NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

July 15, 2003

Human Performance

GROUP CHAIRMAN'S FACTUAL REPORT
ADDENDUM 1

A. ACCIDENT

Operator: American Airlines (flight 587)
Location: Belle Harbor, New York
Date: November 12, 2001
Time: 0916 Eastern Standard Time
Aircraft: Airbus A300-600, N14053
NTSB Number: DCA02MA001

B. HUMAN PERFORMANCE GROUP

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C. ACCIDENT SUMMARY

On November 12, 2001, about 0916 Eastern Standard Time, American Airlines flight 587, an Airbus A300-600, was destroyed when it crashed into a residential area of Belle Harbor, New York, shortly after takeoff from the John F. Kennedy International Airport (JFK), Jamaica, New York. Two pilots, 7 flight attendants, 251 passengers, and 5 persons on the ground were fatally injured. Visual meteorological conditions prevailed and an instrument flight rules flight plan had been filed for the flight destined for Santo Domingo, Dominican Republic. The scheduled passenger flight was conducted under Title 14 Code of Federal Regulations (CFR) Part 121.

D. DETAILS OF THE INVESTIGATION

Following completion of the Human Performance Group Chairman's Factual Report on October 3, 2002, the Human Performance Group has conducted additional activities and compiled additional factual material that is summarized in the present report.

D.1 Chronology of AAMP events

To assist the investigation of training issues, the Group prepared a chronology of major events in the American Airlines Advanced Aircraft Maneuvering Program (AAMP) related to the accident crew. The chronology is presented in Attachment 1.

D.2 Meeting at American Airlines Training Academy

From December 2 - 4, 2002, the Human Performance group met at the American Airlines Training Academy, DFW Airport, Texas to examine AAMP training on rudder use. The Group accomplished the following activities:

- reviewed ground school training from an AAMP videotape made at the time the accident crew completed the ground school
- interviewed simulator instructors who trained the accident first officer
- conducted an experimental study in the A-310/300 training simulator that examined different pilot strategies of rudder use in response to the AAMP excessive bank angle recovery exercise
- interviewed the crew of American Airlines Flight 934 who were involved in a rudder-related A300-600 incident on 10/28/02.

For the AAMP videotape, group members viewed the tape "Unusual Attitude Recovery" which was the first of several videotapes prepared by the AAMP program and distributed to all American Airlines pilots. According to a representative of American Airlines, most of this videotape was prepared by editing recordings of two actual AAMP ground school classes conducted at the American Airlines Training Academy in early 1997. Because both accident pilots attended AAMP ground school during this period,[1] this part of the videotape was viewed as documenting rudder use philosophy in place at American Airlines at the time when both pilots were introduced to AAMP concepts and procedures. The final portion of the videotape consisted of review comments made by the instructor without a class. According to an American Airlines representative, this final portion was prepared late in 1997 in response to industry comments on the AAMP program. It was not presented in the ground school classes attended by the accident pilots, although they could have been exposed to this material because the videotape was subsequently distributed to all American Airlines pilots in December 1997 by the Manager of Flight Standards. Attachment 2 provides a verbatim transcript of the instructor's statements during all segments of the videotape that directly addressed rudder use.

The Human Performance Group contacted three simulator instructors who provided the most recent AAMP simulator training to the accident first officer.[2] The focus of the effort was to learn more about the AAMP simulator exercise in excessive bank angle recovery, an exercise with possible similarities to the accident situation such as a wake turbulence setting, and group members documented how the instructors presented this exercise and what guidance they provided on rudder use. Instructors Cook and Goff, who trained the first officer most recently (12/2000), were interviewed by telephone and interview summaries are provided in Attachments 3 and 4. Instructor Walbridge, who provided the first officer's original upgrade training on the A300-600 (9/98) and initial A300 recurrent training (9/99), met the group in person and served as instructor for an experimental study conducted in the simulator. He provided the pre-simulator briefing to the Group on the excessive bank angle recovery exercise and then acted as instructor to six pilots from the Human Performance Group who individually performed the exercise under varying rudder input recovery strategies. The purpose, procedure, and results of the experimental study will be described in an upcoming report.[3]

Finally, the Human Performance group conducted interviews of the first officer and captain of the Flight 934 incident, interviewing each independently. Interview summaries are provided as Attachments 5 and 6. Attachment 7 shows

[1] The accident captain attended AAMP ground school training in May, 1997 and the first officer in March, 1997. An American Airlines representative indicated that, because of the dates involved, either the first officer or captain may have been present at one of the sessions shown in the videotape.

[2] Attempts were made to contact two additional instructors who provided AAMP simulator training to the first officer but these were unsuccessful.

[3] Human Performance Group Study Report, American Airlines Simulator Exercise (in preparation).

measurements made of the first officer's seating and leg dimensions relative to the rudder control layout in an A300-600 simulator cockpit.

D.3 Visit to Veridian Flight Research

On January 9, 2003, four NTSB investigators (Benzon, Brenner, Poland, O'Callaghan) visited the Veridian Flight Research Group in Buffalo, NY, a research facility recognized for technical expertise in flight control design and in-flight training programs. The purpose of the trip was to discuss flight control issues and to participate in a flight demonstration of handling quality characteristics in the Veridian Learjet Model 24 in-flight simulator. For the flight demonstration, a safety-pilot/instructor was seated in the left seat of the Learjet to coordinate the demonstration and program the airplane simulation characteristics. Three NTSB investigators (Brenner, Poland, O'Callaghan) took turns individually seated in the right seat and flew the airplane in a succession of defined maneuvers, including Dutch roll entry and recovery, while it was programmed to provide varying handling quality characteristics. The demonstration included:

- quick onset of 0.5 g vertical acceleration
- lower damping ratio than Learjet
- heavier damping ratio than Learjet
- high frequency airplane response with abrupt reaction ("quick feeling")
- low frequency airplane with lag in response resembling a heavy transport
- small vs. large displacements of controls, showing increased PIO tendency with small displacements in the aerodynamics and flight control configuration being demonstrated
- Dutch roll recovery with aileron, rudder or both

D.4 In-flight Upset training

On January 23-24, 2003, two NTSB investigators (Benzon, Ivey) and one Human Performance Group member (Thompson) attended the Upset Recovery Training Ground School in Roswell, NM provided by Veridian Flight Research Group under FAA sponsorship. It consisted of three days combining classroom instruction and flight training in an aerobatic F33 Bonanza airplane and Learjet Model 25 in-flight simulator. The training provided an opportunity to compare actual airplane to simulator training for upset programs.

D.5 Meeting in Washington, D.C.

On February 19-21, 2003, Human Performance Group met at NTSB Headquarters, Washington, D.C. The purpose of the meeting was to review all

available factual evidence (including that derived from cockpit voice recorder (CVR), flight data recorder (FDR), and previous experimental efforts conducted at the NASA-Vertical Motion Simulator, Airbus Industrie, and American Airlines Training Academy) and discuss areas of further investigation necessary to complete the factual record. The group met with Dr. Ron Hess of the University of California - Davis to discuss the possibility that pilot-induced-oscillation (PIO) issues were reflected in the accident.

D.6 Rudder check by the first officer

As part of a review of rudder use by the accident first officer, the Group explored the rudder check performed by the first officer prior to takeoff and captured on the accident FDR.

