A321 Lateral Control in Turbulence and Icing Conditions

Customer Services

AIRBUS

A321 Lateral Control in Turbulence and Icing Conditions

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In service events

- On A321, several in service events between 1998 and 2003 highlighted unusual roll sensitivity in short final
  - 4 cases in icing conditions (2 the same day on the same airport in 1998, and 2 the same day on the same airport in 2002)
  - 2 cases with gusty crosswind around 20kt (1 in 2001, and 1 in 2003)
- Worst consequence was a wingtip damage during a gusty Xwind landing
- In all cases, landing in Conf 3 after a Go around was performed without apparent difficulty

Icing conditions

- On one of the involved A321, ice accretion on flaps leading edge was confirmed after landing. On the other cases, ice accretion on flap leading edge was suspected .

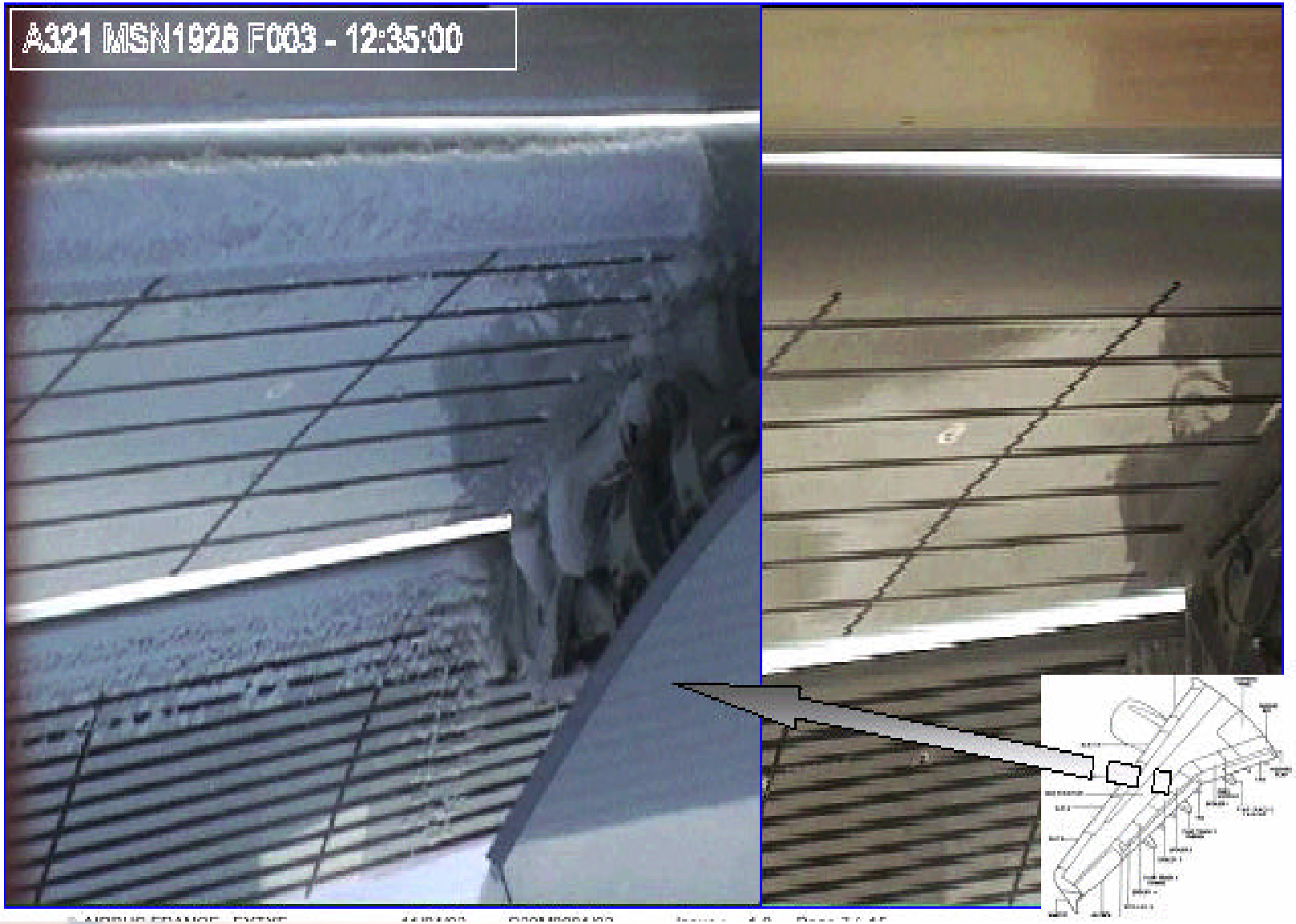
- Analysis of available data (DFDR) shows that spoilers efficiency was increased versus the « dry » aircraft.

