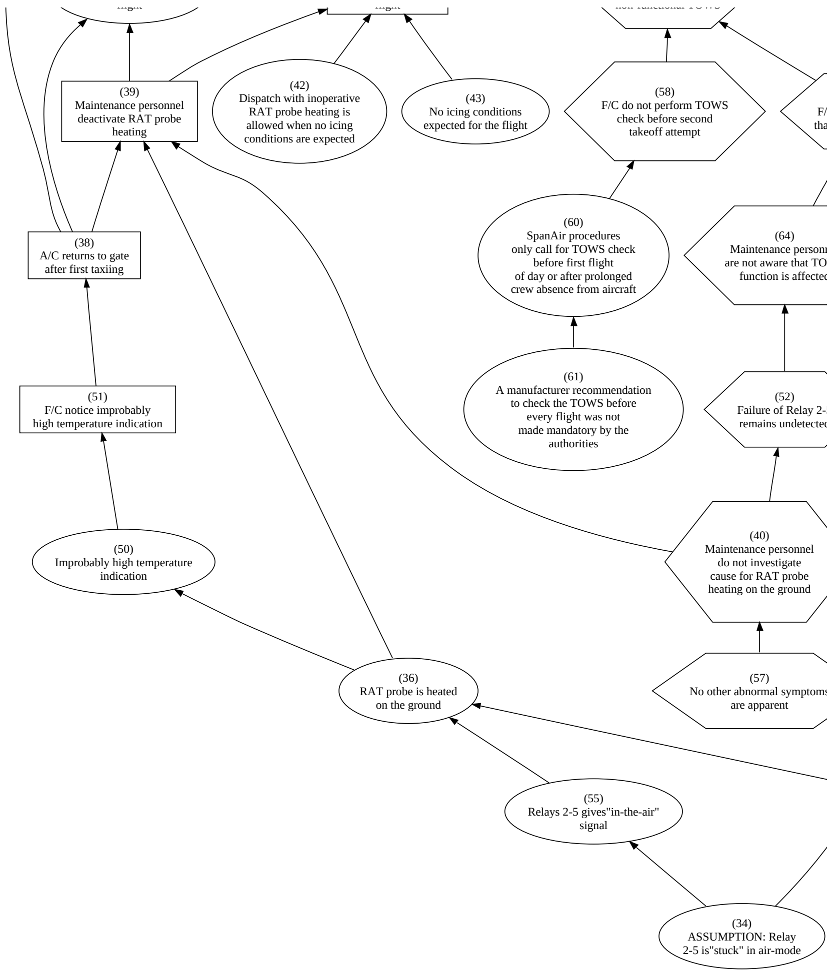
Graph Atlas

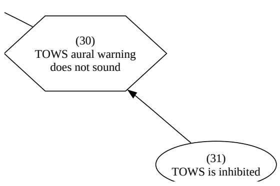

0.00.1
1.01.1
(28) 152 People die
(1) A/C is destroyed
(5) Fuel tanks rupture
(3) A/C hits obstacles
(9) Uneven terrain between runways 36L and 36R
(6) A/C slides off even grass strip at the runway side
(7) A/C changes its trajectory to the right
(8) A/C banks heavily, alternating left and right
(13) A/C becomes uncontrollable
(10) A/C touches the ground at the side of the runway
(18) A/C maintains stalled condition
(19) A/C starts to descend again
(11) A/C reaches high pitch angle
(27) Recovery procedures (Maximum thrust, FLAPS 15) are initiated too late or not at all
(71) Handling characteristics of swept-wing T-tail aircraft
(12) A/C enters stalled condition
(16) A/C airspeed is well below stall speed
(14) A/C starts to leave ground effect
(66) Auto-slat stall recovery system is inoperative
(67) Stick-pusher stall recovery system is inoperative
(17) Stall speed is very high
(21) A/C briefly becomes airborne
(68) Auto-slat system depends on slats being extended to"mid-seal" position
(23) A/C is in"clean" configuration
(69) Stick-pusher system depends on slats being extended
(22) Ground effect increases lift close to the ground
(24) ASSUMPTION: F/C do not set correct slat/flap configuration for second takeoff attempt
(49) F/C do not perform slats/flaps checklist item thoroughly
(48) ASSUMPTION: F/C distracted and/or hurried because of the delay
(30) TOWS aural warning does not sound
(44) A/C is late for scheduled flight
(41) A/C is dispatched for flight
(59) F/C are not aware of non-functional TOWS
(31) TOWS is inhibited
(39) Maintenance personnel deactivate RAT probe heating
(42) Dispatch with inoperative RAT probe heating is allowed when no icing conditions are expected
(43) No icing conditions expected for the flight
(58) F/C do not perform TOWS check before second takeoff attempt
(65) F/C are not informed that TOWS is affected
(32) TOWS is inhibited in the air
(33) TOWS gets"in-the-air" signal
(38) A/C returns to gate after first taxiing
(60) SpanAir procedures only call for TOWS check before first flight of day or after prolonged crew absence from aircraft
(64) Maintenance personnel are not aware that TOWS function is affected
(53) Relay 2-5 continues to give"in-the-air" signal
(70) There is no redundancy controlling the air/ground condition of the TOWS
(51) F/C notice improbably high temperature indication
(61) A manufacturer recommendation to check the TOWS before every flight was not made mandatory by the authorities
(52) Failure of Relay 2-5 remains undetected
(50) Improbably high temperature indication
(40) Maintenance personnel do not investigate cause for RAT probe heating on the ground
(36) RAT probe is heated on the ground
(57) No other abnormal symptoms are apparent
(35) Relay 2-5 controls TOWS
(55) Relays 2-5 gives"in-the-air" signal
(37) Relay 2-5 controls RAT probe heating
(54) Relay 2-5 controls no other systems with immediately apparent effects on the ground
(34) ASSUMPTION: Relay 2-5 is"stuck" in air-mode
(63) Design and Layout of ground/air sensing and signalling system