The CVR transcript indicated that the first officer performed the pre-takeoff rudder check at the direction of the captain[4] and confirmed when it was complete.[5] At the request of the Human Performance Group, the FDR Group Chairman prepared an FDR record of the rudder check.[6] In addition, the FDR Group Chairman measured the duration of all rudder checks recorded on the accident FDR by pilots flying the accident airplane in the time period immediately before the accident. Attachment 8 summarizes the 24 rudder checks observed (in reverse chronological order), including the measured time period of approximately 17.4 seconds used by the first officer in completing the rudder check before the accident.

D.7 Rudder use during takeoff roll

As part of a review of rudder use by the accident first officer, the Group examined the accident FDR for any additional evidence of rudder use by the first officer from the time the captain assigned control of the airplane to the first officer[7] until the accident period beginning with the first wake encounter.

A careful review of the FDR record revealed only one period during which there were rudder inputs. This occurred early in the takeoff roll and consisted of several rudder inputs resembling steering. At the request of the Human Performance Group, the FDR Group Chairman prepared an FDR record of these

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[4] 0902:05, HOT-1: "your leg, you check the rudders." The company A-300 operating procedure did not specify which pilot should perform the rudder check, but the rudder check was typically performed by the captain since the tiller was located on the captain's side of the cockpit and tiller use might be needed to counteract nosewheel inputs that resulted from the rudder check.

[5] 0902:23, HOT-2: "rudders check."

[6] Addendum 1, Flight Data Recorder Group Chairman's Solid State Flight Data Recorder Factual Report, July 9, 2003.

[7] 0913:21, HOT-1: "you have the airplane."

inputs.[8] In addition, the FDR Group Chairman prepared a record of rudder inputs from the three preceding takeoff rolls recorded on the accident FDR, allowing comparison of the accident first officer's inputs with those of the pilots who performed the three previous takeoffs in the accident airplane.

D.8 Rudder design data

At the request of the Safety Board, both Airbus Industries and Boeing Airplane Manufacturing Company provided data on rudder displacement and force characteristics for all large transport-category airplanes in their product line. The data are included as Attachments 9 to 10, respectively.

D.9 Rudder and pedal responses in airplane and simulator

The Human Performance Group conducted several tests to verify that rudder pedal responses at different airspeeds were similar in the actual airplane and the American Airlines simulator to the nominal characteristics provided by Airbus Industries.

On January 31-February 1, 2002 three NTSB investigators (Elias, Ivey, Poland) performed tests in an A300-600 airplane at the American Airlines Maintenance facility at Tulsa, Oklahoma. Assisted by an American Airlines representative (Young), they measured the rudder pedal limits at different imposed airspeeds, the travel of the wheel, and the dimensions of the wheel. For measurement of pedal limits, an NTSB investigator (Ivey) sat in the left cockpit seat and, on command, pushed the left pedal with normal force to its bottom stop ("A300-Normal Force"). A second investigator (Poland), located at the right cockpit seat, recorded the actual pedal motion. Measurements were made at airspeeds of 30, 150, 165, 190, 220, 240, 250, 275, 310, and 335 knots (not in order). Following this first series of measurements, a second series of measurements was performed in which the investigator, on command, pushed the left pedal as hard as he was physically able ("A300-High Force"). Measurements were made at the same nine airspeeds.[9] The airplane remained stationary on the ground with engines running during all measurements and an electrical manipulation of the pitot system was used to make the rudder limiter system engage as though the airplane was operating at the designated airspeeds.

On September 10-17, 2002 the Human Performance Group convened at the Airbus Facility in Toulouse, France to participate in ground tests of the A300-600.

[8] Addendum 1, Flight Data Recorder Group Chairman's Solid State Flight Data Recorder Factual Report, July 9, 2003.

[9] Because the measurement process itself required about 5 seconds, the values determined for high force reflect whatever value the investigator was able to maintain over this time period.

These included tests during which three pilots made full reverse inputs on the rudder pedal at three rates: 0.25 Hz (or one cycle every four seconds), 0.5 Hz, and 1 Hz. The tests provided data on the pedal characteristics of the actual airplane in response to dynamic inputs from a pilot and a detailed description of the tests and data is in preparation.[10]

On April 23, 2003, three investigators (Brenner, Poland, Ivey) performed tests in the A-310/300 training simulator at the American Airlines Training Academy, DFW Airport, Texas. Assisted by two American Airlines representatives (Thompson, Young), they repeated the measurement series performed previously at Tulsa to compare how the simulator portrayal of pedal characteristics compared to those of the actual airplane. An investigator (Ivey), sitting in the left cockpit seat performed a series of trials in which he pushed the left rudder pedal with normal force to its stop ("Simulator-Normal Force") and then performed a series of trials in which he pushed the pedal with as high force as possible ("Simulator-High Force"). A second investigator (Poland) recorded the actual pedal motion from the pedal at the right cockpit seat position, and additional measurements were output from the simulator of rudder position and pedal force.

Attachment 11 provides graphs that plot data from the three sets of tests. Figure 11A displays rudder motion in the simulator produced by normal and high input forces on the pedal and compares it to nominal values in Airbus literature. Figure 11B displays rudder pedal motion in the simulator and airplane produced by normal and high input forces on the pedal and suggests different pedal effects with different input forces. Figure 12C further develops this difference, displaying the degree of cable stretch observed when comparing high/fast input forces to normal forces in the airplane and simulator in the three tests. According to representatives of American Airlines and Airbus Industrie, the cable stretch of the simulator is simulated mathematically rather than determined by actual cables.

Submitted By:

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[10] Human Performance Group, Study Report: Airbus A300-600 Ground Test, in preparation.

LIST OF ATTACHMENTS

1. Chronology of major AAMP events related to the accident pilots.
2. Transcript of selections on rudder use from the AAMP videotape “Unusual Attitude Recovery”
3. Interview Summary, Instructor Walter Marvin Goff
4. Interview Summary, Instructor John Michael “Mike” Cook
5. Interview Summary, First Officer James Douglas Clark
6. Interview Summary, Captain Richard R. Pollum
7. Anthropometric measurements on First Officer Clark
8. Table of the approximate durations for each of 24 pre-takeoff rudder checks recorded on the accident flight data recorder (FDR).
9. Rudder design data provided by Airbus Industrie for large transport aircraft products.
10. Rudder design data provided by the Boeing Commercial Airplane Company for large transport aircraft products.
11. Figures comparing rudder pedal data as a function of airspeed from an A300 airplane and simulator.

Attachment 1
Chronology of major AAMP events related to the accident pilots (compiled from company records and witness interviews).

April 1995— Formal development of American Airlines Advanced Aircraft Maneuvering Program (AAMP) began.

October 1996 – Implementation of AAMP ground school for all American Airlines line pilots
March 26, 1997—Accident first officer attended AAMP ground school.

May 23, 1997—Accident captain attended AAMP ground school.

August 31 – September 2, 1997—Flight sequence in which the accident first officer was paired with Captain Lavelle and during which, according to Capt. Lavelle, he responded aggressively to a wake turbulence encounter and attributed this response to AAMP training.[11]

November 15-18, 1997— Accident first officer attended recurrent training on the B-727 that included AAMP simulator training on upset recovery (instructor Stevens).[12] This was the first recurrent training attended by the accident first officer during which he received AAMP simulator training.

December 4-7, 1997—Accident captain received recurrent training on the B-727 that included AAMP simulator training on upset recovery.

