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An International Survey of Transport Airplane Pilots' Experiences and Perspectives of Lateral/Directional Control Events and Rudder Issues in Transport Airplanes (Rudder Survey)

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16. Abstract

Following the AA587 accident, the National Transportation Safety Board requested that the FAA explore certain elements of transport aircraft and rudder usage, including but not limited to awareness that sequential full, opposite-rudder inputs (rudder reversals), even at speeds below the design maneuvering speed, may result in structural loads that exceed those addressed by Title 14 of the Code of Federal Regulations (CFR) part 25, § 25.1507. The Transport Directorate initiated a Web-based survey developed in conjunction with the FAA Civil Aerospace Medical Institute to survey the population of Transport Category Airplane Pilots' (TCAP) understanding of the use of rudder and their experiences with rudder, both as the pilot flying and as the pilot not flying. The survey also explored TCAP's experiences with upset, including magnitude and recovery. The survey further explored TCAP's experience with rudder training, unusual attitude recovery training, and their perceptions of additional training needed. Additionally, the survey explored the issue of maneuvering speed and movement of rudder, aileron, and elevator controls.

Survey results indicated: 1) Rudder is reported to be used more than the Rudder Survey Team expected; 2) Rudder is reported to be used or considered for use in ways not always trained and in ways not recommended by the manufacturers; 3) Erroneous and accidental inputs occur, and it is reasonable to believe that this will continue in the future; 4) Some respondents reported making pedal reversals (cyclic rudder-pedal commands); 5) Some respondents are not clear on appropriate use of rudder, and many felt they needed more training; 6) Wake vortex encounters were reported to be the most common initiator of upset; these were most likely to be reported in the approach phase; and 7) Respondents did not seem to be concerned with differences among control system designs across aircraft. Given these findings, a set of recommendations is suggested to guide further research.

17. Key Words Transport Airplane, Upset(s), Rudder, Lateral/Directional Control Events, Upset Recovery Training Aid, Unusual Attitude Recovery Training, Simulator Training, Maneuver Speed, Wake Vortex, Sequential Opposite Rudder Input, Rudder Reversal		18. Distribution Statement Document is available to the public through the Defense Technical Information Center, Ft. Belvoir, VA 22060; and the National Technical Information Service, Springfield, VA 22161	
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CONTENTS

AN INTERNATIONAL SURVEY OF TRANSPORT AIRPLANE PILOTS' EXPERIENCES AND PERSPECTIVES OF LATERAL/DIRECTIONAL CONTROL EVENTS AND RUDDER ISSUES IN TRANSPORT AIRPLANES (*RUDDER SURVEY*)

On November 12, 2001, American Airlines (AA) flight 587, an Airbus Industrie A300-605R, crashed into a New York City neighborhood shortly after takeoff from John F. Kennedy International Airport (National Transportation Safety Board (NTSB, 2004a). The flight had departed in visual meteorological conditions. While accelerating to approximately 255 knots during initial climb, it twice experienced turbulence consistent with encountering wake vortices from a Boeing 747(B747) that had departed ahead of them. The B747 and the A300-605R (AA 587) were approximately 5 statute miles and 90 seconds apart at the time of the vortex encounters.

The flight data recorder (FDR) of AA 587 indicated several large rudder pedal and surface movements to full or nearly full- available rudder deflection in one direction, followed by full or nearly full-available rudder deflection in the opposite direction. During this time, the airplane experienced a series of yaw oscillations that ended with in-flight separation of the vertical stabilizer as a result of forces beyond the aircraft's ultimate load capability. This accident focused international attention on how pilots apply rudder controls and industry-wide pilot training of rudder usage in transport airplanes.

More broadly, accidents resulting from a loss of airplane control have been, and continue to be, a major contributor to fatalities in the worldwide commercial aviation industry. NTSB data show that between 1994 and 2003, there were at least 32 worldwide airline accidents attributed to airplane upset, resulting in more than 2,100 fatalities. Upsets have been attributed to environmental factors, human factors, and aircraft anomalies (Upset Recovery Industry Team, 2008).

The NTSB issued a safety recommendation on February 8, 2002, urging the Federal Aviation Administration (FAA) ensure that all manufacturers and operators of transport-category airplanes implement enhanced pilot training programs. Recommendations included that programs: (1) explain the structural certification requirements for the rudder and vertical stabilizer on transport-category airplanes; (2) explain that a full or nearly full rudder deflection in one direction followed by a full or nearly full rudder deflection in the opposite direction, or certain combinations of sideslip angle and opposite rudder deflection, can result in potentially dangerous loads on the vertical stabilizer, even at speeds below the design maneuvering speed; and (3) explain that, on some aircraft, as speed increases, the maximum available rudder deflection can be obtained with comparatively light pedal forces and small pedal deflections (NTSB, 2004b).

On February 15, 2002, the FAA issued Notice N8400.28, *Transport-category Airplanes—Rudder and Vertical Stabilizer Awareness*.[1] This notified Principal Operations Inspectors (POIs) of air carriers operating transport-category airplanes about the operational use of rudder pedals and the potential, subsequent effects on the vertical stabilizer. The notice directed POIs to be certain that transport-category air carriers were aware that sequential full, opposite rudder inputs (rudder reversals), even at speeds below the design maneuvering speed (V_A), may result in structural loads that exceed those addressed by Title 14 of the Code of Federal Regulations (CFR) Part 25, § 25.1507. The NTSB also noted, based upon interviews after the AA587 accident, that pilots may have the impression that the rudder travel limiter systems installed on most transport-category airplanes prevent sequential full opposite rudder deflections from damaging the structure. However, the regulations did not take into account that sequential opposite rudder inputs, even when a rudder limiter is in operation, can produce loads higher than those required for certification and may exceed the structural capabilities of the airplane (even at speeds below V_A).[2]

Following publication of Notice N8400.28, the FAA developed a survey to document pilot experience with lateral control events. This *Rudder Survey* had two goals: (1) to assess understanding among responding pilots of the guidance and limitations communicated after the AA587 accident, and (2) to document pilot experiences

[1] This notice was cancelled and superseded by the Airplane Upset Recovery Training Aid (Upset Recovery Industry Team, 2008), developed by an aviation industry working group and the FAA. The first version of this guide was published in 1998, and Revision 1 was published in August 2004. The Airplane Upset Recovery Training Aid, Revision 2, published in 2008, includes a new supplement called "High Altitude Operations." The complete training aids, including the supplement, can be downloaded using links listed in the references section.

[2] FAA-certified transport-category airplanes meet the airworthiness standards in 14 CFR 25, Subpart C, pertaining to the airplane structure, including Section 25.351, titled, *Yaw Maneuver Conditions*. This section requires that the airplane be designed for loads resulting from the following series of maneuvers in unaccelerated flight, beginning at zero yaw: (1) full rudder input resulting in full rudder deflection (or as limited by the rudder system); (2) holding this full rudder deflection input throughout the resulting over-swing and steady state sideslip angles; and (3) while the airplane is at the steady state sideslip angle, a release of this rudder input and the return of the rudder to neutral. Resulting loads do not approach those encountered with full reversal of rudder, which may exceed the ultimate load capability of the aircraft.

with airplane upsets (that may or may not have included unusual attitudes), their use of rudder controls in such events, and future intentions for control usage in response to an upset event or unusual attitude.[3] The survey included sections asking specific questions about pilots' experiences in rudder training and unusual attitude training before and after February 2002, when FAA Notice N8400.28 was published. It also provided opportunities for pilots to provide details of their flight experiences.

The *Rudder Survey* defined *upsets* as "unintentional conditions describing an airplane motion that a pilot believed required immediate corrective action." This is a broader definition than that appearing in the *Upset Recovery Training Aid* (Upset Recovery Industry Team, 2008):

- Pitch attitude greater that 25 degrees nose up
- Pitch attitude greater than 10 degrees nose down
- Bank angle greater than 45 degrees
- Within the above parameters but flying at airspeeds inappropriate for the conditions.

The broader definition in the survey was designed to capture as many pilot experiences as possible, for several reasons. First, the research team believed upsets to be very rare events and that the more stringently they were defined, the fewer events we would learn about from pilots. Second, we did not believe that pilots were likely to remember precise rudder displacements experienced in an upset event; their attention would be appropriately focused on regaining control. Third, the team believed it important to understand those experiences where pilots believed they must make inputs, regardless of whether the airplane was in an unusual attitude of defined magnitude. Fourth, we believed that pilots may sense and respond to accelerations and perceive an upset prior to making any excessive displacements.[4,5] We also collected information on the magnitude of each reported upset that would allow interpretation in light of more specific definitions. This paper reports the results of the survey and discusses them in the context of guidance provided by the FAA and industry groups (listed in Appendix B) in response to the NTSB recommendations to address the issue of rudder usage and airplane upset.

[3] In 2008, research and discussion within the commercial aviation industry indicated it was necessary to establish a descriptive term and definition. These terms included but were not limited to "unusual attitude," "advanced maneuver," "selected event," "loss of control," and "airplane upset." "Airplane upset" is the industry and FAA convention. However, other upset recovery terminology may be found in the body of the survey.

[4] Note that American 587, for example, did not meet the Upset Recovery Training Guide definition of an upset until after rudder inputs were applied by the First Officer, although they did experience unusual accelerations during the event.

[5] Lambregts, Nesemeier, Wilborn, and Newman (2008) proposed a new definition of aircraft upsets that incorporates acceleration parameters.

METHOD

Survey Development Team

The group referred to as the *Rudder Survey Team* was compromised of the following organizations: the FAA Transport Airplane Directorate (which defined the research requirement), Seattle, WA; the William J. Hughes Technical Center, Atlantic City, NJ; the Civil Aerospace Medical Institute, Oklahoma City, OK; FAA Headquarters, Washington, DC; and the International Air Transport Association (IATA) Safety Department, Montreal, Canada. They jointly developed the Web-based survey.

Survey Deployment

The *Rudder Survey* was deployed via the Internet and hosted by IATA, an international trade organization representing more than 230 airlines and comprising 93% of scheduled international airline traffic. IATA invited all transport-category pilots to participate in the survey through publication (broadcast e-mails, newsletters, and notices), summits, symposiums, and safety seminars.

Survey Development

Survey development proceeded in four steps:

(1) development of questions by experts based on objectives (See Appendix C),
(2) testing and refinement among FAA pilots,
(3) "beta" testing by pilots from 10 international airlines, and
(4) refinement of items based upon responses from these groups.

Following Bureau of Transportation Statistics and Office of Management and Budget approvals (required under the Paperwork Reduction Act of 1995), the survey was launched in April 2006 to coincide with IATA's Global Operations Forum in Singapore. The survey remained available online until December 31, 2006.

Survey Organization

The *Rudder Survey* consisted of 52 questions divided into six parts:

- Flight Background Information,
- Experience With Upsets,
- Rudder System Characteristics,
- Training and Experience,
- Maneuver Speed, and
- Demographics (see Appendix A). Mapping of survey questions to survey objectives appears in Appendix C.

