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

September 26, 2003

Human Performance

STUDY REPORT
AMERICAN AIRLINES SIMULATOR EXERCISE

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

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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 STUDY

D.1 OVERVIEW OF THE INVESTIGATION

On December 4, 2002, the Human Performance Group conducted a study in the A-310/300 training simulator as part of its meeting at the American Airlines Training Academy, DFW Airport, TX. The purpose of the study was to examine the Advanced Aircraft Maneuvering Program (AAMP) "excessive bank angle recovery exercise," a simulator scenario in which the instructor induced an excessive bank angle in a wake turbulence context. Following initial ground training and simulator briefings, six pilots from the Human Performance Group performed the scenario multiple times using different pilot rudder input strategies to evaluate whether the scenario encouraged particular pilot inputs.

D.2 PROCEDURE

In preparation for the simulator activity, all members of the Human Performance Group viewed the AAMP training video on "Unusual Attitude Recovery" which was taped about the time that the accident pilot completed AAMP ground school training in 1997. The Group also interviewed two instructors who provided simulator training to the accident pilot that included an AAMP upset exercise such as the one on excessive bank angle.[1]

A third simulator instructor, who twice provided training to the accident pilot, served as simulator instructor for the study. He provided a normal AAMP simulator briefing to the entire Human Performance Group on the excessive bank angle scenario. A summary of this briefing is included in Attachment 1.

Six members of the Human Performance Group served as pilots in the simulator study (Haworth, Ivey, Jacob, Michaelis, Thiel, and Thompson). All six

[1] These activities are detailed in the Human Performance Group Chairman's Factual Report, Addendum 1.

had previously piloted large transport category airplanes as either line or test pilots, and three had never before experienced the AAMP excessive bank angle exercise (Haworth, Jacob, and Thiel). Each pilot performed individually, sitting in the right cockpit seat of the simulator while an American Airlines representative (Young) sat in the left seat to support the activity. The instructor sat behind the pilots, coordinated the trial, acted as air traffic controller in radio transmissions, and controlled the simulator inputs (including the initiation of the roll maneuver by depressing a button on the instructor console). Two NTSB investigators (Price, Brenner or Poland) also sat behind the pilot to assist in data collection of pilot evaluations. The simulator motion platform was "on" throughout the study.

For purposes of the study, the instructor was asked to initiate the roll event at about 240 knots airspeed but, otherwise, to introduce the scenario as a normal AAMP simulator exercise. The instructor set up the exercise as a departure behind a Boeing 747 airplane, in this case having each pilot execute a normal takeoff on runway 31L at JFK airport in day, visual conditions. During a climb to 5,000 feet, the instructor cautioned that the airplane was following behind a large aircraft, directed the pilot to turn, and initiated the roll event while the airplane was banked at an altitude between 2,000 to 2,500 feet. The simulated airplane exhibited an uncommanded roll in one direction (either left or right determined arbitrarily by the computer) followed immediately by a substantial uncommanded roll in the opposite direction. The simulator scenario was programmed to momentarily inhibit the aircraft response to pilot inputs in roll and yaw during the event to allow the simulated airplane to reach a substantial bank angle before recovery began. Each pilot was instructed to recover the airplane according to the AAMP training they received from the training tape and simulator instructors. After recovery, the simulator trial ended and the pilot provided verbal evaluations on structured interview questions (shown in Attachment 2).

This procedure was repeated for 5 additional trials that were identical to the first except that the roll maneuver was initiated during level flight after the pilot indicated his readiness. During the successive trials, the pilot was instructed to respond using one of five specific recovery strategies:

- Partial Wheel, No Rudder (Strategy A)
- Full Wheel, No Rudder (Strategy B)
- Full Wheel, Partial Rudder (Strategy C)[2]
- Full Wheel, Full Rudder (Strategy D)
- Pilot's own preference

Trials 2 to 5 consisted of the first four recovery strategies, with the presentation order of the four strategies counterbalanced across pilots. In Trial 6, all pilots were instructed to employ whatever recovery strategy they thought

[2] Pilots were instructed to apply the same "partial rudder" as described in the AAMP training.

most appropriate. Pilots provided verbal evaluations on an additional set of questions at the end of the session.