December 19, 1997—Date of AAMP videotape on "Unusual Attitude Recovery" distributed to all American Airlines pilots.

July 24 and July 27, 1998—Accident captain received simulator AAMP training as part of his initial A-300 transition training that included simulator training on upset recovery.

[11] As described in the Operations Group Chairman's Factual Report, Interview Summaries pp. 37-40, September 5, 2002. Airline records show that Capt. Lavelle was paired with the accident first officer on only two trips: a trip consisting of a single leg on June 8, 1997, and a three-day, five-leg flight trip from August 31-September 2, 1997. Interviews with flight engineers from the two trip sequences confirmed that the event happened during the second sequence.

[12] The instructor was required to present one of two possible upset exercises as part of the training, either the excessive bank angle exercise or a pitch upset exercise, and training records do not indicate which one was presented at any session. The excessive bank angle exercise, initiated by the instructor through a button press, is the one tested in the "Study Report—American Airlines Simulator Exercise" (in preparation).

November 9 and November 12, 1998—Accident first officer received his initial A-300 transition training that included AAMP simulator training on upset recovery (instructor Walbridge and check airman Sharp).

November 16, 1998—Accident first officer received initial check ride as a first officer on the A-300 in the simulator.

July 7-11, 1999—Accident captain received A-300 recurrent training that included AAMP simulator training on upset recovery .

November 8-12, 1999—Accident first officer received A-300 recurrent training that included AAMP simulator training on upset recovery (instructor Walbridge).

July 19-23, 2000—Accident captain received A-300 recurrent training that included AAMP simulator training on upset recovery .

December 19, 2000—Accident first officer received recurrent training that included AAMP simulator training on upset recovery (instructor Goff).

December 22, 2000—Due to maintenance problems in the simulator on December 21, when the accident first officer was originally scheduled to complete his recurrent training, the first officer received a refresher simulator training session that included AAMP simulator training on upset recovery (instructor Cook).

December 23, 2000—Accident first officer's last A-300 recurrent check ride

January 5, 2001—Accident first officer's completed A-300 recurrent ground training.

June 18-22, 2001—Accident captain' received A-300 recurrent training that included AAMP simulator training on upset recovery .

June 21, 2001—Accident captain's last A-300 recurrent check ride.

November 22-November 26, 2001—Accident first officer was scheduled for recurrent training during the period.

Attachment 2
Transcript of selections on rudder use from the AAMP videotape "Unusual Attitude Recovery"

Transcribed below are the instructor's comments from those selected portions of the videotape that provide direct guidance on rudder use. These portions occur in three places: in the discussion of recovery from an unusually nose high attitude, in the discussion of recovery from an unusually nose low attitude, and in the closing review segment.

In the discussion of "unusually nose high recovery:"

"the next thing [in the checklist procedure] then says "roll." Well, since you've unloaded, what are you going to roll with? Well, you're going to roll with ailerons and spoilers, aren't you? Rudder won't roll this airplane at low angle of attack. Ailerons and spoilers roll it.

So we come in with ailerons and spoilers and we roll toward the nearest horizon, i.e. if you are right wing low, roll right.

Now some of you out there might say "well, I'm going to use a little coordinated rudder to help the nose come down. Fine, that's fine, that's good technique. A little, OK, smoothly applied. I mean, understand right here: If you jam full right rudder, that's the spin entry procedure, see? So what we want is we're going to use roll controls here and then a little coordinated rudder.

…then it [the checklist] says, make a coordinated roll and I have that word "coordinated" underlined. And the reason that I do, is cause I want to get it straight between us today what I mean by that, because rightfully there 's a lot of different meanings for that word out there. OK? But in everything we do today, when I say "coordinated rudder" what I mean is that we will apply rudder in the direction we are trying to roll the plane. Left rudder, left roll. Right rudder, right roll. And just the amount of rudder that it takes to get the desired roll response. And these are very powerful rudders. It only takes smooth, small applications to get the desired results in most of our fleets. There is no time today we will use opposite rudder. None. Nothing we are going to do today involves opposite rudder. The only use I have for opposite rudder in these airplanes is crosswind landings and crosswind takeoffs. OK? We will always be using coordinated rudder.

In the discussion of "unusually nose low recovery:"

As we roll toward the sky pointer, notice that I get to the next one [checklist item] which, in yellow, says "apply coordinated rudder." Well, why am I saying

put in coordinated rudder since I just said rudder will not roll the plane at this alpha? But yet, I'm going to tell you to put your coordinated rudder fully in, fully, all of it, right now. Because, as many of you know, the rudder in this portion of the roll becomes what aerobatic pilots call "top rudder." It becomes the elevator of the airplane now. And these airplanes spend a lot of time in this portion of the roll, they don't roll that fast. So if you'll get your rudder fully in, in the direction that you're rolling, it will keep the nose from dropping through. Cause in this portion there is nothing lifting. And if you don't put that rudder in what's going to happen when you get to this portion of the roll she's going to slice out, just like that. But if you got the rudder all the way in, it will hold the nose.

Now most fleet aircraft, the nose will still drop slightly even though the rudder is all the way in, depends on how fast you are going. But the rudder ratio kind of accommodates that so at most speeds you're still not going to be able to hold it. OK?

The MD-11…you MD-11 guys that are here, you need to be aware you have got the most powerful rudder on the planet. And you should know that. In your case, you don't actually need all the rudder. When I was doing this…I did this in all fleet aircraft. In the MD-11 I found that I could actually stop the nose drop. Have you guys ever seen an MD-11 rudder? It's this great big segmented barn door. It comes off the tail and it goes all the way back to the nose. You seen anything? It is unbelievable. So, for you MD-11 guys, use the rudder but use it judiciously cause it is very effective on that airplane. You guys can actually hold your nose in this portion of the roll. I mean, you can control it, it won't come down at all. The rest of us, even with all the rudder in, it's going to be coming down somewhat. But at a very slow rate.

OK now, we get through to Bullet #4 which says "with bank angles less than 60 degrees." So what's happening here? We're holding the yoke full forward, we're rolling, right now we got all the rudder in too, don't we, in coordinated direction? We get in here, and when the bank angle comes less than 60 what's coming up now? The lift vector, isn't it? So now, we're going to go from pushing to pulling. And as we pull back, you won't believe what happens next. Cause your left foot, in this example, is all the way deployed on the rudder. When you pull back, what goes up? Angle of attack. When angle of attack goes up, what rolls the plane? Rudder, exactly. And that rudder is all the way in, it will—whack—it will try to snap roll. That's fine. Just neutralize the rudders real quick, OK? Cause you want your lift vector up, don't you, and you want it up right now. But, but neutralize real quick or it will go on by.

Review segment[13]

To complete this unusual attitude recovery procedures segment of the Advanced Aircraft Maneuvering Program, I'd like to briefly review the proper use of rudder at high angles of attack. As I state in the aerodynamic segment, smooth application of small amounts of rudder, coordinated with the aileron, will significantly improve the roll response at high angles of attack.

[On-camera text: "Watch the Side-Slip…"]

I'd like to reemphasize that we have very large, powerful rudders on our aircraft. We do not want to introduce high sideslip angles at high angles of attack, by either kicking the rudder or applying the rudder in excess at high alpha. It only requires a small amount of smoothly applied, coordinated rudder to achieve the desired result. This coordinated rudder will significantly improve the roll response at high angles of attack.