The Flight Background section asked about:
• pilot certificates,
• flight hours,
• transport airplane models,
• crew positions,
• type of employment, and
• country of primary employment.

Background questions were used to assess the representativeness of our sample relative to the worldwide pilot population.[6]

The Experience With Upsets section asked about yaw/roll upsets, including the following elements of a particular yaw/roll upset:
• airplane model,
• phase of flight,
• pilot flying,
• cause of upset
  » including initial conditions,
  » triggering event,
  » rate and sequence of events, and
  » recovery techniques used in the upset.

This section also asked about the magnitude of the upset, including:
• pitch attitude reached,
• bank angle reached,
• air speed reached,
• G-load reached,
• altitude lost,
• duration, and
• yaw angle reached.

The Rudder System Characteristics section contained questions about:
• unexpected rudder system characteristics,
• rudder system malfunctions resulting in yaw/roll upsets,
• automatic systems making inappropriate rudder inputs,
• auto throttle inputs,
• sequential opposite rudder pedal inputs (rudder reversals),
• over-controlling or wrong-direction roll or pitch control inputs,
• unintentional or accidental application of rudder,
• how pilots monitor rudder pedal when acting as the *monitoring pilot (*or *non-flying pilot*),[7]
• applying rudder pedal longer than necessary,
• under what circumstances and during which phases of flight pilots believe that the rudder pedal should be used,
• pilots' reactions to yaw/roll incidents.

The Training and Experience section of the survey asked about:
• unusual attitude- recovery training,
• including airplane, simulator, and classroom instruction,
• and the axes (roll, pitch, and yaw) covered in training.
• instructed use of rudder pedals for:
  » upset recovery,
  » engine failure,
  » countering light turbulence,
  » countering turbulence in excess of moderate turbulence,
  » during crosswind conditions,
  » passenger comfort,
  » turn coordination,
  » yaw damper hardovers or other malfunctions, and
  » Dutch roll after a yaw damper failure.

We requested information about:
• additional training in rudder-usage before and after February 2002,
• recurrent training,
• acrobatic training,
• and rudder usage topics covered in training:
  » aerodynamics,
  » airplane systems,
  » mechanical/hydraulic,
  » input-output characteristics,
  » limitations of rudder/flight control systems, and
  » maximum design maneuvering airspeed.

The Maneuver Speed section asked (for periods both before and after guidance responsive to NTSB recommendations were published) about:
• their understanding of rudder,
• maneuver speed, and
• structural overload.

We inquired about:
• moving the rudder, aileron, and elevator controls within their full range of motion and back again or to the opposition position.

We also asked about:
• foot force and pedal displacement at high and low speeds.

[6] These questions may also be used to explore differences in upset training, experiences, and recovery intentions, but were deferred for future analyses.
[7] Airlines vary in how they describe the roles of *pilot flying*, who makes flight control inputs, and the *monitoring* or *non-flying pilot*, who manages configuration and systems, accomplishes checklists, communicates externally, and monitors the flight performance of the aircraft. Note that this differs from the terms *pilot in command* or *captain* versus *second- in -command*, *co-pilot*, or *first officer*. Captains typically delegate flying responsibilities to first officers on about half of all flights and serve as the monitoring pilot during those flights. Pilot-in-Command responsibilities for the safe conduct of the flight always reside with the captain.

Finally, the Demographics section asked pilots:

- to report their age category,
- gender, and
- to voluntarily list their E-mail addresses to clarify information provided in the survey. When provided, E-mail addresses were held in confidence on the IATA Web server and were unavailable to the FAA.

Survey Development Limitations

The survey approach provided a useful exploration of issues but had several methodological limitations. Though the survey was made available to a large population of pilots around the world, participation was voluntary and optional, so our sample cannot be characterized as being random. To claim a random sample, we must be able to assert that each member of the population had an equal chance of being represented. That does not apply to this sample because the respondents were volunteers, and we did not directly contact either all transport pilots or a controlled, stratified sample to request participation. To the good, more than 90% of the population of transport category pilots could have chosen to respond; however, less than 1% did respond. We cannot assume respondents were representative of the population of air transport pilots or that their results generalized to the population. A random sample, with analysis of characteristics of respondents and nonrespondents, is necessary to assure that statistics among a sample generalize more broadly. We may have received responses only from pilots who were motivated to report, potentially over-representing the frequency or magnitude of their reported events, training experiences, or future intentions. In contrast, a random sample, such as in most political polls in the United States, allows one to place a confidence interval around the parameters (e.g., candidate preferences or issue positions) measured. The Rudder Survey team cannot claim, for example, that a specific percentage of all airline transport pilots have experienced an aircraft upset, within a specified margin of error. Additionally, we face issues of reliability of memory of events in asking about events occurring over the career of a pilot. These limitations were recognized during analysis of the survey data.

Nonetheless, we can assess the representativeness of respondents relative to characteristics of the pilot population by reference to statistical characterizations of the population. That is, we assess whether our sample included proportions of specific aircraft types and categories and regions of pilot residence statistically similar to the pilot population at large. As a result, we will use inferential statistics only in comparing our sample to the reference population, focusing on whether a particular fleet or group of pilots was over- or under-represented in responses to particular items.

We also attempt throughout our analyses to assess whether aircraft models are over-represented in the events reported in this survey. In analyses in which counts of events associated with an aircraft model are examined, some effort must be made to assess the frequency by which such reports would be expected at a proportional rate in normal operations. Otherwise, we might infer a problem with an aircraft based upon report frequency, when this might be due solely to the relative number of pilots who have flown the aircraft. One difficulty with doing this analysis accurately is that events reported by survey respondents were not identified by date, making it difficult to determine the number of each aircraft model in operation at the time of the *event*. Given this limitation, the distribution of aircraft in the fleet and respondents' current aircraft model flown at the time of the survey are used as rough approximations of the distribution over the reporting period. Where fleet over- or under-representation was found, it will be described in the analysis. If no differences were found, fleet comparisons will not be discussed. In these analyses, aircraft models not specifically mentioned appeared in their statistically-expected proportion. Care must be taken in interpreting trends of over- and under-representation. Over-representation in these analyses may identify a known and explainable characteristic of an aircraft model, an unconsidered issue, or a methodological or statistical anomaly. (See the Discussion section for further comments).

Additionally, the survey addresses events that should not or we would prefer not happen at all (upsets) and recovery techniques that the industry, regulatory agencies, and the public expect to be well-understood. When upsets are reported, they are a concern. When reported intentions for future recovery actions depart from guidance, our collective job is not complete.

The *Rudder Survey Team* deemed this approach appropriate for the limited goals of the survey – an initial assessment of understanding of the guidance and limitations communicated after the AA 587 accident, exploration of pilot experiences with unusual attitudes, use of rudder controls in such events, and future intentions for control usage. These goals are somewhat independent of normative documentation.

RESULTS

Respondent Characteristics

The survey was hosted on the IATA Website from April through December of 2006. Seventy-eight percent of the respondents accessed the survey during the first three months, April to June. Total survey traffic was 2,179 with 992 participants completing a portion of the survey, 434 participants completing at least 75% of the survey, and 184 participants completing every question on the survey. Analyses were limited to pilots who reported:

- flying a transport-category aircraft within the last 5 years,
- the number of civil or military transport hours in a transport-category aircraft,
- the airplane model they flew and the crew positions held (pilot, copilot, instructor/check pilot), and
- current type(s) of flying.

After screening respondents on these variables, surveys for 914 pilots were available for further statistical analysis. As not all pilots completed all questions on the Rudder Survey, the number of respondents varied and is documented for each item. For comparison, 141,935 active pilots held airline transport pilot ratings in the United States in 2006 (FAA, 2008).

Pilot Demographics and Statistics

Responding pilots were 96% male and 4% female with:

- 8% under age 30
- 26% ages 30 and 39,
- 31% ages 40 and 49,
- 28% ages 50 and 59,
- 7% age 60 or older, and
- Three-fourths were between the ages of 30 and 59.

Most pilots reported current employment by civil airlines (90%,) with 88% of the total serving as line pilots and 25% serving as training or check pilots. The examination of pilots' total flight time revealed 20% reported flying less than 4,900 total hours, 40% less than 7,900 hours, 60% less than 10,500 hours, and 80% less than 14,700 hours. Less than 1% reported flying more than 28,000 hours. Civil flight time was similarly distributed, with 20% reporting less than 3,500 hours, 40% less than 6,200 hours, 60% less than 9,000 hours, and 80% less than 13,000 hours. Fewer than 1% reported flying more than 24,500 flight hours. Military flight time was distributed very differently with 78% of respondents reporting having no military flight time. Hours reported by pilots with military time ranged from less than 100 to 10,000 hours; the median was 2,000 hours.

We compared respondents' current aircraft to worldwide and U.S. fleet distributions (Flight International, 2007). Distributions were available for the current aircraft flown by 816 of the responding pilots. Analyses revealed the sample to be representative of turbojet operations but not of turboprops. Turboprops are 19% of worldwide transport aircraft, but only 38 (4%) current pilots of turboprops responded to the survey, resulting in every fleet and all turboprops being under-represented (binomial probability <.01). For turbojets, only current B-767 pilots were statistically over-represented among respondents (10.3% of sample versus 4.7% worldwide, $p < .01$). In contrast, pilots of B-737 (17.9% vs. 24.6%), CRJ (2.2% versus 6.7%), ERJ-145 (.7% vs. 4.6%), and MD-80/90/95 (1.6% vs 6.9%) pilots were under-represented among respondents ($p<.01$). Additionally, we received no responses from pilots of ERJ-170/190 (1.4% worldwide) and F-28 (.5% worldwide) aircraft. Pilots of other aircraft manufacture (e.g., Airbus) and model (e.g., A-320) participated in proportions that would be statistically expected for their numbers in the worldwide fleet.

The survey attracted responses from pilots around the world. Country of employment was stated by 908 respondents. Reported geographic regions included: Africa (28), the Americas (Central, North, and South America) (327), Asia (84), Australia and New Zealand (18), Caribbean (5), EurAsia (2), Europe (367), Middle East (67), the Pacific Islands (7), and Other (3). The fewest responses were from Africa and the Pacific region. Given our Web-based methodology, we have a reasonable, non-random sample of world-wide turbojet operations.

