August 7, 1998

The Honorable James Hall
Chairman
National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, DC 20594-2000

Dear Chairman Hall:

In September 1997 ALPA forwarded to the NTSB its submission regarding the accident involving USAir Flight 427. Today ALPA feels even more strongly that the points raised in that submission are valid and correct. However, during this past year there has been additional investigative work, resulting in additional evidence on which ALPA would like to offer comment. This addendum focuses on this new evidence and **is not intended to replace the findings from our 1997 submission, but rather to further explain and refine our positions through use of this new evidence.**

Thank you for the opportunity to comment.

Sincerely,
Captain Herb LeGrow
ALPA Coordinator

Addendum Sections: Aircraft Performance, Human Performance, Hypotheses 1-4, Conclusion

Aircraft Performance

In ALPA's September 30, 1997 submission we detailed our thoughts regarding the limitations in any results obtained from the kinematic study conducted during this investigation. We wanted to take this opportunity to reiterate or re-enforce those thoughts. The results of any kinematic study are a function of:

- Flight Data Recorder data accuracy and sampling rate,
- Simulator model equations of motion and the accuracy in modeling the effects of wind or other atmospheric disturbances such as wake vortices,
- Aerodynamic and fight control system data used in the simulator model, and
- Assumptions regarding aircraft weight, center of gravity, effect of wind or atmospheric disturbances on the aircraft.

Changing any of the above can alter the results of the kinematic study. Overall ALPA believes that the kinematic model was a useful tool to use during the course of this investigation. However, the results of this model can change depending on the variables listed above. With the known limitations of the kinematic study, the Board must consider the results of the kinematic study in context with the results obtained from the other investigative groups. The other, key, groups during the course of this investigation include Aircraft Systems and Human Performance.

Recently the NTSB has developed their own B737 simulation enabling them to also conduct a kinematic analysis. By using this simulation NTSB staff experts were able to match the flight recorder information from the Eastwinds B737 upset incident by simulating a secondary valve jam of the main rudder PCU. Boeing, using their simulation model, was also able to match the Eastwinds DFDR but assumed a pilot rudder input in conjunction with a yaw damper malfunction. Both scenarios match the same recorded DFDR data, demonstrating that it is possible to match the maneuver with different scenarios by varying the assumptions and interpretations of the source data. However ALPA believes that the Board is more accurate in their scenario since the rate of the rudder input required to match the maneuver is the same rate which would result from a PCU secondary valve jam.

NTSB staff, using their simulation, has also been able to match both the USAir 427 and UAL 585 accident upsets by assuming a PCU secondary valve jam. In all three cases the rudder input rate needed to match flight recorder data is consistent with the rudder rate which would result from a secondary valve jam. It is extremely unlikely that three different pilots in three different B737s, on three different days would use the same rudder rate. Yet, if the secondary valve were jammed in each case, it would result in the same rudder input rate.

As mentioned, the kinematic study is just one investigative tool. The results of the kinematic study must be reviewed in context with the results of the other investigative groups. A secondary valve jam of the PCU matches the DFDR data for each of the events and is consistent with possible failure modes identified by the Aircraft Systems Group.

Human Performance

ALPA recognizes that an analysis of the crew's speech and breathing patterns is only circumstantial evidence, however, we feel that it is some of the most direct evidence of the crew's actions. In our previous submission, we examined and offered explanations for the crew's breathing patterns and speech utterances such as rapid inhalations and grunting. In that submission we concluded, based on the work of experts who were consulted by the Safety Board, that the first officer was attempting to operate the flight controls throughout the upset period, and that the captain did not attempt to take over controls until the aircraft was clearly unrecoverable. We likewise noted that analysis performed by expert consultants to the NTSB suggested that neither crewmember panicked or "froze- up" during the initial stages of the upset. That submission also referred to "grunting sounds" and "rapid inhalations" that were indicative of physical straining, as referenced in NTSB's "Speech Examination Factual Report," dated May 5, 1997.