[On-camera text: "Don't Over-Control with Rudder…"]

Additionally, there is a lead-lag relationship associated with using the rudders at high angles of attack. That is, you must wait a second or two to see and feel the results of the rudder application. A lack of understanding of this effect can lead to an overcontrolling the aircraft. The high angle of attack maneuvering demonstration that you will be doing in your fleet simulators will familiarize you with this effect.

[13] As noted above, the review segment was not presented during the ground school classes attended by the accident pilots but could have been available to them through the videotape being distributed to all American Airlines pilots.

Attachment 3
Interview Summary

Interview:	Walter Marvin Goff (by telephone),[14] A300 Simulator Instructor, American Airlines
Represented by:	Self
Time/Date:	1000 cst., Tuesday, December 03, 2002
Location:	American Airlines Training Facility
Present:	Human Performance Group

In his interview, Mr. Goff provided the following information:

Instructors present either the roll or pitch maneuver on every flight but Mr. Goff couldn't remember whether he had done a roll maneuver or a nose up pitch maneuver with the accident first officer. He stated that there was a 50-50 chance that the accident first officer experienced the roll maneuver during his training. Mr. Goff then discussed the roll maneuver. He said that he first would do a briefing, during which he would tell the pilot that he (she) was going to be rolled to more than a 45-degree bank. They would then go into the simulator. When Mr. Goff initiated the event, the airplane would usually be in level flight between 2,000 and 10,000 feet altitude and between 200 and 250 knots speed. He might tell the pilot that the airplane was flying behind a heavy jet or that an aircraft crossed in front and then Mr. Goff would push the button. He might give a caution for wake turbulence warning (but, if they were following behind a heavy jet, the turbulence was somewhat intuitive even without Mr. Goff providing such a warning). Mr. Goff believed that the wake turbulence scenario was the most common set-up for the roll scenario and that most other instructors also used the wake turbulence scenario. He would instruct pilots to first turn off the autopilot and auto-throttles during recovery.

The roll maneuver was always performed with the cab motion on. The airplane would first be bounced to the right and then to the left, or vice-versa (10-15 deg in one direction and then 45-60 deg in the other). The recovery from the roll was always during level flight but there was no pitch input. Typically pilots would use full aileron. Mr. Goff said that if you just use aileron you would put yourself into a side-slip condition so you should also use a little bit of rudder. Pilots would typically lead with the aileron and then put in the amount of rudder necessary for coordinated input. He cautioned the pilots not to 'kick' the rudder pedals: "apply smooth rudders, don't over control." When questioned about the reduction in control effectiveness immediately after the button press, Mr. Goff stated that he was aware that something happened with the controls but he didn't know exactly what effect the button press had on the controls. Over control was defined by

[14] Mr. Cook and Mr. Goff were interviewed previously by the Operations/Human Performance Group.

Mr. Goff as using more aileron or more rudder than needed. He stated: " You can feel this in your body, in the seat of your pants. If too much rudder is applied, you can feel the sideslip."

Mr. Goff stated that a successful recovery in the simulator occurred when the pilot didn't crash, didn't get a stall warning, rolled the wings to level, and recovered in a reasonable amount of time. He indicated that the recovery was better when the pilots got on the controls earlier. The pilots needed to make the corrections immediately. Mr. Goff stated that typical problems he noticed were failure to turn the autopilot off and sometimes a slight over correction, but that most pilots were able to accomplish the task without problems. He said that only about 5% of the pilots had trouble with the maneuver. He didn't remember anyone being confused about which direction they were rolling. Nor did he notice a large variation in the aggressiveness of different pilots, but did say that some pilots were smoother than others. In terms of rudder use by the pilots, Mr. Goff stated that he was able to see what the pilot was doing and see the trapezoid to determine if too much aileron or rudder was used. He also believed that the pilots used the trapezoid during the simulator session. He had never seen a pilot get into a pilot induced oscillation (PIO) situation using the rudder in the simulator. Feedback was provided to the pilot either during the simulator session if the pilot's actions needed correction or immediately after the session.

Mr. Goff discussed the amount of time pilots may spend doing this roll recovery exercise over a four-year period. He said that pilots would typically only see this maneuver for about 5 minutes total during the four-year period.

Mr. Goff discussed the rudder limiter system and indicated that he was aware that the rudder was limited as the airspeed of the plane increased. He stated that the rudder pedal travel limits were reduced as the airspeed increased but that he didn't brief pilots on the rudder limits or the rudder pedal limits. He assumed they were taught about the limits in ground school. He also mentioned that pilots are shown the rudder limiter when they are trained initially but not during recurrent training.

When questioned about the fidelity of the simulator when compared to an actual airplane, Mr. Goff said that pilots need to put in small corrections on the simulator and can not trim it up and then fly hands free as in the real aircraft. He felt as though the roll maneuver was realistic based on his experience with wake turbulence and he was not aware of any aircraft in the American Airlines fleet experiencing a wake turbulence upset like that portrayed in the exercise. Mr. Goff discussed the occasions for rudder use on the aircraft. He stated that rudder would be used for an engine out condition, an aborted take-off to stay on the runway, and for lateral asymmetry.

Mr. Goff flies this maneuver during his recurrent training, as do all the instructors, but he does not fly the A300. Mr. Goff indicated that he flies jumpseat in the A300 airplane. He, like all other A-300 instructors, held an A-310 type rating. In addition, he said that there is a standardization coordinator who rides in the simulator with each instructor every 3 months and the instructor is observed by a check airman at least once per year. The operation bulletin describes the maneuvers used in the simulator.

Attachment 4
Interview Summary

Interview:	John Michael "Mike" Cook (by telephone), A300 Simulator Instructor, American Airlines
Represented by:	Self
Time/Date:	1130 cst., Tuesday, December 03, 2002
Location:	American Airlines Training Facility
Present:	Human Performance Group

In his interview, Mr. Cook provided the following information:

Mr. Cook was asked why he had described the accident first officer as confident during a previous interview and indicated that he did not remember specifics about his session with the first officer (December, 2000). He had a distinct visual impression of the first officer, remembered that the first officer had a distinct name, and that the first officer addressed Mr. Cook by name. Mr. Cook had an overall impression that the first officer performed well in the simulator. He described the first officer as confident because of his demeanor since most people consider simulators a threat. Mr. Cook was unable to elaborate further, saying that the session was a long time before and that he remembered overall impressions but nothing specific.

Asked about the first officer's flying technique, Mr. Cook indicated that he had an overall positive impression of the first officer's procedures and techniques but did not remember specific events (and did not even remember what type of training the first officer was taking).

Mr. Cook indicated that an upset event was taught at every recurrent session, once during the five days. Regarding his own presentation procedure, Mr. Cook stated that he set up this exercise from level flight at 5,000 feet. In his briefing before the session, he would instruct students that they were going to do two unusual attitude events, nose high and nose low. He would then discuss the nose high exercise, indicating that the simulator would pitch up to a very nose-high attitude and that the student should respond by releasing a bit of backpressure to move away from the critical angle of attack to stall. He would explain that it is difficult to let off backpressure in a simulator. The student should use coordinated aileron and rudder until the nose would naturally start to fall, maintaining some g forces, and wait until the nose began falling on its own because the addition of power would result in nose up forces. Once level with the horizon, the student should coordinate aileron and rudder.