Experience With Upsets

This survey defined "upset" as an airplane motion that a pilot believed required immediate corrective action. A total of 283 pilots provided the number of upsets they had experienced in their careers. Seventy-seven percent of those reporting an upset event had experienced three or fewer events. When asked to describe upsets by make, model, magnitude, cause, and phase of flight, 278 pilots reported experiencing a total of 405 aircraft upsets on up to four aircraft types or models. Comparison of the distribution of aircraft on which the 405 upsets were reported to the distribution of aircraft currently flown by respondents suggested that the B-727 (6.9% of reported upsets vs.2.2% of sample), DC-9 (6.2% vs.1.2%) and MD80/90/95 (6.7% vs.1.6%) were over-represented in upset reports ($p<.01$). In contrast, the A-320 (7.6% of reported upsets vs.13.6% of sample), A-330 (0.74% vs.4.5%), A-340 (0.74% vs.5.9%), B-747 (3.2% vs. 7.6%), B767 (3.5% vs.10.3%), and B-777 (0.49% vs.3.7%) were under-represented ($p<.01$) in upset re-

Table 1
Characteristics of Reported Upsets, by Dimension of Deviation

Dimension	Number of reported upsets	Mean of dimension value	Lowest quartile	Highest quartile
Nose-up (degs)	142	8.4	2	15
Nose-down (degs)	135	4.2	0	10
Bank (degs)	306	39	20	45
Yaw (degs)	115	6.9	0	10
Alt. loss (ft)	262	461	200	1000
Duration (s)	322	5	2	5

ports. Fleets over-represented in reported upsets were narrow-body aircraft; however, the B-737, the most common narrow-body aircraft, was neither under- nor over-represented. With the exception of the A-320, under-represented fleets were wide-body aircraft.

Respondents described the phase-of-flight of occurrence for up to four reported upsets. Thirty-four percent of pilots reported upsets had occurred during approach, 18% during cruise, 13% during takeoff, 13% during climb, and 11% during landing. Eighty-three percent of respondents were serving as the pilot flying for the first upset they reported.

Respondents described the perceived cause of up to four reported upsets. Sixty-two percent were attributed to wake vortex encounters; 21% to atmospheric disturbances; 5% to unintended control inputs, 4% to a mechanical systems fault, 1% to a high-speed upset, and 1% to an autopilot fault (6% did not select a perceived cause).[8] See IATA (2008) for an analysis of textual discussion provided by responding pilots.

Respondents described the parameters of up to four reported upsets (Table 1[9]).

In addition, respondents reported experiencing:

- minimum g-loading for 52 events, with 23% reporting less than 1 g.[10]
- maximum g loading for 80 events, with 53% reporting no incremental g loading, 35% between 1 and 2 g, and 12% reporting more than 2 g.

Reported upsets were predominately roll events, which is consistent with 62% having reported wake vortex encounters.

As discussed in the method section, the *Rudder Survey* defined upsets as "unintentional conditions describing an airplane motion that a pilot believed required immediate corrective action" because we wanted to understand the circumstances where pilots believed they had to take immediate action. Survey responses can be contrasted with the definition used in the *Upset Recovery Training Aid* (URTA): an aircraft pitch attitude greater than 25 degrees nose-up, greater than 10 degrees nose-down, or bank angle greater than 45 degrees. Only 179 (44%) of the reported events exceeded nose-up (15 events), nose-down (39 events), or bank (125 events) attitudes, as defined by the URTA. However, because of our definition, all of the reported events were understood as requiring immediate corrective action by the pilots on the scene.

Rudder System Characteristics

Unexpected rudder characteristics. A total of 118 pilots reported encountering 155 unexpected rudder characteristics on up to four aircraft types; 90% of these pilots reported unexpected rudder characteristics concerning two or fewer aircraft. Comparison of the distribution of aircraft for which unexpected characteristics were encountered to the distribution of aircraft currently flown by respondents revealed that the DC-9 and MD-80/90/95 were statistically over-represented.

Of the 118 pilots reporting an unexpected rudder characteristic, 37% reported an unexpected force, 31% reported an unexpected motion, 43% reported a lack of response, and 40% reported an unexpected input sensitivity.[11]

[8] Reasons for not selecting a perceived cause are unclear and represent a methodological limitation. It may be that the respondents did not know or recall the cause, did not notice the request to select a perceived causal category, or that the list of selections did not adequately describe what occurred. See IATA (2008) for analysis of comments associated with this item, which almost exclusively described wake and atmospheric turbulence events.

[9] Note that respondents were not asked to report accelerations, as it was not reasonable to expect they could measure or estimate their parameters.

[10] Respondents also were asked and reported minimum and maximum speed values during upsets. However, it was not possible to interpret reported values statistically. Instead, examination of individual events to break down the phase of flight and speed regime in which the upset occurred was required, making each value event-unique and not meaningful on average.

[11] In retrospect, "input sensitivity" left ambiguity of definition. Pilots may have interpreted it as input forces too light, displacements too short, or output greater than expected.

Malfunctions. Sixty pilots reported a total of 66 rudder-system malfunctions that resulted in a yaw or roll upset.

Inappropriate automatic system inputs. Twenty pilots reported 21 events in which an automatic system made an inappropriate rudder input in response to a yaw or roll upset.

Autothrottle inputs. Eighteen pilots reported 18 events in which an auto throttle input caused a problem in recovering from a yaw or roll upset.

Control Input Issues

Sequential opposite pilot inputs to rudder. Thirty-seven pilots reported a total of 38 events in which they made sequential opposite-rudder pedal inputs.

Pilot over-control or wrong-direction inputs. One hundred forty-eight pilots reported 150 events in which they over-controlled[12] or made inputs in the wrong direction that had to be neutralized or reversed. Seventy-five percent of these events involved over-control; 25% were wrong-direction. Fifty-three percent of wrong-direction inputs involved yaw, 50% involved roll, and 10% involved pitch.

Unintentional crossed controls. A total of 41 pilots reported they had unintentionally commanded uncoordinated rudder-pedal and control-wheel or sidestick commands on up to three aircraft models.

Inadvertent rudder inputs. A total of 174 pilots reported making inadvertent, or accidental, inputs. Comparison of the distribution of aircraft on which accidental rudder inputs were reported to the distribution of aircraft currently flown by respondents revealed that A-320 (4% of reported upsets vs.13.6% of sample) and A-340 (0.6% vs. 5.9%) aircraft were under-represented, while MD-80/90/95 aircraft were over-represented (5.2% vs. 1.6%), ($p<.01$) in accidental inputs. Pilots explained these inadvertent inputs as stretching/yawning/sneezing (39%), adjusting seat position (29%), turning in the seat (23%), and reaching (9%). Additional explanations by individual respondents included turbulence, making a seat change, getting out of the seat, picking up a dropped item, and testing the brakes.

The magnitude of deviations resulting from inadvertent rudder was small, except for bank and yaw angle. Only seven pilots described nose-up pitch, all of less than 5 deg. Only one pilot described nose-down pitch (3 deg). Only 12 described any g-loading. Most (85%) of the events had a duration of 3 s or less. However, respondents described bank angle for 75 events ranging from 0 to 20 degrees (mean = 2.7 deg); 48% reported zero bank angle and 29% more than 15 degrees. Sixty-eight respondents described yaw ranging from 0 to 20 degrees (mean = 4.5 degrees); and 60% between 1 and 5 degrees.

Application of rudder longer than required. Eighty five pilots reported applying or holding rudder longer than required. Respondents described 70 situations in which this occurred, mainly engine out-operations and crosswind takeoffs and landings. Several described encountering this in training and learning from the experience.

Observed PF confusion. Ninety-one pilots reported observing another pilot apparently confused by aircraft reaction to an upset. Comparison of the distribution of aircraft on which confusion was reported to the distribution of aircraft currently flown by respondents revealed that only the B-757 was over-represented (12.07% vs. 3.39%).

Observed PF incorrect control inputs. One hundred eighty-eight pilots reported observing another pilot making inappropriate over-controlling or wrong-direction inputs that had to be neutralized or reversed on up to four aircraft. Most (71%) involved over-control and 29% involved inputs in the wrong direction. Sixty percent of reported events involved erroneous yaw input, 58% involved erroneous roll input, and 6% involved pitch. Comparison of the distribution of aircraft on which incorrect input was observed to the distribution of aircraft currently flown by respondents revealed that only the MD-80/90/95 was over-represented (5.9% versus 1.6%).

Observed PF application of rudder longer than required. One hundred thirteen pilots reported observing another pilot holding a rudder input longer than required on up to four aircraft.

Observed PF inadvertent rudder application. One hundred forty-eight pilots reported observing another pilot accidentally making a rudder input on up to four aircraft. In 87% of these events, the PF recognized that he or she had made an inadvertent input. Comparison of the distribution of aircraft on which inadvertent rudder inputs were reported to the distribution of aircraft currently flown by respondents revealed that the A-340 was under-represented (0% vs.5.9%).

Monitoring

Observing other pilot's control inputs. Four hundred sixty-nine pilots described the flight controls they monitor and how they monitor the flight controls during each phase of flight while serving as the non-flying pilot. Responses were analyzed for up to six aircraft and are in Table 2. Most respondents describe monitoring control column and wheel for most phases of flight, and monitoring rudder during takeoff, approach, and landing. Fewer respondents described monitoring sidestick pitch and roll across phases.

[12] "Over-controlled" in the survey meant the pilot's perception that a greater than required input was applied.

Table 2
Percentage of Pilots Reporting Monitoring Controls When Acting as Pilot Not Flying, Categorized by Control Type and Phase of Flight

Control Type	Phase of Flight				
	Takeoff	Climb	Approach	Landing	Other
Control column	87%	58%	69%	81%	42%
Sidestick pitch	44%	22%	29%	35%	15%
Control wheel	79%	57%	69%	78%	44%
Sidestick roll	41%	21%	31%	37%	16%
Rudder pedal	85%	48%	74%	86%	40%

Five hundred twenty-six pilots responded to additional items further discussing monitoring of rudder pedals when acting as the non-flying pilot on up to seven aircraft. Several respondents reported additional flight phases in which they monitor rudder, including during the control check, during climb, whenever below 10,000 ft, during flap extension, and during taxi. Most (84.9%) reported monitoring using light foot pressure on the rudder pedals, but 17.5% reported monitoring the rudder visually, and 9% reported using other methods including observing the rudder index, control surface position, or slip displays/indicators, and placing feet just aft of the pedals to detect displacements rather than pressure.

Controls that cannot be monitored. One hundred sixty pilots reported control inputs that they could not monitor on up to four aircraft they had flown during their career. Comparison of the distribution of aircraft on which monitoring difficulties were reported to the distribution of aircraft currently flown by respondents revealed that this issue was reported mostly (74%) for sidestick control aircraft (23% were scattered over six column/wheel control models). IATA (2008) analyses of the 141 comments associated with this question indicated that issues involved flight controls either on the edge of peripheral vision or completely out of sight (79% who commented said they could not see the other sidestick, 13% could not the see rudder, and 8% could see neither).