Icing conditions

- To better understand the phenomenon, a natural icing Flight Test campaign on A320 and on A321 (both fitted with adequate Flight Test Installation) was performed in 2003. The purpose was to evaluate ice accretion patterns on flap leading edges and the aero consequences.

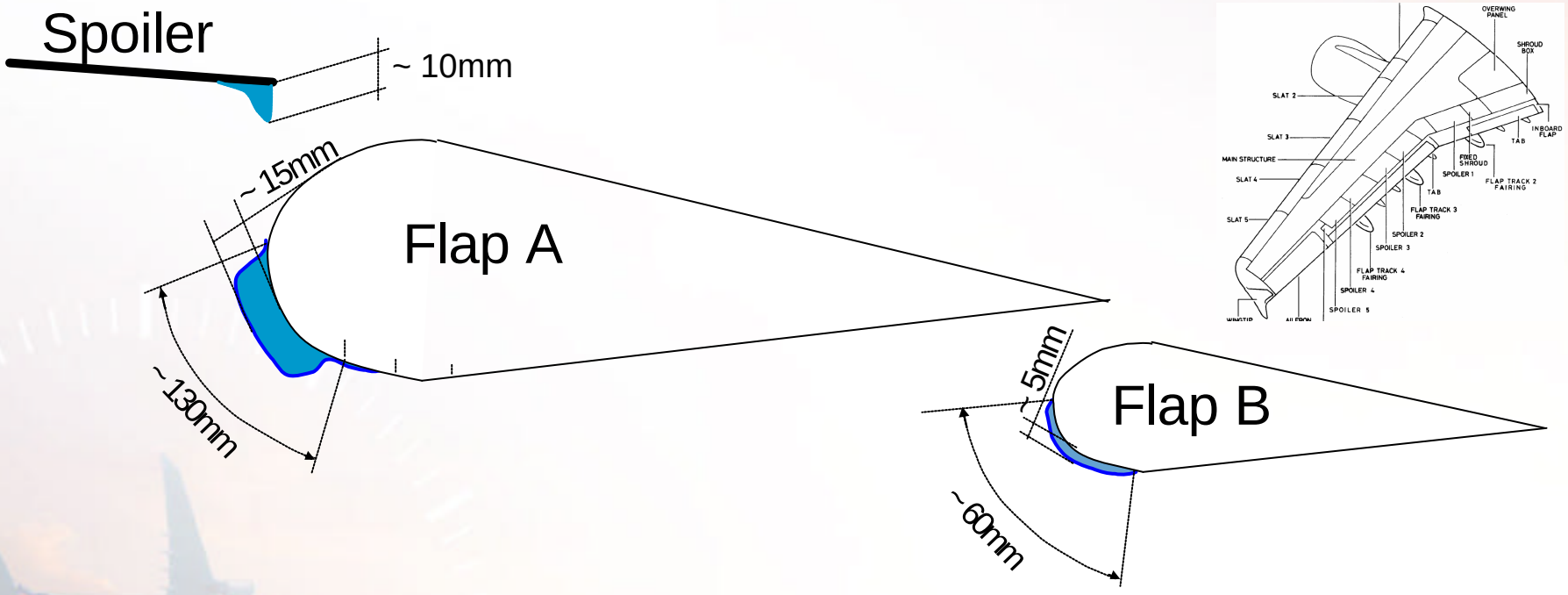
- Main findings were:
  - Similar ice accretion on both A/C.
  - Increased spoilers efficiency on both A/C.
  - Increased roll sensitivity only on A321.