For the roll maneuver, Mr. Cook would instruct students that they would end up in a greater than 90-degree roll attitude. They should first release positive g force and, while still maintaining some g force, roll in the shortest distance to the

horizon. He usually used an airplane on a stick for demonstration purposes. Any backpressure would pull the nose down towards the earth creating a disaster. Asked whether the roll event would be considered nose high or low, Mr. Cook indicated that the nose was really about level with the horizon. Asked whether he discussed wake turbulence as part of the setup briefing, Mr. Cook indicated he did not discuss wake turbulence during the briefing. However, in the simulator, he would tell the student that they were five miles behind a heavy jet as though it were a wake turbulence event.

Mr. Cook indicated that he typically "pushed the button" to initiate the roll event when the airplane was at 250 knots in a clean condition. Regarding his standards for a successful recovery, he said he would definitely not judge a recovery successful if there was a tendency to keep back pressure that would bring the nose down. It was difficult for pilots to realize how much backpressure they needed to release, then they needed to roll in the right direction. Regarding problems, he said that students would split S the airplane or roll the wrong way. But it was very seldom that new students had difficulty. During recovery procedures, he was looking for pilots to be smooth on controls, roll in right directions, and disengage auto throttle and autopilot.

Asked whether he would counsel a pilot for lack of smoothness, he indicated he would but that he didn't see that problem regularly. He would debrief immediately after the session except in the case of an incorrect recovery, when he would tell the student the problem and then present it again so they could do it correctly. Mr. Cook indicated that the events following the button press seemed realistic, although he did not know whether there was any similar actual event on any American Airlines flight.

Mr. Cook indicated that he presented the excessive bank exercise in both hand-flying or autopilot on situations. He did not notice any differences in the pilot reactions because the first thing is to turn off the autopilot. As he remembered the exercise, the simulator would first roll to the right approx 10 degrees then almost immediately roll left almost to 90 degrees. The first event would happen so quickly, pilots wouldn't react. Then, as the simulator rolled the other way close to 45 degrees, pilots would knock off the autopilot. The maneuvers would be pretty abrupt. When asked, Mr. Cook indicated that he believed that pushing the simulator button took authority away from rudder. He said that pilots used a great deal and maybe full aileron for recovery applying their maximum level of aileron shortly before they reached 90 degrees of bank. It had always been Mr. Cook's experience that pilots would lead a roll event with aileron before putting in rudder. Asked whether he had seen an abrupt roll reversal when the pilot recovered control authority following the button press (due to a large amount of aileron input with no authority), Mr. Cook said it would take a large amount of aileron even once authority was returned to counter the roll and bring the airplane back to level. He had always seen pilots lead with aileron and then use rudder. He could not tell how much rudder was used in recovery but he never

saw what might be described as a yaw. Asked whether pilots ever used insufficient rudder, he indicated that it can not be felt in a simulator. Regarding pilot understanding of the rudder design system, Mr. Cook indicated that it was primarily a ground school issue. Mr. Cook indicated that he had never seen pilots overshoot a wings-level position in attempting to recover from the maneuver, but had occasionally seen pilots roll in the wrong direction and then roll back.

Asked whether the AAMP program emphasized techniques or procedures, Mr. Cook noted that there were definite procedures and that there was early discussion that United Airlines was teaching pilots to continue rolling in one direction, potentially 360 degrees. The AAMP program agreed on a procedure to disconnect autopilot/auto throttle. The instructors were looking to see that pilots employed the procedures they talked about. The instructors did not cover the effects of different airspeeds, this was more of a ground school issue. Mr. Cook estimated that the total time spent on AAMP exercises in the simulator over a four year period was perhaps five minutes.

Mr. Cook indicated that he would discuss differences between the simulator and actual aircraft on the first day of the transition. The students were wonderful pilots, but in a simulator they would not experience all the accelerations, positive/negative g forces that they would in an actual aircraft and thus they may tend to under-control slightly. Normally a pilot used tactile senses, sound and sight and did not have all that in a simulator. He would not recommend that pilots fly differently because they were in a simulator. At least initially, they would tend to use more aileron, especially in VFR conditions, than was necessary. They were expecting to feel things that they weren't feeling. Mr. Cook did not think that pilots used the visual trapezoid to indicate when they were out of trim because trapezoid on this airplane was fairly small and almost out of scan. Rather, most judgments would be made by feel.

Asymmetrical thrust was the main situation for rudder use. Occasionally nose high attitude would require rudder, and in bank angle it would take some rudder to get near the horizon. Regarding problems of rudder use, Mr. Cook said that pilots sometimes did not use enough rudder in nose-high initial attitude situations. Regarding control strategy to recover from a bank, Mr. Cook indicated that he believed more in the gradual input of flight controls than in a pulse type input control. He believed that rudder would be needed to compensate for extreme aileron input.

Mr. Cook stated that a successful recovery on the excessive bank angle exercise meant no over-control, a smooth control, roll in the correct direction, and no loss of attitude. There should not be a tendency to pull the nose toward the earth. They should be beyond before pulling back. He said that a successful recovery was not dependent on the use of rudder. He could only judge use of rudder because he was sitting behind in the simulator.

Mr. Cook was working at American Airlines when the AAMP program was initiated, and said that he believed it was a reaction to the Pittsburgh accident. He believed that the Pittsburgh crew was in an inverted position and attempted a split S input. He felt that the AAMP program was a good idea for pilots who had never flown at the extremes of the envelope to get a feel of the aerodynamics. He did not remember a tendency of pilots to overshoot a wings level attitude during the recovery, and stated that he was never concerned about a heading during the recovery but was just concerned that a pilot minimize the pitch attitude. Simulator motion was on during the upset exercise. Mr. Cook would present both the pitch and roll upset exercises during recurrent training. Since the accident, they no longer use the button to introduce the excessive bank attitude so he briefs that the other person in the simulator will put the pilot in the unusual attitude.

Attachment 5
Interview Summary

Interview:	James Clark, First Officer, Flight 934, American Airlines
Represented by:	Mr. Ray Duke, APA attorney
Time/Date:	1330 cst., Wednesday, December 04, 2002
Location:	American Airlines Training Facility
Present:	Human Performance Group

In his interview, Mr. Clark provided the following information:

His date of hire: October 11, 1999
Total flying time: 4000 hours
Time with American Airlines: approx. 1000 hours
Time on A300: under 200 hours
Type ratings: A310, Citation
Overview of his background: he was an enlisted helicopter mechanic in the U.S. Army. He then began civilian flight training in Houston, TX. Prior to coming to American Airlines, he had flown a Citation 2 turbojet for a Houston company. Since being at American Airlines, he had served as a flight engineer and first officer on the B-727 and first officer on the A-300.
He stated he finished training in approximately August, 2002.

This was his first flight with this captain and it was a three-day trip. The trip began with a flight from Miami, FL (MIA) to Guayaquil, Equador (GYE) with a layover. The second day of the trip consisted of a return flight to MIA and continuation to New York (JFK) with a layover. The final day of the trip consisted of a return flight to MIA. Flight #934 was the flight on the second day of the trip, 10/28/02, GYE-MIA. Mr. Clark stated that the airplane they had flown from MIA remained with them during the layover and was the same airplane they flew on this leg. The captain was the pilot flying on this second flight segment of the trip. Mr. Clark stated the number one autopilot was inoperative. Prior to the event, it was a normal flight during taxi, take-off, and cruise. They were flying at Mach 0.79. The flight conditions were VMC at the time and it was a smooth ride. They were at 31,000 feet and had requested deviations around cloud build-ups ahead. They were operating in the command mode on #2 autopilot.

