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BEA

Bureau d'Enquêtes et d'Analyses
pour la Sécurité de l'Aviation Civile

Le Bourget, le 13 janvier 2004

N° /BEA/

Objet : AA 587 accident
V/réf :
P.J :

Mr Robert Benzon
Investigator In Charge
NTSB/AS-10
490 L'Enfant Plaza S.W.
Washington, DC 20594
United States of America

Dear Bob,

Please find attached the BEA's comments on the report entitled "An Inquiry into whether a Pilot-Induced oscillation was a factor in the crash of American Airlines Flight 587", which was submitted to the Human Factors group.

Since, in the context of the accident, this is the only study available on this subject, we would like to make some comments on it.

We would like to thank you for this opportunity to review this document and hope that the comments we have made may contribute to advancing the investigative process.

Best regards,

Pierre Jouniaux
Accredited Representative

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BEA comments on the report entitled
"An Inquiry into Whether a Pilot-Induced oscillation was a factor in the crash of American Airlines Flight 587".

Regarding the general approach:

On section II, « PIO phenomenon », we have no comments on the veracity of what is presented. What may, however, lead to confusion is the choice of the examples and the definitions given.

This section presents a digest of what is known on the subject of PIO, but it should be emphasized that:

The two examples selected (the C17 and the Space Shuttle) describe phenomena where the flight control used acts directly on the axis to be controlled (aileron/roll for the C17, control column/pitch for the Shuttle). The main difference with AA587 resides in the fact that, in the latter case, the pilot used rudder control inputs in an attempt to control roll. The main identifiable cause of time delay between the control inputs and aircraft response is, in this case, the time delay to induce roll. This subject is, however, never examined in this study.

In the following section, a conclusion is reached through syllogism, based on the judgment that there is PIO and that this phenomenon is attributable to the sensitivity of the airplane's flight controls. This short cut fails to take into account induced roll, characteristic of rudder control, that is common to all transport airplanes in this category, which generates a time delay between the pilot's control input and the response perceived. The Airbus simulation on the relation between PIO on the roll axis and the sensitivity of the controls appears to show that even a light rudder pedal input may create a divergent output. This system remains stable simply by using the control wheel with high gain.

As far as we know, no studies have been undertaken on PIO on the yaw axis since the rudder is not a primary flight control. It therefore seems important to treat this problem in a global manner, without omitting any elements.

The definition of sensitivity applied in this report for the purpose of comparing the A300-600 with other transport aircraft marks out the A300-600 without being representative of the handling qualities of the airplane.

To summarize, hypothetical PIO can be considered to be caused by a time delay between the control input and the expected parameter. This time delay is the sum of different elements:

- Pilot response time, which can be broken down into perception time and reaction time. It is commonly agreed that reaction time is about 0.2 seconds. As regards perception time and time to analyze the perception, this can be variable. In fact, this depends on factors relating to habituation. A trained pilot who knows the characteristics of the system well uses short cuts (Rasmussen model, « Skill Based Behavior »).
- The sensitivity of the flight controls, as mentioned in the report. There is, however, a lack of factual data to characterize the sensitivity of A300-600 rudder pedals and, in general, data on PIO induced by rudder pedal inputs.
- Time delay due to saturation of the servo-controls. The speed of the servo-

controls is about 45°/s for the ailerons and 60°/s for the rudder. This should be compared with other systems.

- Time delay specific to the use of the rudder (induced roll, etc).

Consequently, the approach used in the report, which does not include all of these parameters, cannot be considered as complete. The complexity of these phenomena requires additional precautions to be taken in the presentation of the results.

Comments on section III:

III.B.1: Bearing in mind all of the reservations expressed on this report, it does not appear to us to be convincing to state that the PIO phenomenon has been clearly established just on the basis of observations made on oscillation frequencies. We note that following the first right open loop rudder input there was a first rudder doublet over a period of two seconds, stabilization for two seconds and then a second doublet over a period of two seconds. These observations do not lead to the conclusion that there is a cyclical phenomenon.

It is likely that the pilot reacted to unusual perceptions and that his actions in turn reinforced his perceptions. Given the complexity of the system, with reactions in all three axes, it seems to us difficult to make a simple judgment that the flight controls are implicated. Further, and in accordance with E. Cooper's warning on the evaluation of an airplane's handling qualities, only an evaluation carried out with a pilot would make it possible to draw any conclusions on the sensitivity of the flight controls:

At present the applicability of the mathematical analysis including representation of the human operator is restricted to the analysis of restricted task. Since the intended use (mission) is made up of several tasks and several modes of pilot-vehicle behavior, it is difficult first to describe accurately all modes analytically, and, second to integrate the quality in the separate tasks into a measure of overall quality for the intended use. "(G. E. Cooper NASA, the use of pilot rating in the evaluation of aircraft handling qualities)

III.B.3: sensitivity was defined, by the human factors group, as "magnitude of aircraft <u>motion</u> in response to a given amount of rudder pedal force above the breakout force (simple measure = lateral acceleration in cockpit resulting from the yaw moment)". However, this report uses another definition of sensitivity "A300-600 rudder pedal is more sensitive than Boeing design if you compare the <u>degrees</u> of rudder commanded per pound of pedal force above breakout".

This new definition of sensitivity cannot be taken into account as a significant factor, since an airplane with different flight control surface dimensions may have identical sensitivity, even though the reactions felt may be very different. Comparisons with other manufacturers on this basis seem meaningless and inappropriate.

We do not agree with the physiological data described in this study. The size of a muscle has no influence on control sensitivity. Comparisons with helicopter yaw control and automobile brake control would serve to illustrate our point.

III.B.5.a

The last phrase contains a short cut that does not satisfactorily establish the relation between rudder/pedal sensitivity and a longitudinal axis PIO. While it is true that uncoordinated actions on the roll and rudder controls may have disoriented the pilot, it is still not proven that the sensitivity of the rudder controls was the initial causal factor.

III.B.5.b

The use of these results is surprising. Observations made on servo-control rate saturation can be applied to all aircraft. There is no aircraft on which the servo-controls respond instantaneously. This means that the time delay which is mentioned here is a general characteristic. It is, of course, necessary to take this into account in the study but it would be reasonable to include (as in table 1) the relative position of the A300-600 in relation to other airplanes in the same category and to add that the other airplanes have the same limitations. Thus the time delay which is mentioned for the time delay calculation would apply to any servo-control, and it is worth noting that this time delay is of the order of a half a second. In any case, it has not been proven, on the basis of the FDR parameters, that there was any saturation of the rudder, only of the ailerons.

Comments on section IV:

The proposition that “the pilot did not use the rudder/pedal implies no PIO” does not mean that “the sensitivity of the rudder/pedal implies PIO».

The preceding remarks and questions call into question the conclusion of this report. The only source of time delay accepted is the sensitivity of the rudder pedals. By omitting the time delay associated with the induced roll that develops when the pilot uses the rudder pedals, as well as the impact of pilot conditioning on the gain, the topic is examined only partially. It is thus difficult to use this document as it stands in the context of the analysis of this accident. It does, however, provide a springboard for questions that may lead to an understanding of this event.