Turbulence

Five hundred twenty pilots described encounters with turbulence such as wake vortices and their perception that airplane motion was stopping on its own or required pilot action to ensure passenger comfort or to maintain aircraft control. Most (68%) reported encountering motion that was stopping on its own, 47% reported pilot action was required for passenger comfort, and 52% reported pilot action was needed to maintain control. At face value, these percentages appear to be contradictory, but review of the textual descriptions suggests that many of the respondents had encountered multiple situations and selected two or more of the responses. "Stopped on its own" and "required intervention" appeared to be answered for different events. Comparison of the distribution of aircraft on which turbulence encounters were reported to the distribution of aircraft currently flown by respondents revealed that the A-340 (1% reported vs. 5.9% of sample) and B-777 (.5% vs. 3.5%) aircraft were under-represented and B-737 (28.3% vs. 17.9%), DC-9 (7% vs. 1.2%), and MD80/90/95 (10.2% vs. 1.6%) aircraft were over-represented.

With few exceptions, the 211 written descriptions of encounters provided can be characterized as reports of events that pilots perceived as requiring intervention (IATA, 2008).

Intentions to Use Rudder

Six hundred thirty-seven pilots described the phases of flight and circumstances in which they would consider using the rudder pedal in a transport airplane. Responses were analyzed for up to nine aircraft (in which only the B-747 was marginally over-represented, $p<.05$) and are listed in Table 3.

Intentions were varied for upset recovery, with 57% considering rudder use on takeoff, about a third in climb, cruise, and descent, and 58% on landing. Rudder use for engine failure was considered by at least two-thirds in all phases, almost all on takeoff, and over 80% for climb and landing. Intentions to use rudder to counter light turbulence were reported by many fewer respondents, with about 10% on takeoff and landing, and less than 5% in other phases. Rudder use in crosswind was considered by few respondents in climb and cruise, but by 84% on takeoff, 18% during descent, and 82% during landing. Intentions for use for passenger comfort was reported by few respondents, except for during descent (13%) and landing (20%). Use for yaw damper hard-over or other malfunction was considered by about half of respondents in all flight phases. Use to control Dutch roll after a

Table 3
Percentage of Pilots Who Would Use Rudder Input Categorized by Flight Situation and Phase of Flight

Flight Situation	**Phase of Flight**				
	Takeoff	Climb	Cruise	Descent	Landing
Upset recovery	57%	40%	32%	34%	58%
Engine failure	96%	80%	69%	66%	86%
Counter light turbulence	10%	4%	3%	4%	11%
Counter in excess of moderate turbulence	21%	2%	10%	11%	4%
During crosswind conditions	84%	5%	3%	18%	82%
Passenger comfort	5%	4%	4%	13%	20%
Turn coordination	20%	17%	11%	14%	20%
Yaw damper hard-over/malfunction	56%	52%	49%	50%	57%
Dutch roll after yaw damper failure	30%	30%	36%	33%	30%

yaw damper failure was considered by about a third of respondents in all flight phases. These intentions should be contrasted to manufacturer guidance and the Upset Recovery Training Aid. A cursory review suggests some degree of inconsistency between respondent intentions and published guidance, which will be examined in the Discussion section.

Training

Unusual attitude recovery training. Three hundred ninety-two pilots reported completing unusual attitude training. Respondents reported up to eight courses. Fifty-six percent of respondents reported receiving only a single course, 17% reported receiving a second course, and 2% reported three or more courses. Of these, 25% received training prior to November of 2001, and 25% received training after December 2005. Most (80%) reported training in a simulator, 23% reported receiving training in an aircraft, and 26% reported training in the classroom. Comparison of the distribution of aircraft on which training was reported to the distribution of aircraft currently flown by respondents revealed over-representation in training on the B-737 (25.5% of the sample received training on this aircraft vs. 17.9% of the sample who are currently flying this aircraft), B-747 (11.6% vs. 7.6%), and MD-80/90/95 (5.2% vs. 1.6%).

Scope of simulator training. Three hundred eighty-one pilots described the scope of up to nine unusual attitude recovery events in a simulator. Of these reported training events 77% covered yaw axis recovery, 98% covered roll axis, and 98% covered pitch.[13] Twenty-five percent of these events occurred before December 2002 and 24% after December 2005.

[13] Axis was recorded only for the first reported training event.

Instructed use of rudder – current aircraft. Four hundred nineteen pilots described the phases of flight and circumstances in which they understood training in their current aircraft to recommend consideration of using the rudder pedal. Responses were analyzed for up to six aircraft (Table 4).

Respondent perceptions of training recommendations for rudder use on their current aircraft were fairly consistent with their intentions described in section 4-6 of the *Rudder Survey*. For upset recovery, a quarter to a third of respondents perceived training to recommend rudder use; this was slightly lower than their intentions reported in 4.6 (third to half). Rudder use for engine failure was perceived as recommended by at least two-thirds in all phases; almost all on takeoff and roughly 80% for climb and landing. Rudder use to counter light turbulence was understood as recommended by few respondents, 6% on takeoff and landing, and less than 5% in other phases. Rudder use in crosswind was understood as recommended by few respondents in climb, cruise, and descent but by 83% on takeoff and 90% during landing. Use for passenger comfort was understood as recommended by few respondents; less than 5% for all phases. Use for yaw damper hard-over or other malfunction was perceived as recommended by about a third of respondents in all flight phases, which is lower than respondents' intentions (about half). Use to control Dutch roll after a yaw damper failure was perceived as recommended by 20% to 25% of respondents in all flight phases. These perceptions should be contrasted to manufacturer guidance and the *Upset Recovery Training Aid*. A cursory review suggests some degree of inconsistency between respondent intentions, perceptions of training recommendations, and published guidance, which will be examined in the Discussion section.

Table 4
Percentage of Pilots Reporting That Training on Aircraft Currently Flown Recommended Rudder Use, Categorized by Flight Situation and Phase of Flight

Flight Situation	Phase of Flight				
	Takeoff	Climb	Cruise	Descent	Landing
Upset recovery	36%	30%	29%	25%	35%
Engine failure	97%	79%	66%	66%	88%
Counter light turbulence	6%	3%	3%	2%	6%
Counter in excess of moderate turbulence	11%	5%	6%	11%	11%
During crosswind conditions	83%	7%	3%	5%	90%
Passenger comfort	5%	3%	3%	3%	5%
Turn coordination	15%	14%	12%	12%	15%
Yaw damper hard-over/malfunction	36%	33%	33%	32%	38%
Dutch roll after yaw damper failure	21%	21%	24%	21%	21%

Table 5
Percentage of Pilots Reporting Training Recommended Rudder Use Across All Aircraft Flown, Categorized by Flight Situation and Phase of Flight

Flight Situation	Phase of Flight				
	Takeoff	Climb	Cruise	Descent	Landing
Upset recovery	46%	40%	40%	36%	43%
Engine failure	93%	78%	66%	64%	85%
Counter light turbulence	8%	5%	6%	4%	8%
Counter in excess of moderate turbulence	18%	12%	11%	10%	16%
During crosswind conditions	83%	11%	6%	9%	87%
Passenger comfort	7%	5%	6%	5%	6%
Turn coordination	33%	33%	28%	30%	32%
Yaw damper hard-over/malfunction	37%	34%	35%	32%	38%
Dutch roll after yaw damper failure	22%	23%	29%	22%	22%

Instructed use of rudder – any aircraft. Three hundred and sixteen pilots described the phases of flight and circumstances in which they understood their training in any aircraft to recommend consideration of using the rudder pedal. Responses were analyzed for up to four aircraft (Table 5).

Respondent perceptions of training recommendations for rudder use on any previous aircraft flown were fairly consistent with both recommendations of current aircraft (6.3a) and their intentions described in section 4-6 of the *Rudder Survey*. However, respondent perceptions for upset recovery rudder recommendations were higher than their current aircraft (by about 10%) but still lower than intentions reported in 4-6. Additionally, use for turn coordination was higher, suggesting that many had flown aircraft at some point in their career[14] in which rudder input was required to maintain coordinated flight in turns.

Rudder training. Four hundred twenty-six pilots of transport-category aircraft responded to items concerning their training involving rudder use. Thirty-four percent of respondents received additional training on rudder use in transport aircraft prior to February 2002, and 52%

[14] Review of aircraft currently flown by respondents suggests training to use rudder for turn coordination on those aircraft is very unlikely. Current aircraft flown overwhelmingly use yaw damper for turn coordination.

Table 6
Pilot Rudder-Use Training Percentages, Categorized by Time Frame and Type of Training

Time Frame	Type of Training						
	Recurrent simulator	Recurrent classroom	Safety bulletin	Operations bulletin	Aircraft checkout	Discussion with other Pilots	Personal flying experience
Pre-2002 rudder training	28%	18%	12%	12%	11%	11%	9%
Post-2002 rudder training	40%	31%	28%	28%	22%	16%	5%

Table 7
*Percentage of Agreement with Statements Concerning Rudder, Aileron, and Elevator Movements When Operating Below Maneuvering Speed on Transport Airplanes**

Statement	Level of agreement	Pre-February	Post February
I can simultaneously move the rudder, the aileron and the elevator controls back and forth, anywhere within their full range of movement.	agree	36.1%	25.1%
	neither agree or disagree	12.0%	11.4%
	disagree	51.9%	63.5%
I can rapidly move the rudder control back and forth anywhere within its full range of movement, provided elevator and aileron controls remain fixed.	agree	17.2%	7.9%
	neither agree or disagree	12.6%	11.0%
	disagree	70.2%	81.1%
I can rapidly move the rudder pedals to full deflection but not subsequently rapidly reverse the pedals to the full opposite position.	agree	40.5%	37.2%
	neither agree or disagree	12.1%	11.3%
	disagree	47.7%	51.5%

*Percentages may not total 100% due to rounding.

received additional training after February 2002 (Table 6). Only the B-757 was over-represented in rudder training.

Training effectiveness. Most (89%) respondents described recurrent simulator training as moderately to greatly effective, 75% described training via safety publications as moderately to greatly effective, and 69% described classroom training as moderately to greatly effective.

Additional training. A majority of respondents (58%) believe more rudder usage training in general would be beneficial. Respondents said that they would like more training on these topics:

- 76% recurrent training
- 75% rudder and flight control limitations
- 69% aerodynamics
- 60% maneuvering speed
- 56% input-output characteristics
- 47% mechanical and hydraulics
- 40% airplane systems

Four hundred twenty-seven pilots provided data about other specialized training they had received. Of these, 58% reported aerobatic training (85% of those only a single course; 25% before 1980 and 25% since 1998). Facilities providing this training were widespread, as were aircraft models in which training was provided. Only 4% were graduates of a test pilot school.

Three hundred sixty-six pilots responded to questions about understanding of maneuvering speed limitations prior to February 2002, and 392 pilots responded to questions about understanding of maneuvering speed limitations after February 2002 (Table 7).