The first officer stated he wanted to see what the winds were indicated on the IRS display. The winds mode was not selected and he reached up to select the winds mode. He inadvertently kicked the left rudder pedal with his left foot when he was selecting the winds mode. The autopilot was in the command mode and he did not know why the autopilot disconnected. He said that he caused a bump on the rudder pedal (hit with the left foot) rather than a steady force application. He did not think he hit the column with either foot and did not think he moved the

column. His right foot was slid back against the base of the seat. His lap belt was fastened at this time. As he focused on the selector knob, he heard the captain exclaim that something was wrong with the aircraft and also heard the autopilot warning (aural cavalry warning charge). He then returned his attention forward to outside the airplane and to the flight instruments. The airplane began a climbing right turn with the nose yawing to the right. The airplane felt as though it was 'skidding sideways'. He said that it felt 'pretty violent'. He called out that they were in a bank and climbing. He said he did not recall experiencing any lateral "Gs" while he was turned back toward the IRSs. The captain stated that there was something very wrong with the airplane. The first officer did not get on the flight controls himself. He stated he was looking at the PFD but did look at the trapezoid. He said he did not have a sense of disorientation after turning back forward and sensing the skidding and the climb. He did not have a sense of serious G load during the climb--it was a light climb. The event lasted for approximately 20 seconds until they had the airplane back in level flight.

Characterization of the captain: They had a very good working relationship. The first officer described the captain as being top notch on his systems knowledge. He gave good briefings, had good CRM skills, spoke well, and was able to answer systems questions concerning the airplane. The first officer said that the captain was a very good pilot. The captain was fresh out of training.

Description of captain's actions in recovering the airplane: When the first officer turned forward, the captain was hand flying the airplane and was extremely light on the controls. The controls were not jerked around--he was neutral on the controls. The captain asked the first officer to check the yaw dampers as the captain though they might have been causing the rudder problems. When asked if the captain made any other remarks during the event, Mr. Clark said the captain acknowledged his callouts and stated the aircraft did not feel right. Mr. Clark continued making callouts until they got the airplane straight and level. Mr. Clark said he never got on the controls during the recovery. The autopilot was reengaged later after the recovery.

After recovery, the captain asked what happened and the first officer said that he hit the rudder pedal and caused the event. They discussed the possibility of a Dutch roll and the captain thought that the airplane was probably in a Dutch roll. There was no discussion of the 587 accident.

Asked what ground school instructors trained regarding rudder travel and rudder pedal travel during his training in August 2002, Mr. Clark stated that they teach that as you increase speed, rudder deflection is less than it is at other speeds. Rudder, not the rudder pedal.
Asked whether instructors provided any rudder travel information in terms of degrees, Mr. Clark indicated that they did but he did not remember exactly what was said. Roughly 30 degrees and reduced to about 3 degrees. It tops out at about 250 knots. Asked whether instructors talked about rudder pedal

movement in training, he stated no. He did not remember instructors telling him during ground school that the rudder pedal travel varied due to different speeds. After the incident, he read the FCOM Bulletin and there were 4 pages in the bulletin that discussed the rudder pedal travel. Asked whether there had been any new AAMP training information in the recent past, he indicated that pilots were instructed not to observe the AAMP poster in the briefing rooms and not to use data provided by it.

Asked whether he could feel when he hit the rudder, Mr. Clark said that he felt the sole of his foot hit the pedal and that his heel slid on the floor against the rudder pedal. He indicated that he could not tell how far he displaced the pedal, that it felt light. As soon as he felt it, the captain exclaimed and then they were off for the ride. He thought that his input to the rudder was applied for a duration of no more that one second, and indicated that he withdrew his input immediately

Note: He sometimes flew at cruise with his feet on the floor or on the stirrups but he believed his feet were on the floor before this incident. The first officer recommended anti-slip material on the floor.

Attachment 6
Interview Summary

Interview:	Richard R. Pollum, Captain Flight 934, American Airlines
Represented by:	Mr. Ray Duke, APA attorney
Time/Date:	1500 cst., Wednesday, December 04, 2002
Location:	American Airlines Training Facility
Present:	Human Performance Group

In his interview, Mr. Pollum provided the following information:

His date of hire: Sept. 30, 1988
Total flying time: 10,000 hours
Flying time with American Airlines: 7300 hours
Time on A300: 120 hours
Type Ratings: A310, Metroliner SA227, citation CE500, 727, 757, 767, MD-11
His previous background: Flew captain on the 227, CE500, 727 and A300 (727 and A300 with American). Checked out on the A300 in August 2002.

Description of First Officer: He doesn't remember anything out of the ordinary. He usually assesses the first officer during the briefing. The first officer had good knowledge of the aircraft. He had a good personality and they worked well together.

Description of Flight: One autopilot was inoperative and he thinks it was the #2 autopilot. He stated that it was an uneventful flight up until the incident. The autopilot functioned normally in all the modes that they used it. The autopilot was in the NAV mode, at level flight, at 310 at the time of the incident. They were in VMC but were deviating for some buildups, south of Panama with some intermittent, light chop. They were in a 15-degree right deviation but still straight and level. His feet were flat on the floor at this time. He doesn't remember where his hands were but they were not on the yoke. The first officer was checking the winds.

Captain Pollum felt a sudden and violent tail shift from the left to the right instantly followed by the autopilot disconnect and the chime. He did not know (at the time of the interview) why the autopilot disconnected. His first reaction was to go onto the controls. He moved his feet up to the rudder pedals and his hands on the wheel. In less than a second, the airplane began climbing slowly and banking to the right up to about 25 degrees bank. The airplane then began to Dutch roll. He noticed the trapezoid moving back and forth through the center. He fed in some (right) rudder because he felt that they were skidding. He also neutralized the ailerons after rolling wings level to deal with the Dutch roll. He was holding right rudder during this time. He felt that he was holding a portion of right rudder because he fed in about 1 inch. He didn't want to put it into the stop.

They were at high-speed cruise and it did not seem like the right thing to do. He asked the first officer if the yaw dampers were engaged because he thought they might have lost them. He felt that the yaw dampers were not damping. It was a prolonged event. The yaw dampers were both on. The airplane swung maybe 3-4 times before it was under control. He did not recall any input (back feed) through the rudder pedals as he was applying input. The airplane climbed approximately 750 feet. Once the Dutch roll had stopped, the airplane topped out at 31,750 feet and slowly descended to rejoin the airway. He released the rudder slowly. He doesn't remember any feedback from the airplane at that point.

Ground School/Simulator Instruction on Rudder and Rudder Pedals: They discussed that the rudder has limited travel as you increase in airspeed (from 30 deg to 6 deg) and it tops out at about 250 knots. He does not recall a mention of the rudder pedals in ground school. He did not know, at the time of the incident, that the rudder pedals reduced their amount of travel as a function of airspeed. During the event, he did think about the Flight 587 accident and thought he had a tail event because of the initial skid.

Note: In a bulletin he read, he understood that you could use rudder to correct a sideslip due to an abnormal situation. Therefore, he felt that holding in rudder would be appropriate. The bulletin was issued in March in an 80-page document-Large Aircraft Flight Dynamics-that American Airlines issued.