Graphtile 0.0

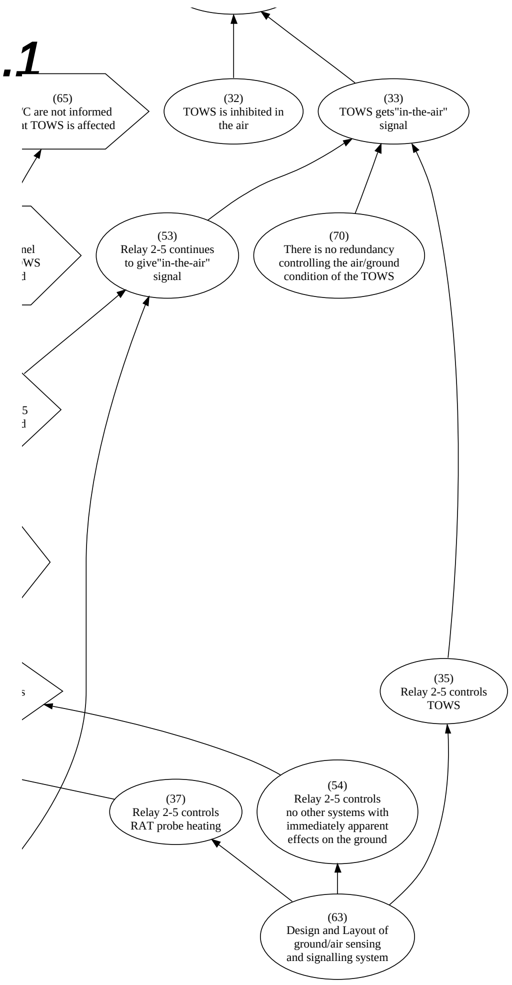


Graphtile 1.0




(30)
TOWS aural warning
does not sound
(31)
TOWS is inhibited

Graphtile 1.1



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
16 A/C airspeed is well below stall speed
17 Stall speed is very high
18 A/C maintains stalled condition
19 A/C starts to descend again
20 F/C rotate A/C at calculated speed for FLAPS-11 configuration
21 A/C briefly becomes airborne
22 Ground effect increases lift close to the ground
23 A/C is in "clean" configuration
24 ASSUMPTION: F/C do not set correct slat/flap configuration for second takeoff attempt
25 "V"-speeds calculated for FLAPS-11 configuration
26 ASSUMPTION: F/C believe they have set correct slat/flap configuration
27 Recovery procedures (Maximum thrust, FLAPS 15) are initiated too late or not at all
28 152 People die
29 Uncontained Fuel is ignited
30 TOWS aural warning does not sound
31 TOWS is inhibited
32 TOWS is inhibited in the air
33 TOWS gets "in-the-air" signal
34 ASSUMPTION: Relay 2-5 is "stuck" in air-mode
35 Relay 2-5 controls TOWS
36 RAT probe is heated on the ground
37 Relay 2-5 controls RAT probe heating
38 A/C returns to gate after first taxiing
39 Maintenance personnel deactivate RAT probe heating
40 Maintenance personnel do not investigate cause for RAT probe heating on the ground
41 A/C is dispatched for flight
42 Dispatch with inoperative RAT probe heating is allowed when no icing conditions are expected
43 No icing conditions expected for the flight
44 A/C is late for scheduled flight
45 F/C retract slats/flaps while taxiing back to the gate
46 A/C starts takeoff run
47 A/C taxies to second takeoff attempt
48 ASSUMPTION: F/C distracted and/or hurried because of the delay
49 F/C do not perform slats/flaps checklist item thoroughly
50 Improbably high temperature indication
51 F/C notice improbably high temperature indication
52 Failure of Relay 2-5 remains undetected
53 Relay 2-5 continues to give "in-the-air" signal
54 Relay 2-5 controls no other systems with immediately apparent effects on the ground

55 Relays 2-5 gives "in-the-air" signal

57 No other abnormal symptoms are apparent

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

59 F/C are not aware of non-functional TOWS

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

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

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

63 Design and Layout of ground/air sensing and signalling system

64 Maintenance personnel are not aware that TOWS function is affected

65 F/C are not informed that TOWS is affected

66 Auto-slat stall recovery system is inoperative

67 Stick-pusher stall recovery system is inoperative

68 Auto-slat system depends on slats being extended to "mid-seal" position

69 Stick-pusher system depends on slats being extended

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

71 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:

23 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.

24 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.

25 "V"-speeds calculated for FLAPS-11 configuration

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

26 ASSUMPTION: F/C believe they have set correct slat/flap configuration

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

27 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.

28 152 People die

Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

29 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.

30 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.

31 TOWS is inhibited

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

32 TOWS is inhibited in the air

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

33 TOWS gets "in-the-air" signal

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

34 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.

35 Relay 2-5 controls TOWS

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

36 RAT probe is heated on the ground

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

37 Relay 2-5 controls RAT probe heating

Type of Factor: State
Date/Time:
Actors involved:
Annotation:

38 A/C returns to gate after first taxiing

Type of Factor: Event
Date/Time:
Actors involved:
Annotation:

39 Maintenance personnel deactivate RAT probe heating

Type of Factor: Event
Date/Time:
Actors involved:
Annotation: Apparently by pulling the associated circuit breaker, "Z29".

40 Maintenance personnel do not investigate cause for RAT probe heating on the ground

Type of Factor: UnEvent
Date/Time:
Actors involved:
Annotation:

41 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.

42 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 improbably 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