These data indicate that a minority of respondents had inaccurate understanding of control limitations below maneuvering speed before FAA Notice N8400.28 was released and that subsequent information transfer apparently reduced misunderstandings. However, up to one-fourth of the participants may have overestimated the protections offered by maneuvering speed. As discussed earlier in this report, *it is possible to overstress the rudder below the maneuver speed by full cyclical deflections of the rudder, regardless of control surface deflections in the other axes.*

DISCUSSION

Although the Web-based survey resulted in a non-random but representative sampling of turbojet air transport operations worldwide, it was not representative of turboprop operations. Survey methodologies have a number of limitations, which were discussed above. However, an additional methodological issue limits interpretation of over-and under-representation of aircraft in a number of our analyses. We have information on aircraft that pilots currently operated, and we can tell how well our sample represents the pilot population during the period on which the survey was conducted. However, we do not have data on all the aircraft that respondents have flown during their career and the time periods in which they operated each model. Statistical differences in aircraft representation in upset experiences, system characteristics, and control issues could be due to known characteristics of an aircraft model, an unconsidered issue, or a methodological or statistical anomaly. They may be due solely to exposure – during their career, pilots may have flown older (at the time of the survey) and narrow-body aircraft, than newer and wide-body aircraft. Where over-representation has been found, it is worth examining but cannot be construed as having discovered an aircraft category or type problem in our data. Without these analyses, a reader might have, for example, cited the A-320 as the most common aircraft on which upsets were reported, not recognizing that it was simply the most common aircraft currently flown by respondents. We must be careful also not to over-interpret that B-727, DC-9, and MD-80/90/95 were over-represented in upset reports.

Results suggested that while upsets remain rare events, they can reasonably be expected at some point in a pilot's career. Pilots reported and quantified 405 upset events. These events were perceived as resulting primarily from wake vortex encounters and atmospheric disturbances. Malfunctions and faults and unintended inputs were described for far fewer reported events. Approach was the most frequent phase of flight in which upsets were reported. Narrow-body aircraft appeared to be over-represented in upset reports. The B-727, DC-9, and MD80/90/95 were over-represented, but B-737s, A-320s, and regional jets were not. Typical upsets (approximately the central 50% of each distribution; 25th to 75th percentiles) were 2 to 15 deg nose-up and/or 0 to 10 deg nose- down, 20 to 45 deg of bank, and 0 to 10 deg of yaw. These events were predominantly roll events, consistent with wake vortex encounters. Slightly less than half of reported upsets described a pitch or roll exceedance of one or more of the upset criteria of the *Upset Recovery Training Aid*. However, because of the definition used in the survey, *all* of the reported events were understood as requiring immediate corrective action by the pilots on the scene. This is important because it indicates that pilots may perceive the need to intervene from unexpected accelerations towards an upset event, rather than by observing extreme values. That level of awareness is desirable but underscores the need to apply control corrections appropriately.

Areas of Concern

The results suggested several areas of concern.

Control Inputs

About one-sixth of pilots who reported encountering upsets also reported over-controlling or making opposite direction inputs that had to be neutralized or reversed. Situations included sequential opposite-rudder pedal inputs, over-controlling or wrong-direction inputs requiring neutralizing or reversing inputs, unintentionally applied crossed controls, unintentional inputs to the rudder system, and application of rudder longer than was required.

About one-eighth of pilots reported unexpected rudder characteristics, including forces, motions, responses, or sensitivity, malfunctions that resulted in a yaw or roll upset, and inappropriate inputs by an automatic system in response to or during recovery from upsets. IATA (2008) reported respondent comments describing inappropriate inputs; these were limited to yaw damper or rudder control system and autothrottle anomalies. There were a number of reports of observing another pilot confused or making inappropriate control inputs.

Analyses also suggested some degree of mismatch between respondents' perceptions of training recommendations and their reported intentions to use rudder versus guidance provided by manufactures and the *Upset Recovery Training Aid*. For example, the *Aid* states:

> Large, swept-wing transport aircraft are normally not maneuvered with the rudder, except for non-normal flight control conditions, takeoff and landing crosswinds, or when there are asymmetric thrust requirements (p. 3.8).

In contrast, one-third to one-half of respondents (depending upon the phase of flight) said they would use rudder in upset recovery, and one-third would use rudder to counter Dutch roll following a yaw damper failure. Smaller numbers describe similar intentions in other situations. There are some further mismatches between reported intentions and perceptions of training recommendations. Fewer respondents describe their training in their current aircraft as *advocating* rudder use for upset recovery than the number of respondents who would *consider* rudder use in those situations. An examination of percentages in Tables 4 and 5 allows documentation of inconsistency with published guidance. For example, the percentages of those who said they would consider rudder use for upset recovery, turbulence, and Dutch roll coordination are inconsistent with industry, manufacturer, and FAA guidance. Other percentages, such as intention to use rudder for crosswind correction or engine failure on takeoff or landing, should approach 100% but did not in the responses we received. These are potentially valuable data points for training revision or emphasis; they suggest that training initiatives following the AA 587 accident have not yet produced the desired results.

The number of sequential opposite-direction rudder inputs and reversed over-applications of rudder reported by the respondents is important. It implies that the AA 587 Airbus accident differs in magnitude but not in fundamental misinterpretation or application error from events reported by respondents. Pilots reported a number of situations, mostly erroneous inputs requiring neutralization or reversal, which had the potential to exceed certification criteria but probably did not reach ultimate load (Hess, 2008). This is consistent with findings reported by Hoh (2010), which found that pilots in a simulator experiment tended to over control and apply large g forces to the vertical stabilizer when attempting to augment aileron with rudder inputs. This indicates an ongoing concern.

Monitoring Controls by the Non-Flying Pilot

While the majority of respondents reported efforts to monitor the controls when acting as non-flying or monitoring pilot in a variety of phases of flight, monitoring sidestick pitch and roll was reported by many fewer respondents. Respondents describe monitoring control column and wheel for most phases of flight, and rudder during takeoff, approach, and landing. However, monitoring sidestick inputs is challenging, because they are not yoked on the airplanes flown by survey participants, as are control columns, and are near the limit of peripheral vision.[15] Monitoring the rudder was described as requiring light contact with the pedals or keeping one's feet adjacent to the pedals to detect displacement. Visual monitoring of the rudder is limited to observing indices or slip indicators. A reasonable inference is that non-flying pilots may not be aware of small rudder inputs being made by the flying pilot or at least not as aware as they would be of a control column or wheel input.

Aircraft Differences

With one exception (observability of sidestick inputs), the concerns highlighted in the survey are not make, model, or manufacturer-specific issues. Individual models were over-represented in a small number of disparate analyses. Several narrow-body aircraft were over-represented and wide-body aircraft were under-represented in the upset analyses. As a result, survey responses may not appear to offer much guidance for equipment or control design. However, the degree of mismatch between intentions and guidance regarding rudder use requires caution for rudder system design and characteristics. The rudder was reportedly used or considered for use in ways that were not always trained and in ways not recommended by the various manufacturers. Some of these uses were immediately recognized as errors by respondents in reported events. Future rudder designs should consider accommodating common mistakes made by pilots.

Training

Airlines that employ responding pilots appear to be addressing upset recovery training. Such training was reported by nearly half of respondents. More than three-quarters who reported training described it as covering all three control axes. Training in the simulator and classroom were most frequently reported. However, after 2002, while simulator and classroom training were 30% to 50% more frequent, bulletins concerning rudder characteristics were reported to have doubled in frequency. Pilots described simulator training as being most effective for rudder characteristics. About half of all respondents received aerobatic training at least once in their career. Importantly, however, the data reveal continuing inconsistency between respondent intentions, perceptions of training recommendations, and published guidance concerning application of rudder. Specific areas requiring further emphasis based upon survey responses include:

- Avoidance of over-controlling or opposite-direction inputs, particularly involving rudder
- Explanation and understanding of rudder characteristics, including forces, motions, responses, and sensitivity
- Efforts to bring intentions to use rudder into close alignment with guidance provided in the *Upset Recovery Training Aid*

The majority of pilots believe they could benefit from additional training and prefer receiving it in the simulator, rather than via classroom instruction or bulletins. The majority of pilots would also like training on additional topics related to the rudder, as well as recurrent training in rudder usage. However, there are real concerns raised when pursuing additional simulator training, because simulators have limited fidelity when

[15] Whether sidestick *inputs* need to be monitored and observed can be debated. The monitoring pilot can observe the resulting deviation or feel the resulting acceleration even if unable to observe the roll or pitch input via the sidestick. Detecting, understanding, and correcting (if needed) the result is critical. On control-column aircraft, the input is clearly observable. The sidestick is not according to responding pilots. Observability may clarify the cause of a deviation as a pilot or autopilot input versus an environmental condition or malfunction.

recreating upset conditions (Hess, 1997, 2002, 2004, 2005, 2006, 2007, 2009; Hess & Stout, 1998; Mitchell & Klydt, 2001; Zeyada & Hess, 2003). Simulation dynamics may not accurately represent actual airplane dynamics, including both recovery performance and the forces and moments generated at high angles of attack (around and post-stall) and for large, sideslip angles. Two types of limitations are relevant to upset recovery training. First, simulators accurately replicate aircraft performance within specified envelopes of pitch, roll, yaw, speed, and configuration. These envelopes typically do not include serious upset conditions. Actions taken in the simulator might result in different performance when applied to the actual aircraft. Second, simulators generally cannot accurately replicate roll, yaw angle motion, and acceleration forces for sustained and large-amplitude maneuvers. The inability to replicate the positive and negative *g* forces that characterize all extreme attitude flight may limit a pilot's ability to prepare for the kinesthetic of a real-world upset.

Further, research resulted in mixed findings when examining transfer of simulator-based upset-recovery training to performance in an aircraft in flight. Though each study has limitations, appropriate upset recovery responses in aircraft trials were disappointingly low. Gawron (2002) found no recovery performance differences in a variable-stability Learjet 25, modified to simulate the control characteristics of an air transport airplane, among five groups of airline pilots with varying degrees of upset recovery training and/or aerobatics experience. Using the same aircraft, Kochan (2005) found that judgment, defined as the ability to analyze and learn from an in-flight upset, was a significant factor in successful upset recovery, especially when a pilot was not trained to proficiency in recovery. In a survey, Kochan, Breiter, Hilscher, and Priest (2005) found that, while pilots rated their ability to recover from loss-of-control situations as being greatly improved by upset-recovery training, most were unable to recall specific details about recovery maneuvers taught during their training. Pilots trained in a centrifuge-based flight simulator capable of generating continuous g-forces were only marginally more successful than those trained on Microsoft Flight Simulator (Leland, Rogers, Boquet, & Glaser, 2009; Rogers, Boquet, Howell, & DeJohn, 2009).

FINDINGS AND RECOMMENDATIONS

Findings

1. Rudder is reported to be used more than the *Rudder Survey Team* expected.
2. Rudder is reported to be used or considered for use in ways not always trained and in ways not recommended by the manufacturers.
3. Erroneous and accidental inputs occur, and it is reasonable to assume that this will continue in the future.
4. Some respondents reported making rudder pedal reversals (cyclic rudder-pedal commands).
5. Some respondents are not clear on appropriate use of rudder, and many felt they needed more training.
6. Wake vortex encounters were reported to be the most common initiator of upset events; these were most likely to be reported in the approach phase.
7. Respondents did not seem to be concerned with differences among control system designs across aircraft (no one mentioned a preference or disdain for any particular system).