Icing conditions

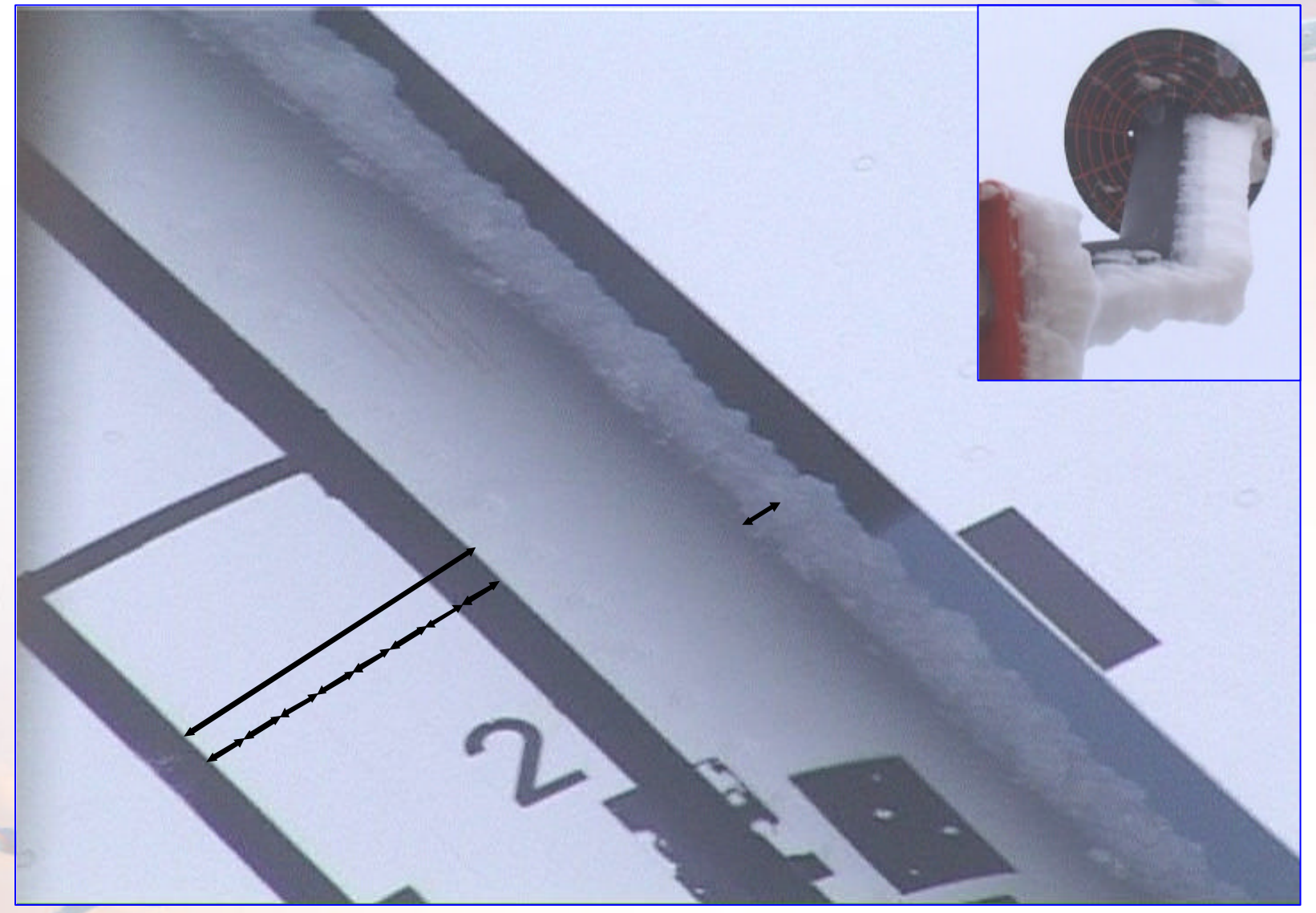


Icing conditions

- To go further and allow extensive testing of iced aircraft, ice shapes were manufactured using videos from natural ice flights.



Icing conditions



Icing conditions

- Flights with ice shapes allowed to quantify spoilers efficiency increase (+25%) on both A320 & A321.