On June 16, 1998, the NTSB issued "Speech Examination Factual Report Addendum." That addendum stated, "These observations of pilot straining are of critical interest to the human performance investigation, since they occurred during a brief time period during which the airplane went from controlled flight into a loss of control situation. Therefore Safety Board staff attempted to measure all sounds by the first officer related to physical straining on the possibility that this information would be meaningful to understanding the actions of the first officer during this period." The Safety Board identified and documented six distinct human sounds between times 1902:57.6 and 1902:57.8 (134.6 - 142.1). These sounds, as documented by the NTSB Speech Examination Group, were as follows:

- the statement "zuh" from 1902:57.6 to 1902:57.8 [134.6-134.8]
- a sound like a rapid inhale from 1902:59.7-1902:59.9 [136.7-136.9]

- a sound like soft grunting from 1903:00.3-1903:00.5 [137.3-137.5]
- a sound like loud grunting from 1903:01.5-1903:01:6 [138.5-138.6]
- a sound like a loud exhale from 1903:01.8-1903:02:1 [138.8-139. 1]
- the statement "oh #" from 1903:04.6 to 1903:05:1 [141.6-142.1]

To better understand the significance of these speech sounds, ALPA referred to the "NTSB Speech Examination Factual Report," dated May 5, 1997. In this report the NTSB cites the work of two experts that the NTSB consulted for this accident, Dr. Alfred Belan and Dr. Scott Meyer. Below are direct quote excerpts from the reports of these experts:

Dr. Meyer stated:

> "The two grunting sounds of the F/O heard after the onset of the emergency are indicative of muscular exertion or physical straining." [underline added for emphasis]

> "Generally, during increased muscular exertion, it is common for the individual performing the movement to apply a considerable exhalatory force against a closed or partially closed glottis in the throat. When the breath is finally exhaled, it is forceful and quick and usually accompanied by a grunting sound. The forceful movements of weight lifting and other short duration, high intensity physical activities are routinely accompanied by grunting." [underline added for emphasis]

> "The grunts suggest that the F/O was straining possibly in an attempt to manipulate the controls of the aircraft to override the autopilot." [underline added for emphasis]

According to Dr. Belan:

> "A person making a great physical effort develops a musculoskeletal "fixation" (of the chest), which leads to deterioration of the normal expansion and ventilation of the lungs (inhaling and exhaling). These changes are manifested during speech. Sounds such as grunting and strain appear in speech as the person tries to minimize the outflow of air. Inhaling and exhaling become forced and rapid." [underline added for emphasis]

> "The first officer, from the moment 1902:59.5 most likely was actively involved in the control of the airplane. Beginning at this time, and continuing for several seconds, speech disruptions could be observed that included grunting and forced exhalations (1902:59.5, 1903:01.1, and 1903:02.0)... These are signs of high physical loads. Normal use of the cockpit controls should not produce the types of sounds shown in this period. These sounds indicate that the first officer was struggling unusually hard, for example if he was pushing a control against its stops or if he was experiencing an unusual resistance in the use of a control." [underline added for emphasis]

The words that ALPA underlined above for emphasis are: muscular exertion, physical straining, increased muscular exertion, high intensity physical activities, straining, great physical effort, strain, high physical loads, and struggling unusually hard. By these descriptive adjectives, it is clear that each of these experts believed that the first officer was straining and under high physical loads during this time period.

ALPA evaluated a comprehensive list of events that could have caused the first officer to strain and exert high physical loads on the aircraft. We narrowed the list to four hypotheses.

The evaluated hypotheses were that the first officer was:

1. struggling with the flight controls because each pilot was "on the controls" in an attempt to regain aircraft control;
2. struggling to push or pull the control column forward or aft;
3. struggling to turn the aircraft with roll control (aileron) by turning the control wheel left or right;
4. struggling to depress a rudder pedal.

Hypothesis 1

With respect to Hypothesis 1, we note the work of Drs. Belan and Meyer. Dr. Belan stated that, "… Sounds such as grunting and strain appear in speech as the person tries to minimize the outflow of air. Inhaling and exhaling become forced and rapid. None of these effects appear in the captain’s speech during this period. Based on all the above evidence, it could be concluded that the captain did not apply high physical loads to the controls. His actions were limited to the commands and attempt to evaluate the situation." Dr. Belan concluded from his analysis, "From the beginning of the accident sequence until the time 1903:17.4 the captain did not apply high physical loads to the controls and, most likely did not participate in the control. The first officer applied physical loads and controlled the airplane."

Dr. Meyer stated, "It is difficult to determine with certainly from the tape whether the PIC used increased muscular force on the controls during the emergency period. There was no audible grunting or straining indicative of muscular exertion heard. There was no indication of muscular strain during any of the verbal communications from the PIC heard on the tape. His initial comments were calm and controlled. His nonverbal breathing was unobstructed. That is not to say that the PIC was not on the controls, but only that he did not appear to be exerting increased muscular force during that time."