Recommendations

1. Authorities, manufacturers, and operators should consider standards, designs, and operations that incorporate the results of this survey to ensure that airplanes are adequately equipped for the environments they fly in, are operated in such a way that wake vortex encounters are precluded, as much as possible, and that flight crews have the training and knowledge to deal with situations highlighted in this survey.
2. Specifically, continued emphasis on appropriate rudder use is warranted, given the frequency of reported events in which rudder reversal was a real possibility.
3. Future rudder designs should consider tolerance of common mistakes or inappropriate control inputs made by pilots.
4. Research is warranted to gain better insight into pilots' capabilities and required rudder-system design characteristics to effectively and safely combine continuous compensatory rudder inputs with roll control inputs during a variety of conditions including:
   - turn coordination,
   - wake vortex encounters,
   - moderate-to-high turbulence, and
   - manual damping of the airplane's Dutch roll motion after a yaw damper failure.

This research may provide additional, valuable pilot training guidance.

REFERENCES

Federal Aviation Administration (2008). Administrator's fact book. Office of the Assistant Administrator for Financial Services, Washington, DC. Retrieved from http://www.faa.gov/about/office_org/headquarters_offices/aba/admin_factbook/

Federal Aviation Administration (2009). Design maneuvering speed limitation statement. FAA-2009-0810; Notice No. 09-10, RIN 2120-AJ21 Federal Register, 74, 45777-45781. Retrieved from http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgNPRM.nsf/0/8ab55a430816ade786257627004f06c6!OpenDocument&ExpandSection=6

Flight International (2007). Flight's annual world airliner census. *Flight International*, 21, pp. 35-54. Retrieved from http://www.flightglobal.com/articles/2007/08/21/216126/exclusive-flights-annual-world-airliner-census-2007.html

Gawron, V.J. (2002). Airplane upset training evaluation report, NASA CR-2002-211405, Moffett Field, CA: NASA Ames Research Center. Retrieved from http://purl.access.gpo.gov/GPO/LPS69667

Hess, R.A. (1997). Unified theory for aircraft handling qualities and adverse aircraft pilot coupling. *Journal of Guidance, Control, and Dynamics, 20*, 1141-1148.

Hess, R.A. & Stout, P.W. (1998). Assessing aircraft susceptibility to nonlinear aircraft-pilot coupling/pilot-induced oscillations. *Journal of Guidance, Control, and Dynamics, 21*, (6) 957-964.

Hess, R.A. (2002). Pilot control. In P.S. Tang & M.A. Vidulich (Eds.), *Principles and Practice of Aviation Psychology,* (pp. 265-310). Mahwah, NJ: Erlbaum.

Hess, R.A. (2004). Handling qualities and flight safety implications of rudder control strategies and systems in transport aircraft. Paper presented at the *American Institute of Aeronautics and Astronautics Atmospheric Flight Mechanics Conference*, Providence, RI.

Hess, R.A. (2005). Rudder control strategies and force-feel system designs in transport aircraft. *Journal of Guidance, Control, and Dynamics, 28*, (6) 1251-1262. doi: 10.2514/1.12632.

Hess, R.A. (2006). Certification and design issues for rudder control systems in transport aircraft. *Journal of Guidance, Control, and Dynamics*, *29*, (5) 1210-1220.

Hess, R.A. (2007). Piloted simulation study of rudder pedal force/feel characteristics. #NNL06-AA04A; WBS 457280.02.07.07.03. Retrieved from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20070018161_2007016816.pdf

Hess, R.A. (2008). Flight control system design for inherent damage tolerance. *Journal of Aircraft,* 45, (6) 2024-2035. doi:10.2514/1.36639.

Hess, R.A. (2008). Metric for the evaluation of pedal force/feel systems in transport aircraft. *Journal of Aircraft*, 45 (2) 651-662. doi: 10.2514/1.32710.

Hess, R.A. (2009) Analytical assessment of flight simulator fidelity using pilot models. *Journal of Guidance, Control, and Dynamics*, 32, (3) 760-770. doi:10.2514/1.40645.

Hoh, R.H. (2010, March). Criteria to mitigate rudder overcontrol in transport aircraft. Paper presented at the *Meeting of Aerospace Control and Guidance Systems Committee,* Stateline, NV.

International Air Transport Association (2008). Survey on yaw/roll upsets: Data analysis final report. Contractor Report. Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ.

Kochan, J. (2005). The role of domain expertise and judgment in dealing with unexpected events. Unpublished doctoral dissertation, Department of Psychology, University of Central Florida, Orlando, FL.

Kochan, J.A. Breiter, E., Hilscher, M. & Priest, J.E. (2005, September). Pilots' perception and retention of in-flight upset recovery training: Evidence for review and practice. Paper presented at the *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting*, Orlando, FL.

Lambregts, A.A., Nesemeier, G., Wilborn, J., & Newman, R.L. (2008, August). Airplane upsets: Old problem, new issues. Paper presented at *the American Institute of Aeronautics and Astronautics Modeling and Simulation Technologies Conference and Exhibit,* Honolulu, HI.

Leland, R., Rogers, R. O., Boquet, A., & Glaser, S. (2009). An experiment to evaluate transfer of upset-recovery training conducted using two different flight simulation devices, Technical Report, DOT/FAA/AM-09/17, Federal Aviation Administration, Office of Aerospace Medicine, Washington DC. Retrieved from http://www.faa.gov/library/reports/medical/oamtechreports/2000s/media/200917.pdf

Mitchell, D. G.,& Klydt, D.H. (2001). Bandwidth criteria for category I and II pilot-induced oscillations. In M.F. Shafer,and P. Steinmetz, (Eds.). *Pilot-induced oscillation research: Status at the end of the century*. doi: 20010038270.

National Transportation Safety Board (2004a*).* In-flight separation of vertical stabilizer: American Airlines flight 587, Airbus Industrie A300-605R, N14053, Belle Harbor, New York, November 12, 2001. Aircraft accident report NTSB/AAR-04/04, Retrieved from http://www.ntsb.gov/publictn/2004/aar0404.pdf

National Transportation Safety Board. (2004b). *Safety recommendations A-04-56 through -62*. Retrieved from http://www.ntsb.gov/recs/letters/2004/a04_56_62.pdf

Rogers, R.O., Boquet, A., Howell, C., & DeJohn, C. (2009). An experiment to evaluate transfer of low-cost simulator-based upset-recovery training. *FAA Technical Report DOT /FAA/AM-09/5, Office of Aerospace Medicine,* Washington, DC, 20591. Retrieved from http://www.faa.gov/library/reports/medical/oamtechreports/2000s/media/200905.pdf

Upset Recovery Industry Team. (2008). Airplane upset recovery training aid, revision 2. *Federal Aviation Administration & Airline Industry,* Washington, DC. Retrieved from www.faa.gov/other_visit/aviation_industry/airline_operators/training/media/AP_UpsetRecovery_Book.pdf

Zeyada, Y., & Hess, R.A. (2003). Computer-aided assessment of flight simulator fidelity. *Journal of Aircraft, 40*, (4) 173-180. doi: 10.2514/2.2836.

APPENDIX A
Rudder Survey

Rudder Survey

Rudder and Flight Control Experience in Transport Airplanes

Purpose and Rationale:

This electronic survey collects information from transport airplane pilots on the use of rudder in transport airplanes and on the use of flight controls during yaw/roll upsets. Yaw/roll upsets are generally caused by turbulence, system malfunction or pilot input.

The information you provide on this survey will enable IATA and industry representatives to assess and understand the use of rudder in transport airplanes and the use of flight controls during yaw/roll upsets based on actual pilot experience and training.

Confidentiality Assured: All responses to survey and demographic items are confidential and anonymous.

A contact information section is provided at the end of the survey. This information is strictly voluntary and will only be used to clarify information you provided in the survey.

Definition: ***Upset -*** In this survey, "upset" means an airplane motion that the pilot believed required immediate corrective action.

When choosing from a pull-down list, please "click-out" of the list before using the scroll wheel on your mouse. Scrolling while still in the pull-down list may cause the value to change unexpectedly.

The survey will take approximately 20 to 30 minutes to complete. Please complete all questions fully and to the best of your ability. Thank you for taking the time to complete this survey.

Start Survey

Contact Us | Help | Privacy Policy | Terms of Use

1-1. Please indicate the Pilot Certificates you hold: (Check all that apply)

- ☐ Commercial Pilot Certificate
- ☐ Senior Commercial Pilot Certificate
- ☐ Airline Transport Pilot Certificate

☐ Other Specify: ( )

1-2. Please indicate your flight time (flight hours) for the following

	Total All Aircraft	Civil Transport	Military Transport
Total Pilot-Time (PIC + CP):			
Pilot-in-Command:			
Simulator:			

1-3. Please indicate the transport airplane(s) in which you are qualified including the model you currently fly and for each indicate, your crew position or positions:

Airplane Model:	Crew Position(s): Please select all the applicable crew positions
A: --Select--	☐ Pilot ☐ Copilot ☐ Instructor/Check Pilot

Click here to enter for another airplane.

1-4a. Please indicate your current type of employment(s): (Check all that apply)

☐ Civil Airline ☐ Training Facility ☐ Military
☐ Manufacturer ☐ Corporate ☐ Other (Specify:)

1-4b. Please indicate the type(s) of flying you currently do: (Check all that apply)

☐ Line Pilot ☐ Training/Checkpilot
☐ Maintenance Test ☐ Engineering Test
☐ Other Specify: ( )
☐ Not actively flying transports
(Last flew transport airplane in the year:)

1-5. Are you currently flying ***other*** airplanes (non-transport, e.g. general aviation, military reserves, etc.)?

◉ Yes ○ No

Please list airplane model(s):

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Rudder Survey

A:

B:

C:

1-6. Country of primary employment:

--Select--

Submit

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Reminder: In this survey **"upset"** means an airplane motion that a pilot believed required immediate corrective action.

2-1. Have you ever experienced any yaw/roll "upsets" in a transport airplane either as the pilot flying (PF) or pilot-not-flying (PNF)?

(•) Yes ( ) No

Event : 1

Please fill in the table below for each yaw/roll "upset" that you have experienced beginning with the most severe.
Please identify all information:

2-1a. Airplane Model:

--Select--

2-1b. Phase of Flight:

--Select--

2-1c. Were you the pilot flying or the pilot not flying?

( ) Pilot flying ( ) Pilot not flying

2-1d. Cause of "upset":

--Select--

2-1e. Please describe the initial conditions, triggering event, rate and sequence of events in the "upset".

2-1f. Please describe the recovery techniques that were used in the "upset".