The collected data consisted of major simulator and pilot control and performance parameters recorded by the simulator (at a frequency of approximately 2.9 Hz.) and self-report evaluations provided by the pilots.

D.3 RESULTS

Attachment 3 provides summaries of the results, reporting simulator and pilot–report data as follows:

Airspeed: Calibrated airspeed (knots) at the time of the upset initiation, as determined by the first data point for positive button press;
Initial bank: Bank angle (degrees) at time of upset initiation, with direction noted by plus or minus sign (right or left bank, respectively);
Max bank: the maximum bank angle (degrees) reached during the scenario, with direction noted;
Max pedal: the maximum pedal input (degrees) during recovery, disregarding direction;
Max wheel: the maximum wheel input (degrees) during recovery, disregarding direction;
Pedal delay: the length of time in simulator digital units (approximately 0.35 seconds per unit) between the start of wheel input leading to maximum wheel and the start of pedal input leading to maximum pedal;
Best/worst: Pilot choice of whether this was the best (B) or worst (W) recovery strategy in the scenario
Authority: Self-report of whether pilot felt enough control authority for recovery
Overcontrol: Self-report of whether pilot felt there was a danger of overcontrol
y-accel: the maximum y-acceleration (g) recorded during recovery, measured at the center of gravity of the simulated airplane
Max rudder: the maximum rudder deployment (degrees) during recovery, disregarding direction.

As shown in Attachment 3, the first trial (“AAMP Recovery”) had an upset initiation when the airplane was typically flying with a 20 degree left bank at 235 knots. All pilots responded with an input of full wheel (77 to 80 degrees) supported by some rudder pedal (6.7 to 14.5 degrees, average=10.8 degrees). For 5 pilots, the pedal input was essentially simultaneous with wheel input (within the same or one subsequent digital data units). Three pilots recovered before the airplane reached a maximum bank angle of 90 degrees, and three recovered

with a maximum bank angle between 108 and 114 degrees.[3] In post-trial comments, four pilots indicated they were surprised by the onset of the event. [4]

As shown in Attachment 3, the final trial ("Pilot's own preference") had an upset initiation while the airplane was approximately level. Most pilots responded with nearly full wheel and consistent pedal inputs, making slightly less input on both controls than on the first trial, and typically delayed the pedal response at least one second after the wheel response.[5] The data indicated that no pilot recovered the airplane on the final trial before it reached a maximum bank angle above 100 degrees.

Strategies A to D provided a range of potential recovery strategies and pilots reported definite preferences. Three pilots selected strategy A as the worst strategy, and all six pilots questioned whether Strategy A provided sufficient control authority to achieve recovery. Two pilots selected Strategy D as the worst one, with several pilots indicating there was a possibility of overcontrol. Based on pilot evaluations and pilot actions on the first and last trial, pilots appeared to prefer a strategy of full wheel and limited rudder in response to the scenario.

Contrary to pilot evaluations, the four recovery strategies showed little difference in terms of maximum bank angle reached. Each recovery strategy showed an average maximum bank angle between 104 and 107 degrees and none of the individual recoveries by any subject was achieved at less than 100 degrees despite the widely varying nature of the inputs provided under the four strategies.

The data suggest a programming anomaly concerning the variables of max pedal and max rudder. At 240 knots, the maximum pedal travel on the A300-600 airplane should be limited to about 7.9 degrees and maximum rudder travel to about 11.1 degrees. However, when pilots were instructed to input full rudder on Strategy D, max pedal input varied from 10.3 to 18.9 degree and max rudder varied from 11.9 to 13.8 degrees. Several pilots reported that they did not have a sensation of going past a pedal stop in making the full pedal inputs. As a result of these findings, the investigation is undertaking additional examination of the

[3] Max bank was consistently lower when the upset was done in the same direction as the initial bank, probably because there was no initial roll in the opposite direction and therefore the aircraft had much less roll momentum when aircraft response to pilot inputs was restored. Examination of the data indicated that the simulator did not always begin with a small roll in the opposite direction on these trials

[4] Three were pilots who had never experienced the scenario before and one was a pilot who stated he did not know the upset could begin when the airplane was banked.