Although they both weighed 210 pounds, the first officer was taller and younger that the captain. The captain had undergone back surgery approximately six months prior to the accident. It is highly unlikely that the captain could have been "on the controls" without straining, when the FO would have been straining to overpower him. If both pilots were on the controls, one would expect to have found that both pilots were straining, and not just the first officer.

Based on all of this information, ALPA rejected the hypothesis that the first officer was straining because he was struggling with the flight controls because each pilot was "on the controls" in an attempt to regain aircraft control. (Hypothesis 1)

Hypothesis 2

We evaluated Hypothesis 2, which stated that the first officer was straining due to his struggling to push or pull the control column forward or aft. This hypothesis was rejected because control column was recorded on the FDR and was shown to be in approximately the "neutral" position during this portion of the upset.

Hypothesis 3

This hypothesis considered that the first officer was straining as he struggled to turn the aircraft with roll control (aileron) by turning the control wheel left or right. To evaluate this, it is important to look at the sequential order of events.

At 1902:57.6 (134.6), the first officer uttered "zuh." As explained by Dr. Meyer's report, "The emergency period starts with the F/O having just remarked that he had located the aircraft traffic. Immediately following his statement and coincidental with the initial, unusual movement of the aircraft was the remark "zuh." This appeared to be an attempt to continue speaking that was abruptly halted with the abnormal departure (pitch, roll, or yaw) of the aircraft. He may have been responding to the situation by seizing the controls to correct the movement and reflexively stopped speaking to concentrate on his duties."

ALPA also believes that at this time the first officer immediately grabbed the control wheel and reflexively began turning it rapidly to the right. The NTSB's independent kinematic analysis and the one largely constructed by Boeing both indicate that a full control wheel input was introduced at this time. In addition to Dr. Meyer's above comments, there are two additional facts that lead ALPA to conclude that the first officer made these inputs:

- the FDR shows small, but rapid, forward and aft movements on the control column, which is characteristic of human input rather than autopilot input.
- the rate of input on the control wheel was aggressive and exceeded the autopilot parameters; to exceed the autopilot parameters would have required approximately 50 pounds of force.

It is very important to note that despite his rapid control wheel movements, which required force to override the autopilot rate, there is no evidence that the first officer grunted or strained at this point. This demonstrates that the first officer could (and did) manipulate the control wheel without any outward signs of straining.

When the straining did occur, it was some 2.5 seconds later. Because the first officer had already demonstrated that he could manipulate the control wheel without straining, ALPA concluded that the CVR sounds that were indicative of straining beginning at 1903:00.3-1903:00.5 (137.3-137.5) were most likely <u>not</u> due to his additional attempts to turn the aircraft with roll control (aileron).

There was another factor that played into ALPA's conclusion that the first officer's grunting was not in response to the fighting against the autopilot. According to Dr. Meyer's analysis, "After the onset of the emergency, two rapid grunting exhalations were heard. The first grunting sound was soft and indicated some submaximal muscular exertion. The second grunting sound was louder and more forceful representative of the use of increased, but probably submaximal, muscular force. The grunts suggest that the F/O was straining possibly in an attempt to manipulate the controls of the aircraft to override the autopilot."

Although Dr. Meyer suggests that grunting may be in response to attempting to override the autopilot, ALPA does not believe that a constant input to override the autopilot would result in a "louder and more forceful … muscular force." In fact, when overriding an autopilot one would expect a steady or even a declining force instead of an increasing force.

Additionally, the kinematic analysis shows that during the time of the first officer's grunting sounds ("soft grunting" 1903:00.3-1903:00.5 [137.3-137.5] and "loud grunting" 1903:01.5-1903:01:6 [138.5-138.6]), the wheel position was not a continuous "ramping-up" of movements. Quite simply, when overlaying these grunting sounds with the derived control positions from the kinematic analysis, there is no reason why the first officer would have been straining due to manipulating the control wheel. There is nothing in the kinematic analysis to support why the first officer would have straining with the control wheel at this point.

For these reasons, ALPA rejected the hypothesis that the straining observed on the CVR was the result of his attempts to fight against the autopilot by attempting to turn the control wheel left or right.