2-1g. Magnitude of "upset":

A: Pitch attitude reached:

	Degrees of Nose Up Degrees of Nose Down Don't Know/Don't Recall	
B: Bank angle reached:	Degrees Don't Know/Don't Recall	Direction: --Select--
C: Air speed reached:	knots (minimum) knots (maximum) Don't Know/Don't Recall	
D: G-Load reached:	g's (minimum) g's (maximum) Don't Know/Don't Recall	
E: Altitude Lost:	feet Don't Know/Don't Recall	
F: Duration (triggering event through recovery):	<1 second seconds	
G: Yaw Angle Reached:	degrees Don't Know/Don't Recall	

Enter Next Event

Submit

3-1. Please indicate any unexpected rudder system characteristics you have experienced on any of the transport airplane (s) that you have flown. Please use the accompanying table and begin with the airplane model you currently fly, or the last airplane model you have flown.

Airplane Model	--Select--
Did you feel unexpected pedal force (e.g. pedal binding, encountering an unexpected control stop, heavy or light pedal forces)?	◯Yes ◯No
Did you feel unexpected pedal motion?	◯Yes ◯No
Did you experience no response to commanded input (e.g. sluggish)?	◯Yes ◯No
Did you experience unexpected sensitivity to small rudder inputs?	◯Yes ◯No

Click here to enter another event.

3-2. In a transport airplane, have you ever experienced a rudder system malfunction that **resulted in a yaw/roll upset**? Examples of rudder malfunctions include yaw damper malfunctions, rudder autopilot malfunctions, trim runaways, or other failures that cause uncommanded rudder motion.

◉Yes ◯No

Airplane Model: Description:

A: --Select--

Click here to enter another event.

3-3. In a transport airplane, have you ever had an automatic system make inappropriate rudder inputs **in response to a yaw/roll upset**?

◉Yes ◯No

Airplane Model: Description:

A: --Select--

Click here to enter another event.

3-4. In a transport airplane, has autothrottle input ever caused a problem in recovering from **a yaw/roll upset** such as a wake vortex encounter?

◉Yes ◯No

Airplane Model: Description:

A: --Select--

Click here to enter another event.

3-5. In a transport airplane, **in response to a yaw/roll upset** have you made sequential opposite rudder pedal inputs (rudder reversals)?

(•) Yes ( ) No

Airplane Model: Description:

A: --Select--

Click here to enter another event.

3-6. Pilots may have to make rapid decisions and rapid inputs within a few seconds. During such times in a transport airplane have you ever overcontrolled or made an input in the wrong direction (even briefly) that you then had to neutralize or reverse?

(•) Yes ( ) No

Event 1:

Which of the following occurred?

( ) Overcontrolled ( ) Controlled in the wrong direction

Which pilot commanded control input did you inadvertently or erroneously apply? Indicate all that apply:

[ ] Rudder/Yaw Control [ ] Roll Control [ ] Pitch Control

Please describe the circumstances; how you or your fellow pilot discovered the over-command or wrong direction control input and how you or your fellow pilot neutralized it for the event

Click here to enter another event.

Submit

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4-1. In a transport airplane, have you ever been in a situation where you unintentionally commanded uncoordinated (cross-controlled) rudder pedal and control wheel/sidestick commands?

(•) Yes ( ) No

Airplane Model: Description:

A: --Select--

Click here to enter another event.

4-2. Have you ever inadvertently pushed on a rudder pedal in flight in a transport airplane?

(•) Yes ( ) No

Please provide airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for each event.

Airplane Model: --Select--

Reason(s) for inadvertent input (Check all that apply):

[ ] Turning in the seat [ ] Stretching, yawning, or sneezing
[ ] Reaching [ ] Adjusting seat position for confort
[ ] Other Describe:

Magnitude of event:

A: Pitch attitude reached: Degrees of Nose Up / Degrees of Nose Down / [ ] Don't Know/Don't Recall

B: Bank angle reached: Degrees / [ ] Don't Know/Don't Recall — Direction: --Select--

C: Air speed reached: knots (minimum) / knots (maximum) / [ ] Don't Know/Don't Recall

D: G-Load reached: g's (minimum) / g's (maximum) / [ ] Don't Know/Don't Recall

E: Altitude Lost: feet / [ ] Don't Know/Don't Recall

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F: Duration (triggering event through recovery): ☐ <1 second
seconds

G: Yaw Angle Reached:
degrees
☐ Don't Know/Don't Recall

4-3. In transport airplanes, do you monitor the rudder pedal, when you are the **pilot not flying**, during any of the following phases of flight? Indicate all that apply for up to the last three airplanes models you have flown.

◉ Yes ○ No

Airplane Model: --Select--

Phase of flight you monitored:

☐ Takeoff ☐ Cruise ☐ Descent
☐ Approach ☐ Landing ☐ Don't Know/Don't Recall
☐ Other

How did you monitor?

☐ Visually
☐ Light Pressure
☐ Other

Click here to enter another airplane model.

4-4 In a transport airplane, have you ever applied rudder pedal longer than was required, for example after an engine-out takeoff?

◉ Yes ○ No

Please provide airplane model and indicate the circumstances, how you realized the unintentional commands and how you neutralized it for each event.

Airplane Model: Description:

A: --Select--

Click here to enter another event.

4-5. In a transport airplane, after encountering a turbulence situation, for example wake vortices, did you perceive that the airplane motion, for any event, ...

...was stopping on its own: ○ Yes ◉ No

...required pilot action to maintain control of the airplane: ◉ Yes ○ No

...required pilot action to ensure passenger comfort: ○ Yes ◉ No

Please provide the airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for each event.

Airplane Model: Description:

A: --Select--

Click here to enter another event.

4-6. Please indicate which circumstances you would consider use rudder pedal in a transport airplane during the listed phases of flight (e.g., to counter turbulence, for roll control, for passenger comfort). Please indicate all that apply for each airplane model you fly beginning with the transport airplane you currently fly or the last transport airplane model you have flown.

Airplane Model --Select--

Rudder Pedal Usage	Takeoff	Climb	Cruise	Descent	Landing
Upset Recovery	☐	☐	☐	☐	☐
Engine failure	☐	☐	☐	☐	☐
Counter Light Turbulence	☐	☐	☐	☐	☐
Counter Turbulence (In Excess Of Moderate Turbulence)	☐	☐	☐	☐	☐
During Crosswind Conditions	☐	☐	☐	☐	☐
Passenger Comfort	☐	☐	☐	☐	☐
Turn Coordination	☐	☐	☐	☐	☐
Yaw Damper Hardovers or Other Malfunctions	☐	☐	☐	☐	☐
Dutch Roll After a Yaw Damper Failure	☐	☐	☐	☐	☐

Click here enter information for another airplane.

Submit

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Please note:
The following six (6) questions are about **your observations** of another pilot's action in the cockpit.

5-1. Do you, as a matter of course, directly monitor the other pilot's control inputs in the transport airplanes that you have flown? (e.g., visually observe or feel column, wheel, pedal, or sidestick movements). Please indicate Yes (Y) or No (N) for each transport airplane you fly, beginning with the transport airplane you currently fly or transport airplane last flown.

Airplane Model --Select--

Phase of Flight	Control Column	Sidestick Pitch	Control Wheel	Sidestick Roll	Pedal
Takeoff	Yes No	Yes No	Yes No	Yes No	Yes No
Climb	Yes No	Yes No	Yes No	Yes No	Yes No
Approach	Yes No	Yes No	Yes No	Yes No	Yes No
Landing	Yes No	Yes No	Yes No	Yes No	Yes No
Other	Yes No	Yes No	Yes No	Yes No	Yes No

Click here to enter for another Airplane.

5-2. If you cannot directly monitor the other pilot's control inputs in transport airplane(s), please explain why (e.g. sidestick out of view).

	Airplane Model:	Description:
A:	--Select--	

Click here to enter another event.

5-3. In a transport airplane, have you observed that any of your fellow pilots ever seemed confused by the airplane's reaction to a yaw/roll upset?

Yes No

Did it appear that the pilot flying was making what you thought were incorrect inputs to control wheel, rudder pedal or throttle?

Yes No

Please provide airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for the event:

	Airplane Model:	Description:
A:	--Select--	

Click here to enter another event.

5-4. As the pilot not flying in a transport airplane, have you been aware that the pilot flying incorrectly applied commanded control inputs either by overcommanding the control or commanding the control in the wrong direction that they then had to neutralize or reverse?

(•) Yes ( ) No

Event 1:
The pilot in question:

( ) Overcontrol ***OR*** ( ) Control in the wrong direction? Which pilot commanded control input did they inadvertently or erroneously apply? Indicate all that apply:

[ ] Rudder/Yaw Control [ ] Roll Control [ ] Pitch Control
Please provide airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for the event:

Airplane Model: Description:

--Select--

Click here to enter another event.

5-5. As the pilot not flying in a transport airplane, have you ever been aware that the pilot flying held the rudder pedal in longer than was required?

(•) Yes ( ) No
Please provide airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for the event:

Airplane Model: Description:

A: --Select--

Click here to enter another event.

5-6. As the pilot not flying in transport airplane, have you ever been aware that the pilot flying accidentally pushed on a rudder pedal?

(•) Yes ( ) No

Event 1:

Rudder Survey

Did the pilot flying realize that he/she had accidentally made a rudder pedal input?

◯ Yes ◯ No

Please provide airplane model and describe the initial conditions, triggering event, rate and sequence of events, cause (if known) and recovery techniques for the event:

	Airplane Model:	Description:
A:	--Select--	

Click here to enter another event.

Submit

6-1. Have you taken unusual attitude recovery training?

(•) Yes ( ) No

Please complete the following, for the **last three** courses of training, in *any airplane*, not just transport airplanes.

	Month	Year	Aiplane Model	Training Type(s) Select all that apply:
A:			--Select--	☐ Airplane ☐ Simulator ☐ Classroom

Click here to enter information for another course.

6-2. Have you received simulator training in unusual attitude recovery in transport airplanes?

(•) Yes ( ) No

	Axes Covered Select all that apply:	Month	Year	Aiplane Model	Training Type(s) Select all that apply:
A:	☐ Pitch ☐ Roll ☐ Yaw			--Select--	☐ Airplane ☐ Simulator ☐ Classroom

Click here to enter information for another course.

6-3a. In your training, for the **transport airplane you currently fly OR the last transport airplane you flew**, were you instructed to use rudder pedal control inputs for any of the following situations? Select the airplane model, usage, and flight phase(s) for each instruction:

Airplane Model --Select--

Rudder Pedal Usage	Takeoff	Climb	Cruise	Descent	Landing
Upset Recovery	☐	☐	☐	☐	☐
Engine Failure	☐	☐	☐	☐	☐
Counter Light Turbulence	☐	☐	☐	☐	☐
Counter Turbulence In Excess Of Moderate Turbulence	☐	☐	☐	☐	☐
During Crosswind Conditions	☐	☐	☐	☐	☐
Passenger Comfort	☐	☐	☐	☐	☐
Turn Coordination	☐	☐	☐	☐	☐
Yaw Damper Hardovers Or Other Malfunctions	☐	☐	☐	☐	☐
Dutch Roll After A Yaw Damper Failure	☐	☐	☐	☐	☐

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Click here to enter information for another course.