He does not recall any noticeable feeling after applying right rudder. He set the rudder and then he worked on the Dutch roll problem. He was focused on the banking.

He slowly released the rudder – no feedback from the airplane.

He did not remember seeing the trapezoid. He focused on the horizon.

He noticed the first officer set his seat and pedals earlier on the flight and observed nothing out of the ordinary. The first officer's move to check the winds on the IRS was normal.

He wanted to put in between a ¼ to 1/3 rudder to recover from the sideslip. He put enough rudder to stop the yawing to the left. He put in a little because he felt he could add more. He did not intend to put in full rudder. After further questioning, he stated that he put enough rudder to stop the yawing motion.

He did not recall any roll when the nose yawed to the left.

His experience with Dutch roll was in training. He expected to roll 1½ times then settle down. It went on for 3 or 4 times.

He has experienced several autopilot disconnects and was not always sure of the cause. He would select another autopilot on occasion.

He felt that the yaw, the climb and the right roll along with the rudder pedal set were simultaneous.

When asked whether he knew about the potential effects of pedal input on yaw damper, or whether he recalled this being discussed in ground school training, he indicated he did not in either case.

Attachment 7
Anthropometric measurements on First Officer Clark

Date 12/5/02

Time 7:35 am

Place AA Training Simulator Dallas, TX

Name James Clark

Gender *Male* Female

Age 40

Handedness *Right* Left

Weight (lb) 195 lbs (self reported)

Stature (in) 71

Vertical distance from standing surface to top of head

Sitting Height (in) 33

Vertical distance from sitting surface to top of head

Shoulder-Elbow Length (in) 14.5

Length from top of shoulder to bottom of elbow

Forearm-Hand Length (in) 12

Length from bottom of elbow to first wrist fold

Hand Length (in) 7

Length from first wrist fold to end of longest finger

Knee Height (in) 22.5

Vertical distance from floor to uppermost point on knee

Buttock-Knee Length (in) 24

Horizontal distance from most posterior aspect of right buttock to most anterior aspect of rt. Knee

Measurements in Cockpit:

Knee Angle Neutral Position: 115 deg Displaced Pedal: 140 deg (full left pedal)

Floor to eye height (in) 46.5 (in the cruise seated position)

Vertical distance from floor to eyes in cockpit pilot seat

Seat Location Full Back Position (in): 22 Take-Off Position (in): 25.5

Horizontal distance from a fixed point to the front of the seat cushion (or railing) -From the back of the center console to the front of the seat cushion.

Location of Arch of Foot on Pedal (in): centered on pedal (heels on pedal)

Aligned length from bottom of pedal to point ¾" forward to shoe-heel

Location of Arch of Foot on Pedal (in) – Relaxed or cruising position: on the floor

Aligned length from bottom of pedal to point ¾" forward to shoe-heel

Additional Measurements:

Horizontal distance from the winds button to the center of the first officer seat: 33 inches

Vertical distance from the winds button to the top of the seat cushion: 45 inches

(Note: The seat was in the cruise position for Mr. Clark. The winds button was longitudinally in the same plane as the joint between the seat cushion and the set back.)

Attachment 8.
Table of the approximate durations (seconds) for each of 24 pre-takeoff rudder checks recorded on the accident flight data recorder (FDR) (data shown in reverse chronological order).

Rudder Check #	Duration (sec)	Comments
1.	17.4	(accident flight rudder check, consistent with CVR comments)
2.	9.1	
3.	5.9	(this occurred approx 3.3 seconds immediately after #4)
4.	4.6	
5.	4.1	
6.	6.0	
7.	7.4	
8.	7.6	
9.	5.1	
10.	8.1	
11.	13.0	
12.	5.7	
13.	6.0	
14.	7.0	
15.	8.5	
16.	6.0	
17.	6.7	
18.	9.3 *	
19.	5.6	
20.	10.1	
21.	10.0	
22.	10.5	
23.	9.0	
24.	10.3	(earliest rudder check recorded on the FDR)

*Difficult to measure because rudder check was not well defined

Attachment 9
Rudder design data provided by Airbus Industries for large transport aircraft products

		V1 (135)			250 kts		
	Breakout Force (lbs)	Pedal Force (lbs)	Pedal Travel (in)	Rudder Deflection (deg)	Pedal Force (lbs)	Pedal Travel (in)	Rudder Deflection (deg)
A300B2-B4	22	125	4	30	125	4	9.3
A310	22	65	4	30	32	1.2	9.3
A300-600	22	65	4	30	32	1.2	9.3
A320 (RH turn)	21.3	80	4	30	36	1.1	8.3
A330-300	32	80.5	4	30	45	1.24	9.5
A340-300	32	80.5	4	30	45	1.24	9.5

Attachment 10
Rudder design data provided by Boeing Commercial Airplane Company for large transport aircraft products

		V_1 (135)			250 kts			$_{FL390}$ MMo		
	Breakout Force □ (lbs)	Pedal Force (lbs)	Pedal Travel (in)	Rudder Deflection (deg)	Pedal Force (lbs)	Pedal Travel (in)	Rudder Deflection (deg)	Pedal Force (lbs)	Pedal Travel (in)	Rudder Deflection (deg)
747	19	80	4.0	30	80	4.0	12	80	4.0	8
757	16	80	4.0	26	80	4.0	6	80	4.0	5
767	17	80	3.6	26	80	3.6	8	80	3.6	7
777	18	60	2.9	27	60	2.9	9	60	2.9	6
707		70	2.3	24	100	1.3	9	100	1.1	7
717	20	75	3.3	29	65	1.6	13	40	0.5	4
727	17	80	3	18	50	1.3	7	45	1.3	6
737	15	70	2.8	18	50	1.0	4	50	1.0	4
DC8		85	3.6	32	65	1.5	13	60	1.0	8
DC9	16	75	2.6	22	60	1.1	8	30	0.4	3
MD80	15	75	2.6	22	60	1.1	8	30	0.4	3
MD90	20	75	3.3	29	65	1.6	13	40	0.5	4
DC10	10	80	3.8	23	65	2.0	14	55	1.5	9
MD11	10	80	3.8	23	65	2.2	15	60	1.7	11

Note: □ The breakout force values shown are on-ground values. In-flight, breakout force values will be 1-2 lbs less than the on-ground values because of lower friction due to increased vibrations levels.

Attachment 11
Figures comparing rudder pedal data as a function of airspeed from an A300 airplane and simulator.

Figure 12A. A comparison of rudder motion produced by pilot input on the rudder pedal at varying airspeeds according to the A300 design, in an A300 airplane during ground test, and in an A300 simulator with normal rudder pedal force and high force.