Hypothesis 4

ALPA looked at the possibility that struggling documented on the CVR could have been in response to the first officer depressing a rudder pedal. This straining occurred within a few milliseconds of the kinematic analysis indicating initial left rudder input. The question raised by ALPA is why would a pilot who is in excellent health strain to depress the pedal of a normally functioning rudder? If the pilot were depressing on the left ruder pedal, then why would this require such a physical load such that it caused him to strain? There are a few situations that require pilots to input large rudder inputs, yet pilots routinely do them without straining. Crosswind takeoffs and landings are two such examples. Another is that during training (every 6 months in the simulator at USAir) pilots are required to perform at least one engine failure at takeoff. Although this maneuver requires a heavy rudder input, the required rudder pedal forces are never high enough to cause pilots to experience muscular exertion, physical straining, increased muscular exertion, high intensity physical activities, straining, great physical effort, strain, high physical loads, and struggling, which were the exact words that the experts used to describe the first officer's utterances on the CVR.

In these examples, there is no need for straining because the rudder is powered by hydraulics, i.e., the pilot makes a rudder pedal input and the rudder is then moved by a rudder power control unit actuator. Dr. Meyer stated that, "[T]he physical act of manipulating the control surfaces of modern aircraft under normal conditions does not usually require excessive muscular force... Nevertheless, during emergency situations, increased muscular force may be needed to manipulate the controls of an aircraft. Generally, during increased muscular exertion, it is common for the individual performing the movement to apply a considerable exhalatory force against a closed or partially closed glottis in the throat, when the breath is finally exhaled, it is forceful and quick and usually accompanied by a grunting sound."

To summarize this point, when a rudder is properly working the pilots will not have reason to struggle with the rudder. However, as documented, pilots attempting to interact with jammed or blocked rudder can require extreme forces. For example, on June 9, 1996, Eastwind Airlines flight 517, a Boeing 737-200, N221US, experienced a roll/yaw upset while on approach to land at Richmond, VA. The crew was able to counteract the failure and safely land the aircraft. While the NTSB's investigation of this event is ongoing (DCA-96-IA-061), it is believed that the event was precipitated by a yaw damper hardover. Following the event the Safety Board interviewed the crew. According to the "Human Performance Group Chairman's Factual Report," dated July 29, 1996, the captain stated that he "pushed quite hard" on the rudder pedal in an attempt to regain control of the aircraft. The first officer stated that he observed the captain "fighting to regain control" by "standing on the left rudder" pedal.

In June 1997, Boeing Commercial Airplane Group conducted a ground demonstration to evaluate rudder pedal movement during simulated rudder Power Control Unit (PCU) secondary servo valve slide jams at different positions. Malcolm Brenner, NTSB Human Performance Group Chairman for this accident, participated in the Boeing-conducted tests. According to his June 12, 1997 memo, Dr. Brenner stated that he occupied the right cockpit seat during these tests while wearing his seat belt.

Dr. Brenner found that when the slide jams were introduced, pressing on the opposite rudder pedal did not resolve the jam. He stated that the movement against his foot pressure was "unrelenting," meaning that no matter how hard he pushed on the pedal, the harder it seemed that the pedal was being forced against his foot. In one case (the 25% off neutral simulated jam), the only way to neutralize the rudder and return it to its normal state of usage was to release all rudder pedal pressure. In another simulated jam (the 50% off neutral jam), Dr. Brenner found that releasing rudder pedal pressure had no effect on stopping the uncommanded rudder movement.

As stated in ALPA's 1997 submission to the Safety Board, ALPA believes that a secondary slide jam occurred during the wake encounter, resulting in an uncommanded rudder movement to the left. As the roll rate began to intensify to the left, the first officer correctly applied right rudder to counter the roll. However, using Dr. Brenner's remarks from above, ALPA concludes that the more pressure that the first officer applied to the right rudder pedal, the more likely it became that the rudder reversal would not clear. The more the aircraft turned to the left, the stronger the first officer's tendency would have been to apply increased right rudder pedal pressure; the harder he pushed on the right rudder pedal, the more certain it became that the jam would not clear. Under these circumstances the strength that the first officer likely used while attempting to press on the right rudder pedal would have required muscular exertion, physical straining, increased muscular exertion, high intensity physical activities, straining, great physical effort, strain, high physical loads, and struggling. These, of course, are the exact words that the experts used to describe the first officer's speech utterances.

After reviewing the above evidence, ALPA accepts the hypothesis that straining heard on the CVR was the result of the first officer attempting to depress a rudder pedal. As supported in the above discussion, we further conclude that the rudder pedal that he attempted to operate was the right rudder pedal, which could not move due to an internal malfunction of the aircraft's rudder system.

<u>**Conclusion**</u>

Based on the above analysis, ALPA believes more strongly that ever that the cause of the accident was a rudder anomaly.