[5] Pilot 6 used a strategy of no wheel and full pedal input to assist the study and reported that it did not feel natural.

accuracy of the simulator modeling of airspeed effects on pedal and rudder variables.[6]

As shown in Attachment 3, five pilots indicated at least once during the study that they felt there was a lack of flight control response during the initial upset.

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[6] These activities include those detailed in the Human Performance Group Chairman's Factual Report, Addendum 1.

LIST OF ATTACHMENTS

1. Summary of the Pre-Simulator Briefing
2. Questions for pilot evaluation
3. Summary tables of results

Attachment 1
Summary of the pre-simulator briefing

Instructor: Ray Walbridge, American Airlines A300 Simulator Instructor
Date/Time: Wednesday, December 04, 2002, about 0930
Location: American Airlines Training Academy, DFW Airport, TX
Present: Human Performance Group

Mr. Walbridge conducted a pre-simulator briefing on upset recovery and unusual attitudes for the entire Human Performance Group, having been asked to provide a briefing such as he would have provided during a recurrent training event in 1997 with an A300-qualified pilot. During the briefing he stated the following:

Although there were two types of AAMP unusual attitude upset exercises available -- pitch or roll -- the requested briefing addressed the roll maneuver. He stated that during a roll maneuver, the maneuver could be associated with wake turbulence and that a nose high, nose low, or a nose level condition could occur. Aileron was discussed as the primary roll control. In addition, during the nose level condition, Mr. Walbridge stated that power adjustments were not necessary and that rudder could be used to coordinate roll. (Coordinated roll was defined as keeping the ball in the center, although he noted that on the A300 there is not a ball but rather a trapezoid that can be used for coordinated roll.)

Mr. Walbridge stated that the amount of roll could vary from a relatively high bank angle to an inverted bank angle. He stated the amount of bank generated could be a function of the pilot response. A quick reaction may prevent an excessive amount of roll. Some coordinated rudder should be used during recovery. Pilots should neutralize controls when approaching wings level. Pilots should try not to over control. He stated that the sky pointer must first be located and then roll control should be applied toward the sky pointer.

Asked whether there was guidance for instructors in the syllabus on how to present the roll upset exercise, he responded that there was not such guidance for recurrent training.

Attachment 2
Questions for pilot evaluation

End of trial questions:

1. In this trial, did you feel like you had enough control authority for recovery?
2. In this trial, did you feel like there was a lack of flight control response during the initial upset?
3. At any point during this simulator trial, did you feel at risk of overcontrol?
4. How do you feel that the simulator trial compared to your experiences with actual flight?
5. Do you have any additional comments about this trial?

End of Scenario Questions

1. What was your recovery strategy in the PILOT'S OWN PREFERENCE condition?
2. Which recovery strategy did you like the best/least, and why?
3. Do your opinions about the simulation apply equally to line pilots and test pilots?
4. How do you feel the button press [by the instructor using this computer scenario] compares to alternate means of inducing the unusual attitude?
5. Do you have any additional comments?

Attachment 3
Summary tables of results

First trial: AAMP Recovery

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.0	-15.9	110.1	6.7	79.7	+20	.403	9.2		yes	no	no
2	241.6	-24.7	-89.9	12.5	78.3	+1	.472	11.2		yes	no	yes
3	238.3	-14.7	108.8	14.5	78.6	+1	.562	11.9		yes	no	maybe
4	235.4	-21.6	-86.9	12.7	78.6	+1	.512	12.5	B	yes	no	yes
5	214.2	-20.9	114.9	6.9	79.4	0	.396	8.2		yes	no	no
6	245.3	-20.3	-88.5	11.6	76.9	0	380	11.3	B	yes	no	. no
Avg	235.6	-19.7	99.9	10.8	78.6	+3.8	.454	10.7				