- Analytic roll inputs showed unusual A321 roll response of the iced A/C (overshoot, degraded turn coordination…). (A320/319 are OK on this aspect).

- This degradation was mainly observed in Conf Full, to a much lower extent in Conf 3.

- Similarly, the increased spoilers efficiency decreased the A321 F/CTL law stability at some piloting frequencies in Conf Full and not in Conf 3. (A320/319 are OK on this aspect).

Crosswind conditions

- Recorders analysis of both events allowed to link the roll oscillations to pedal inputs applied very early in approach (starting from 200ft).

- Rudder was apparently used to co-ordinate the turn (i.e. in the same direction as roll stick input) and/or to increase roll response.

- In one case, after a Go around, rudder was used as recommended (for de-crab) in Conf 3 without any problem.

Icing and crosswind conditions synthesis

- A deep analysis shows that on A321, roll generated by rudder pedals in Conf Full was more important than on other Single Aisle aircraft.

- The additional roll generated by rudder inputs and/or gust can be compared to the increased roll efficiency of spoilers on iced A/C.

- Both icing and crosswind incidents have the same root cause: a reduced stability margin of the lateral normal law (with pilot in the loop) when combined with additional (non linear) roll efficiency (generated by rudder input/gust/ice shapes effects on spoilers).

A321 lateral law stability summary

A321, Conf Full nominal case
(no ice, no crosswind)

Lateral law stability is satisfactory

A321, Conf Full + roll
response modification

Lateral law stability is decreased

➔ Risk of PIO is increased

Corrective actions

- Short term actions:

  A red OEB (153-1, June 2003) was issued to airlines recommending Conf 3 for landing with significant crosswind, in moderate to severe turbulence, or in moderate to severe icing conditions.

- Mid term actions:

  Modifications of the lateral normal control law in Conf 3 and Full on A321.

  → Re-tuning of the gains (Conf 3 and Full) and adjustment of spoilers kinematics (Conf Full).

Corrective actions

- After complete flight test evaluation (including evaluation in crosswind and with ice shapes), modifications were judged satisfactory:

  → Stability margin at the same level than A320.

  → A/C response in « normal » conditions not degraded versus basic A/C (even improved).

  → A/C handling with ice or in turbulence/crosswind significantly improved (for pilot used to fly the A321, lateral behaviour is now similar to the A320).

Corrective actions

A321, Conf Full nominal case (no ice, no crosswind)

Lateral law stability is satisfactory

A321, Conf Full + roll response modification

L81

Impact of roll response modification was decreased (same level as A320)

→ no more risk of PIO

Other modifications introduced in ELAC L83/L91

Some other improvements were introduced on ELAC L83/L91 for A321:

- Autopilot (AP) robustness :
  - AP disengagement logic upon Vc/Mach overspeed conditions is made more robust (same logic as on A330/340 family, based on speed filtering to avoid spurious AP disconnection upon quick/slight overspeed due to gust).

- Aileron anti-droop (option by pin-programming):
  - Improvement of Single Aisle A/C landing and RTO performance using the ailerons as ground spoilers (symmetrical upward deflection) :
    - Increase of A/C drag
    - Increase of vertical loads on wheels to improve braking performance

ELAC L83/L91 certification and retrofit status

- F/CTL modification will be available for airlines in 2 ELAC
  - L83 for ELAC A hardware
  - L91 for ELAC B hardware

- Certification dates
  - End of January 2004 for L83
  - End of March 2004 for L91 (TBC)

- A321 retrofit will then start as soon as possible

Conclusion

- Thanks to an extensive Flight test campaign and Fly by Wire Flight Controls, the issue could be identified and solved quickly.

- ELAC L83/L91 will remove the OEB for degraded weather conditions and will provide the same level of handling as on other Single Aisle in normal conditions.

- Even with ELAC L83/L91, basic recommendations are unchanged:
  - **Restrict use of rudder in approach to "de-crab" the A/C in crosswind** (recommendation FCOM bulletin N°54/1 "Aircraft Handling in final approach")
  - **Extended flight in icing conditions with slats extended should be avoided** (FCOM, Vol 3, supplementary techniques, 3.04.30)

Thank you for your attention

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