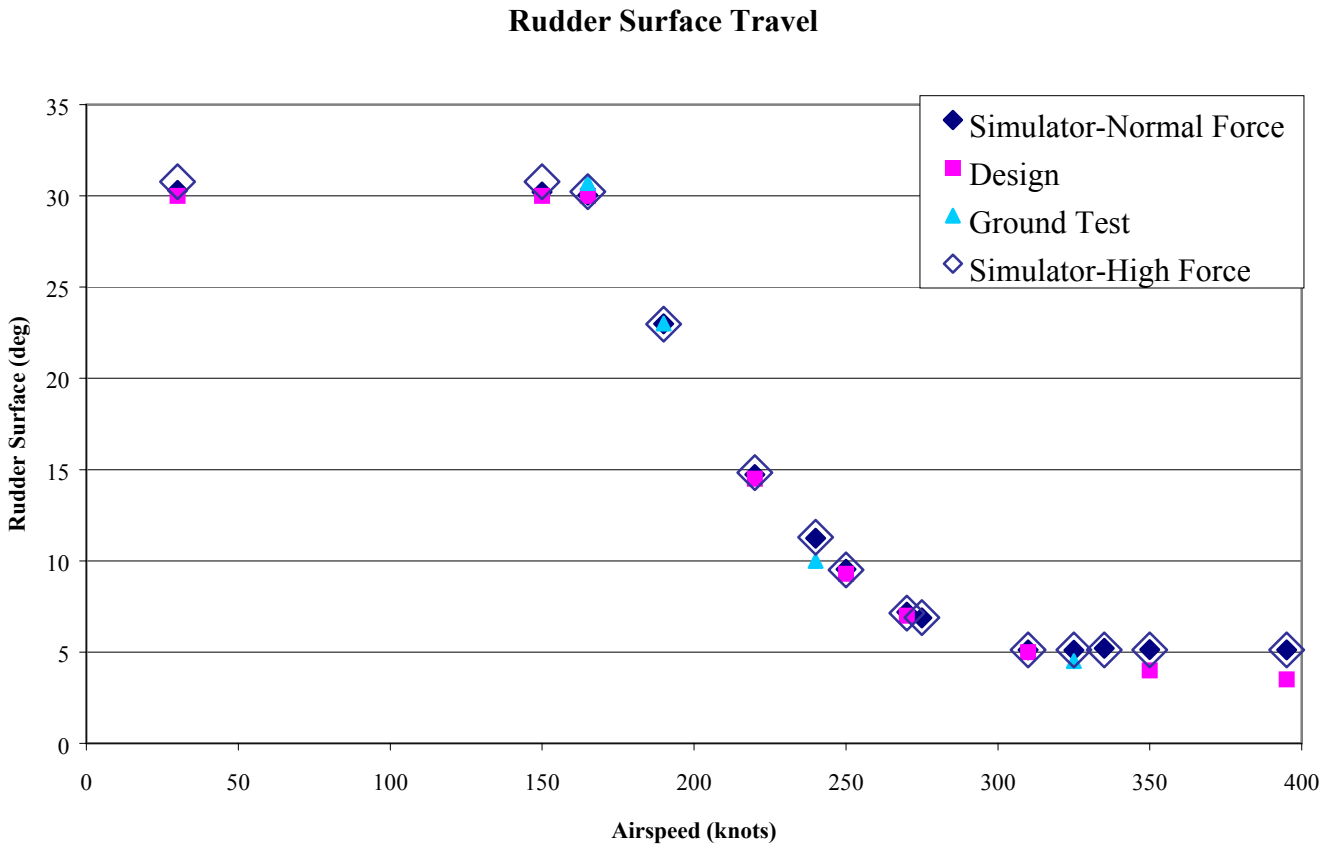

Figure 12B. A comparison of rudder pedal motion at varying airspeeds with normal pilot pedal force and high force in an A300 airplane and simulator.

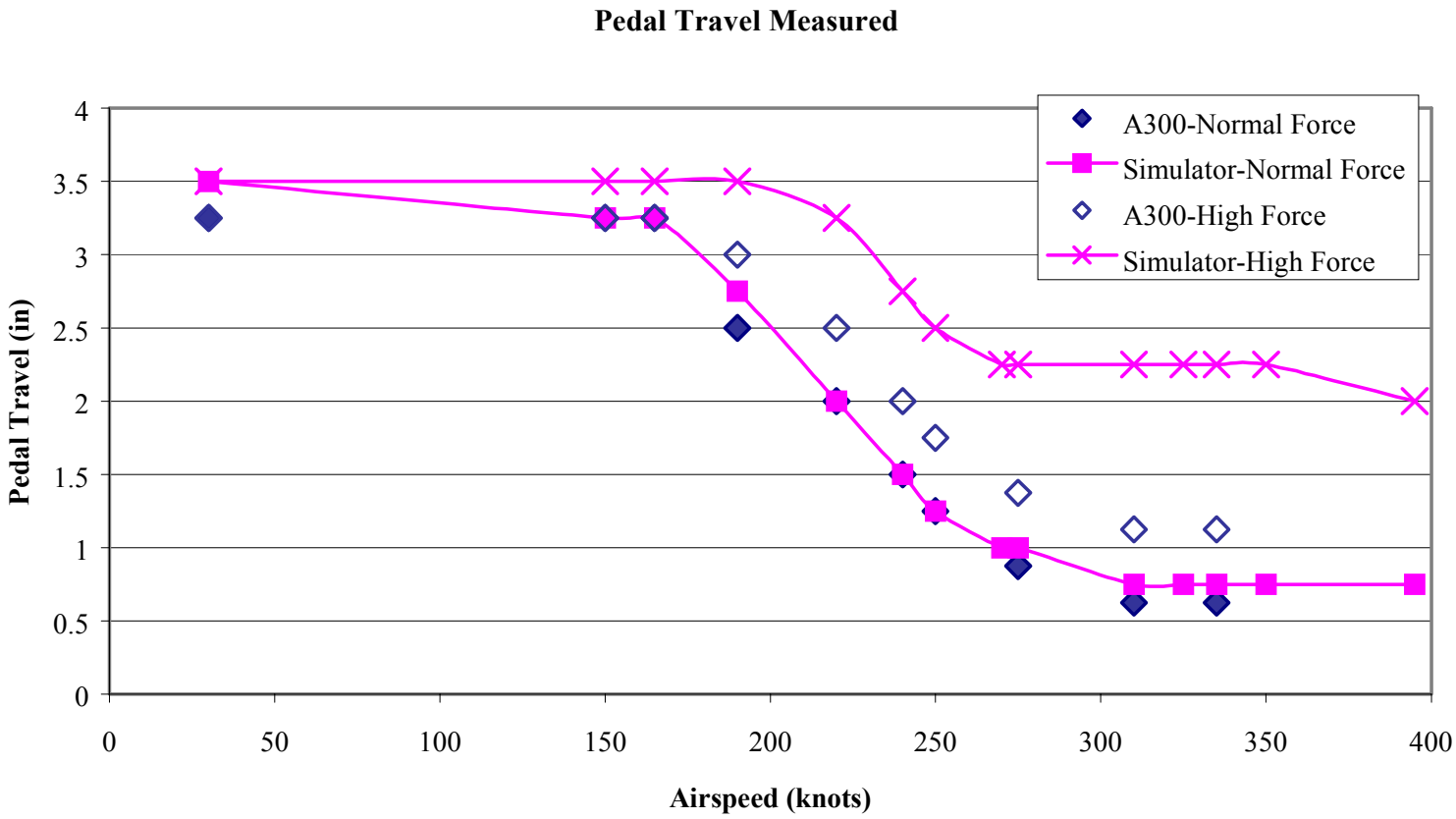

Figure 12C. A comparison of rudder pedal cable stretch produced by pilot input on the rudder pedal at varying airspeeds as determined in three tests using the A300 airplane and simulator. The tests of "A300 – Tulsa" and "AA Simulator" compare pilot high forces to normal forces, while the "ground test" compares pilot fast input to slow input.