6-3b. In your training for **any airplane** (other than the one you currently fly), were you instructed to use rudder pedal control inputs for any of the following? Select the airplane model, usage, and flight phase(s) for each instruction:

Airplane Model --Select--

Rudder Pedal Usage	Takeoff	Climb	Cruise	Descent	Landing
Upset Recovery	☐	☐	☐	☐	☐
Engine Failure	☐	☐	☐	☐	☐
Counter Light Turbulence	☐	☐	☐	☐	☐
Counter Turbulence In Excess Of Moderate Turbulence	☐	☐	☐	☐	☐
During Crosswind Conditions	☐	☐	☐	☐	☐
Passenger Comfort	☐	☐	☐	☐	☐
Turn Coordination	☐	☐	☐	☐	☐
Yaw Damper Hardovers Or Other Malfunctions	☐	☐	☐	☐	☐
Dutch Roll After A Yaw Damper Failure	☐	☐	☐	☐	☐

Click here to enter information for another course.

6-4. Is your **current** understanding of rudder usage in transport airplane(s) consistent with your training prior to February 2002?

○ Yes ◉ No ○ N/A

☐ Recurrent Classroom Training ☐ Recurrent Simulator Training
☐ Personal Flying Experience ☐ Safety Bulletin
☐ Airplane Checkout ☐ Flight Crew Operations Bulletin
☐ Discussions With Other Pilots
☐ Other (Please Specify:)

Submit

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7-1. Have you received **additional** training on using rudder in transport airplane(s) after February 2002?

(•) Yes ( ) No

What type of training did you receive? Indicate all that apply:

[ ] Recurrent Classroom Training [ ] Recurrent Simulator Training
[ ] Personal Flying Experience [ ] Safety Bulletin
[ ] Airplane Checkout [ ] Flight Crew Operations Bulletin
[ ] Discussions With Other Pilots
[ ] Other (Please Specify:)

7-2. To what extent do you feel that the following types of rudder training methods prepared you to deal with yaw/roll upsets in transport airplanes:

Please rank the preparation (if any) that each of the following types of training methods offered you, on a scale of 1 to 5, based on the below chart:

N/A = Do not use
1 = No preparation gained
2 = Limited preparation gained
3 = Moderate preparation gained
4 = Considerable preparation gained
5 = Great preparation gained

	N/A	**1**	**2**	**3**	**4**	**5**
Safety Publications (FCOBs):	( )	( )	( )	( )	( )	( )
Classroom Training:	( )	( )	( )	( )	( )	( )
Simulator:	( )	( )	( )	( )	( )	( )

Please indicate your response to the following questions:

7-3. Have you had upset recovery classroom training for transport airplane(s) after February 2002?

(•) Yes ( ) No

Please specify the three (3) most recent airplanes you have had training in:

A: --Select--

Click here to enter another airplane

7-4. Do you feel more training in transport airplane(s) rudder usage would be beneficial to you?

( ) Yes (•) No

7-5. Do you feel recurrent training in transport airplane(s) rudder usage would be beneficial to you?

Rudder Survey

○ Yes ◉ No

7-6. Please indicate the rudder usage topics covered in your training. Indicate all that apply:

☐ Aerodynamics
☐ Mechanical/Hydraulic
☐ Airplane Systems
☐ Input-Output Characteristics (pedal breakout, forces, displacements)
☐ Limitations of Rudder/Flight Control Systems
☐ Maximum Design Maneuvering Airspeed
☐ Input-Output Characteristics (pedal breakout, forces, displacements)

☐ Other - Please list:

7-7. Have you taken acrobatic training (including military fighter/attack training)?

◉ Yes ○ No

Please complete the following for up to the last three courses of training:

	Month	**Year**	**Facility**	**Airplane Model**
A:	00	0000		

Click here to enter another course.

7-8. Are you a graduate of Test Pilot School?

○ Yes ○ No

Submit

03/24/2005

This question applies to your experiences <u>before</u> February 2002.

8-1. Please indicate your agreement (by referring to the following chart) with the following statement based on your training *prior* to February 2002.

1 = Strongly Disagree
2 = Disagree
3 = Neither Agree or Disagree
4 = Agree
5 = Strongly Agree

At speeds **below** maneuver speed, V_A, I can move the rudder as follows without causing structural overload:

		1	**2**	**3**	**4**	**5**
A:	I can simultaneously move the rudder, the aileron and the elevator controls back and forth, anywhere within their full range of movement.					
B:	I can rapidly move the rudder control back and forth anywhere within its full range of movement, provided elevator and aileron controls remain fixed.					
C:	I can rapidly move the rudder pedals to full deflection but not subsequently rapidly reverse the pedals to the full opposite position.					

This question applies to your experiences <u>after</u> February 2002.

8-2. Based on your knowledge of V_A *after* February 2002, please indicate your agreement (by referring to the following chart) with the following statements.

1 = Strongly Disagree
2 = Disagree
3 = Neither Agree or Disagree
4 = Agree
5 = Strongly Agree

At speeds **below** maneuver speed, V_A, I can move the rudder as follows without causing structural overload:

		1	**2**	**3**	**4**	**5**
A:	I can simultaneously move the rudder, the aileron and the elevator controls back and forth, anywhere within their full range of movement.					
B:	I can rapidly move the rudder control back and forth anywhere within its full range of movement, provided elevator and aileron controls remain fixed.					
C:	I can rapidly move the rudder pedals to full deflection but not subsequently rapidly reverse the pedals to the full opposite position.					

Submit

9-1. Please indicate your level of agreement (by referring to the following chart) for the last transport airplane model flown by you.

1 = Strongly Disagree
2 = Disagree
3 = Neither Agree or Disagree
4 = Agree
5 = Strongly Agree

Please select the airplane model that you have flown last:

		1	2	3	4	5
A:	It requires the same foot force and pedal displacement to reach maximum rudder at both low and high speeds.	○	○	○	○	○
B:	It requires more foot force and pedal displacement at high speed to reach maximum rudder than it does at low speed.	○	○	○	○	○
C:	It requires more foot force and pedal displacement at low speed to reach maximum rudder than it does at high speed.	○	○	○	○	○

Part Seven: Demographics

9-2. Please select your age category.

○ Under 30 ○ 30-39 ○ 40-49 ○ 50-59 ○ 60 and up

9-3. Please indicate your gender.

○ Male ○ Female

9-4. Please provide your e-mail address.

(This is strictly voluntary and will be used only to clarify information you provided in the survey.)

E-mail Address:

Submit

Rudder and Flight Control Experience in Transport Airplanes

A Survey on Rudder Upset Events

Thank You!

Thank you very much for your time and your cooperation is very well appreciated.

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APPENDIX B
Organizations Participating in the Development of the Airplane *Upset Recovery Training Aid* Revision 2

ABX Air, Inc.
A.M. Carter Associates
(Institute for Simulation & Training)
Air Transport Association
Airbus
Air Line Pilots Association
AirTran Airways
Alaska Airlines, Inc.
All Nippon Airways Co., Ltd.
Allied Pilots Association
Aloha Airlines, Inc.
American Airlines, Inc.
American Trans Air, Inc.
Ansett Australia
Bombardier Aerospace Training Center
(Regional Jet Training Center)
British Airways
Calspan Corporation
Cathay Pacific Airways Limited
Cayman Airways, Ltd.
Civil Aviation House
Continental Airlines, Inc.
Delta Air Lines, Inc.
Deutsche Lufthansa AG
EVA Airways Corporation
Federal Aviation Administration
FlightSafety International
Flight Safety Foundation
Hawaiin Airlines
International Air Transport Association
Japan Airlines Co., Ltd.
Lufthansa German Airlines
Midwest Express Airlines, Inc.
National Transportation Safety Board
Northwest Airlines, Inc.
Qantas Airways, Ltd.
SAS Flight Academy
Southwest Airlines
The Boeing Company
Trans World Airlines, Inc.
United Air Lines, Inc.
Upset Doamain Training Institute
US Airways, Inc.
Veridian

APPENDIX C
Survey Purposes and Question Cross-Reference

The survey was designed to determine:

- If and to what extent pilots recognize control upsets, their sources, and their severity
- If pilots perceive higher numbers of control anomalies or difficulties in any one particular axis
- If pilots recognize differences in external disturbances from airplane/pilot induced
- Pilot perceptions of control upsets
- Whether specific categories of airline operators exhibit more control problems than others
- If there are specific airplane types that contribute to control problems
- If specific background/training contribute to control problems
- If pilots have observed fellow pilots miss-control airplanes and what circumstances contribute to miss-controls
- If pilots recognize when the may have made incorrect control inputs
- If any particular axis is more sensitive and has a higher perceived set of control problems
- If there are certain sets of circumstances that may trigger control issues
- Whether pilots perceive positives or negatives in various airplane control systems designs
- If pilots perceive any positive or negatives in specific pedal/rudder control system designs
- Whether pilots are ever confused about which control to use or which direction to apply a control
- How pilots perceive themselves controlling upsets
- From pilots' perspectives, where in the flight envelope, upsets most frequently occur
- Under what types of conditions and circumstances pilots are taught to use rudder
- Whether pilots are familiar with pedal usage in all phases of flight
- Level of system knowledge, particularly of the rudder system
- Pilots' perceptions of deficiencies of rudder control systems

Table C-1. Rudder Survey Purpose and Cross-References to Questions

Survey Quest #	Purpose 1	Purpose 2	Purpose 3	Purpose 4	Purpose 5	Purpose 6	Purpose 7	Purpose 8	Purpose 9	Purpose 10	Purpose 11	Purpose 12	Purpose 13	Purpose 14	Purpose 15	Purpose 16	Purpose 17	Purpose 18	Purpose 19	Purpose 20
1	X		X	X	X	X	X													
2	X	X		X	X	X	X													
3	X		X	X	X	X	X													
4	X	X		X	X	X	X													
5	X		X	X	X	X	X													
6					X															
7					X															
8	X	X		X																
9	X		X																	
10	X																			
11																				
12																				
13								X												
14								X												
15								X												
16									X											
17									X											
18									X											
19																				
20																X				
21	X	X	X	X							X									
22	X	X									X									
23	X	X	X	X					X		X									
24								X			X									
25									X		X			X	X					
26								X			X			X	X					
27											X	X		X	X					
28								X	X		X	X								
29								X	X		X	X								
30															X		X	X		
31																	X		X	

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32																	X	X		
33																			X	
34								X												
35									X					X						
36																				
37																	X	X		
38	X		X	X																
39																		X		
40										X		X	X						X	
41																			X	
42	X																			
43																				X
44	X											X	X							
45												X						X		