Last trial: Pilot's own preference

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.3	-0.2	105.6	6.3	79.8	+8	.308	8.2		yes	no	yes
2	240.7	0.5	105.7	15.4	76.2	+4	.575	14.0	B	no	no	yes
3	239.6	-0.2	107.0	10.9	59.5	+1	.375	12.1	B	yes	no	yes
4	240.1	-0.1	-105.2	4.3	78.3	+4	.315	5.4		yes	no	yes
5	240.8	0.5	-103.6	2.0	77.6	+9	.277	3.3	B	yes	no	no
6	239.9	0.1	-118.9	18.0	2.4	--	.435	13.2		yes	no	no
Avg	240.7	0.9	107.7	9.5	62.3	+4.3	.381	9.4				

Strategy A: Partial wheel, no rudder

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.9	0.0	103.4	1.2	79.6	--	.318	4.5		no	no	no
2	240.5	2.3	106.2	0.2	62.6	--	.287	4.4	W	no	no	no
3	240.3	0.0	-112.6	0.3	30.3	--	.246	4.1		no	no	yes
4	241.8	0.2	-104.8	0.2	76.5	--	.311	4.7		yes/no	no	yes
5	240.4	-0.3	-109.9	0.1	59.4	--	.226	4.0	W	no	no	no
6	240.1	0.3	105.8	0.2	68.0	--	.312	4.5	W	no	no	yes
Avg	240.5	0.5	107.1	0.4	62.7		.283	4.4				

Strategy B: Full wheel, no rudder

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.9	0.3	107.5	2.5	80.0	--	.305	4.6	B	no	no	no
2	240.8	-0.8	105.8	0.3	80.1	--	.332	4.7		no	no	no
3	239.0	-0.3	-106.9	0.2	77.2	--	.294	4.2		no	yes	yes
4	239.4	0.5	-104.1	12.6	79.9	--	.423	12.8	W*	yes	no	yes
5	239.8	1.2	103.2	0.0	80.1	--	.278	4.8		yes	no	no
6	239.9	0.2	102.4	0.2	80.2	--	.336	4.3		--	no	yes
Avg	239.8	0.6	104.5	2.6	79.6		.328	6.7				

*worst because he did not follow directions

Strategy C: Full wheel, partial rudder

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.3	-0.7	-106.7	9.9	78.0	+5	.273	11.6		yes	no	yes/no
2	240.4	-1.4	-104.8	11.6	78.7	+2	.541	13.6		no	no	yes
3	241.5	1.0	-107.8	14.9	76.6	+1	.521	13.2		yes	no	yes
4	240.2	-1.1	106.3	1.3	79.9	+16	.311	4.4		yes	no	yes
5	240.6	1.8	106.0	5.9	79.7	+2	.338	8.4		yes	no	no
6	240.7	0.8	-107.2	7.3	78.9	+5	.332	8.9		yes	no	no
Avg	240.5	1.1	106.5	8.5	78.6	+5.2	.386	10.0				

Strategy D: Full wheel, full rudder

Pilot	Airspeed	Initial Bank	Max Bank	Max Pedal	Max Wheel	Pedal delay	y-accel.	Max Rudder	Best/ worst	Autho-rity	Over-control	Lack of Response
1	239.3	0.4	106.5	14.7	79.8	+7	.336	12.8	W	yes	yes	yes/no
2	238.9	-1.7	-106.0	15.8	76.2	0	.538	13.7		yes	no	yes
3	238.7	0.0	108.0	18.9	78.7	0	.552	13.6		yes/no	yes	yes
4	239.6	-0.9	-104.6	10.3	77.4	+3	.351	11.9		yes	no	yes
5	240.7	-1.7	105.5	15.3	79.4	0	.552	13.5	W	yes	yes	no
6	240.4	-0.9	-101.8	18.0	76.9	+3	.512	13.8		yes	no	no
Avg	239.6	0.9	105.4	15.5	78.1	+2.2	.474	13.2				